KOENIG AND SCHULTZ'S

Disaster Medicine

Comprehensive Principles and Practices

EDITED BY KRISTI L. KOENIG AND CARL H. SCHULTZ

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KOENIG AND SCHULTZ'S DISASTER MEDICINE: COMPREHENSIVE PRINCIPLES AND PRACTICES

As societies become more complex and interconnected, the global risk of catastrophic disasters is increasing. Demand for expertise in mitigating the human suffering and damage these events cause is also high. A new field of disaster medicine is emerging, offering innovative approaches to optimize disaster management. Much of the information needed to create the foundation for this growing specialty is not objectively described or is scattered among multiple sources. Now, for the first time, a coherent and comprehensive collection of scientific observations and evidence-based recommendations from expert contributors from around the globe is available in *Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices.* This definitive work on disaster medicine identifies essential subject matter, clarifies nomenclature, and outlines necessary areas of proficiency for healthcare professionals managing mass casualty crises. It also describes in-depth strategies for the rapid diagnosis and treatment of victims suffering from blast injuries or exposure to chemical, biological, and radiological agents.

Dr. Kristi L. Koenig, Professor of Emergency Medicine and Director of Public Health Preparedness at the University of California, Irvine, is an internationally recognized expert in the fields of homeland security, disaster and emergency medicine, emergency management, and emergency medical services. During the U.S. terrorist attacks of 9/11, she served as National Director of the Emergency Management Office for the Federal Department of Veterans Affairs. With a strong health policy and academic background, including more than 80 peer-reviewed publications and more than 300 invited lectures in more than a dozen countries, she is widely sought for presentations at regional, national, and international forums.

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I dedicate this book to

The people of the world who have suffered from disasters
The frontline disaster workers
The visionaries who are crafting a new science of disaster medicine
My students, residents, fellows, and colleagues
My mother

Kristi L. Koenig, MD, FACEP

In appreciation and gratitude, I would like to acknowledge

The pioneers of our specialty who envisioned and helped create disaster medicine
Robert Bade, MD, and Robert Kingston, MD, who provided courage, guidance, and mentorship
My colleagues in disaster medicine who continue to pursue the dream
My children, Arielle and Eric, who motivate and inspire
My wife, Janet, whose love and incalculable support enabled me to complete this work

Carl H. Schultz, MD, FACEP

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Foreword

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17th Surgeon General of the United States
Distinguished Professor of Public Health, Mel and Enid Zuckerman College of Public Health, University of Arizona
Vice Chairman, Canyon Ranch
CEO, Canyon Ranch Health
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The concept of disaster medicine has been in evolution for decades. Its requisite components were buried within disparate, often apparently unrelated disciplines and specialties. Today, we know these diverse disciplines must work seamlessly together and are essential for disaster preparedness, response, mitigation, and recovery. Events such as the tsunami in Indonesia, Hurricane Katrina in the United States, the cyclone in Myanmar, and the Novel H1N1 (2009) pandemic have served to reinforce our interdependence on one another and the globalness of our interconnected responsibilities. As we view the challenge of "all-hazard" preparedness, we are forced to recognize that our geopolitical borders are meaningless and sometimes a barrier to the public's health. In this new millennium, our nation and the globe must now reflect on contemporary threats that are truly international in scope, such as emerging infections, terrorism, weapons of mass destruction, and other disaster events.

From the late 1960s through today, I have had a unique vantage point to observe and contribute to our ever-expanding knowledge base in the fields of disaster and emergency management, as well as in public health and disaster medicine. As a medic, police first responder, registered nurse, physician, professor, trauma surgeon, and Surgeon General of the United States, I have been a witness and participant in this history.

As our knowledge base has exploded in depth and breadth, we have struggled with our own nomenclature and definition of terms. Such rapid growth has made achieving consensus on many complex issues extraordinarily difficult. Acknowledging the lack of international consensus on disaster nomenclature and other key issues, Koenig and Schultz have adopted a unique philosophical approach. They are moving the science of disaster medicine forward by describing its essential concepts and laying the academic foundation for this emerging specialty. Gathering experts from around the globe, the book reaches beyond state-of-the-art discussions to identify important areas that require immediate attention, hence laying the research agenda for the future. There is a focus on science and outcomes rather than opinions and anecdotes.

The "holy grail" of disaster management and care is the ability to surge as needed into a seamless, efficient, multiagency, and multidisciplinary force, united within an incident command system, addressing any and all hazards that may affect our communities, the nation, or the world. Although initial disaster response is local, disasters do not respect borders, and management approaches vary with available resources and existing infrastructures. The successful recruitment of disaster experts from around the globe to share knowledge from multiple perspectives is a key feature of this book.

Drs. Koenig and Schultz, as editors, have assembled a global force of experts to address the complex, interrelated topics and disciplines needed to create the end product that our nation and the world desperately need. The editors are well respected in the field of disaster medicine and have been promoting an academic approach to research and teaching since the very beginning of the specialty, long before it became popular after the tragic events of September 11.

With this publication, we are another increment closer to understanding the elements necessary to define our global interconnectedness during disasters.

Preface

Kristi L. Koenig

SETTING THE STAGE: *A PERSONAL PERSPECTIVE*

The specialty of disaster medicine has grown substantially since the terrorist attacks of 9/11 in the United States. In support of this growth, a number of disaster-related textbooks have been published. In some cases, however, these treatises have been authored by the 9/12'ers – people who suddenly gained interest and "expertise" in disasters once the topic became popular and U.S. federal funding flowed freely. As a result, much of the subject matter in these works was covered ineffectively. The challenge remained to create the definitive book written by nationally and internationally respected authors. We have considered editing such a book for the last dozen years; however, the timing never seemed right, and there was that ever-present thought that it would not be possible to "do it right" because we did not know exactly what "it" was.

Complicating the situation is the absence of a standard definition of disaster, much less a uniform concept for an academic discipline of disaster medicine. The need to codify this emerging discipline and create such standards is becoming increasingly clear. For example, the president of the United States issued a Homeland Security Presidential Directive (HSPD) on October 18, 2007 entitled "Public Health and Medical Preparedness." HSPD-21 "establishes a National Strategy for Public Health and Medical Preparedness, which builds upon principles set forth in Biodefense for the 21st Century (April 2004)." It further emphasizes that "the Nation must collectively support and facilitate the establishment of a discipline of disaster health. The specialty of emergency medicine evolved as a result of the recognition of the special considerations in emergency patient care, and similarly the recognition of the unique principles in disaster-related public health and medicine merit the establishment of their own formal discipline. Such a discipline will provide a foundation for doctrine, education, training, and research and will integrate preparedness into the public health and medical communities."

A definitive text is one of the requisites for crafting a scholastic foundation for disaster medicine and for proving its existence as a unique academic discipline. Yet it will be challenging to write a text when standardized nomenclature is lacking. We acknowledge this challenge but believe we can meet it by providing a conceptual framework and including a lexicon of the various terminologies without insisting that one depiction is "right" or "wrong." In addition, we suggest a future research agenda by gathering the top experts from across the globe as authors and asking them to include a section in each chapter discussing directions for future academic inquiry.

The use of established national and international experts results in individuals representing multiple disciplines. Depending on your specialty, you may not recognize some of the authors. Therefore, we have included a brief biography on each contributor to provide insight into the vast amount of expertise and activities that exist around the globe in the emerging field of disaster medicine.

DISASTER NOMENCLATURE

What then is a disaster? There are multiple definitions. The World Health Organization definition is a "sudden ecological phenomenon of sufficient magnitude to require external assistance." Conceptually, at the most basic level, we are describing a scenario in which the need exceeds the available resources at a given moment. It is not the event itself that defines a disaster; rather it is the functional effects of that event on the system of reference at the time. For example, if an airplane crashes, is this a disaster? From the perspective of the regional trauma hospital, if everyone is uninjured or if everyone dies, there may be absolutely no effect on hospital operations, and thus this might not be considered a disaster. From the perspective of the first responders or the mortuary teams, if the crash does generate mass fatalities, baseline operations would likely need to be augmented, and this event would require the implementation of disaster protocols.

In an attempt to assist with the concept of disaster, one approach is to discard the term "disaster" – which is ill-defined – and replace it with the acronym PICE: potential injury/illness-creating event. PICE is a concise and precise phrase that immediately characterizes the incident and communicates the need for outside assistance. Although this method has not been validated or widely embraced, it has been described in major emergency medicine textbooks and referenced in the world literature and in the U.S. Joint Commission standards. Descriptive modifiers surround this root word "PICE" and account for all possible scenarios. The description is time sensitive and may be modified over the course (or life cycle) of the event. The model is useful for disaster planning, management, and research.

Sometimes the term "emergency management" is used in lieu of "disaster," for example by the U.S. Joint Commission and in the social science literature. Comprehensive emergency management has four phases – mitigation, preparedness, response, and recovery – that describe the life cycle of a disaster. Although clearly described, studied, and well known to some audiences, others – even "experts" in disaster medicine – may be unfamiliar with the term.

Several words or phrases have crept into the disaster lexicons that simply do not make sense. The term, "lessons learned" is an example. After an incident, it is common to prepare an "after action report" and provide a list of "lessons learned." This list is typically similar from event to event despite the variety or time course (e.g., "volunteers will converge at the scene" and "communications are a problem"). "Lessons learned" may be a term more suitable to describe an individual who "learns" from a personal experience. Everyone may need to touch a hot stove once to incorporate the experience into memory and "learn" not to do so. What we need is actually "sustainable knowledge," not merely individual experience. Although it is true that in some systems there is a robust continuous quality improvement process that incorporates lessons from prior events to improve preparation and responses to future events (e.g., in the country of Israel), the term "lessons learned" is often a misnomer and should be used with caution if at all. Rather scientific "findings" should be used to form the basis for continuously expanding the body of academic knowledge.

Another example is the word "preplanning." Why should we plan before we plan? Are we not in fact simply planning? Likewise, do we "pre-position" supplies, or are we actually positioning them? Let us keep the terminology simple and descriptive and discard these words from the lexicon. More logical terminology could include "pre-event planning" and "pre-event positioning" of supplies.

Additional disaster descriptors, commonly applied to healthcare facilities, are "internal" and "external." Although it is true that an event can sometimes occur completely within or outside a facility, the real question is the functional impact on the organization's operations and not its location. Furthermore, many incidents are internal and external simultaneously, for example, an earthquake that causes both citywide and hospital internal disruptions.

Sometimes the etiology of a disaster is the focus of the terminology. This is the case with the terms "natural" and "manmade." The literature is replete with the phrase "natural and manmade disasters." Yet there are in fact few if any differences in the management of an event based on etiology. There are also many instances in which it is initially unknown whether the event is "natural" or "manmade." For instance, the deliberate spraying of salad bars with salmonella in the state of Oregon in an attempt to sicken voters and sway an election was probably the first known bioterrorism attack in modern times in the United States, but it was thought to be a "natural" occurrence until many years later. Another example would be a wildfire disaster that is determined to be the result of arson. Although some might term the wildfire a "natural" disaster, the arsonist created it and, depending on the intent, it could even be classified as a type of "manmade" terrorism.

It is also insufficient to classify an event merely via its etiological agent. For example, an anthrax letter attack, although "biological," is managed more like a traditional "chemical" event. That is, there is a discrete "scene" and time of the occurrence. This scenario has been described as a "sudden impact, defined scene" event to distinguish it from a more classic bioterrorism attack (e.g., aerosolized release of weaponized inhalational anthrax) that would be managed as an evolving public health emergency.

The use of acronyms is also problematic. One can sit in a room with a group of "experts" and fail to communicate. Take "MCI" as an example. Does this mean "mass casualty incident" or "multiple casualty incident" or "multi-casualty incident?" In addition, are there a certain number of victims needed to qualify the event as an "MCI?" Is the point not really whether the volume and/or type of casualties exceed our current ability to manage them rather than an absolute number? The very same number of casualties could lead to a "business as usual" response or a full activation of a disaster plan. Furthermore, what is a "casualty?" There is no consistency as to whether the word "casualty" means "death" or "injury or illness" caused by the event. There is a huge difference in managing patients with potentially treatable injuries and illnesses versus those who are deceased. For the purposes of this book, we will define casualty as anyone incurring an injury or illness or dying as a direct result of the event. In addition, there may be secondary or delayed casualties (e.g., patients with exacerbations of chronic medical conditions due to lack of access to routine healthcare or medications). Types of casualties (e.g., deceased) can be further subdivided for analysis.

Even the same word can mean different things to different experts. For example, "surveillance" has a very different connotation for the intelligence or law enforcement communities than it does for a public health audience. Whatever terminology we use to describe "disaster," there is currently a tendency to "send all you have" to a disaster scene (if a discreet "scene" even exists) rather than analyze the needs and tailor the response. More work is needed on methods to determine the exact nature of the event and match the response to these needs via techniques such as resource typing.

CONCEPT OF DISASTER PREPARATION

During my tenure as National Director of the Emergency Management Office in the U.S. Federal Department of Veterans Affairs, the most common question from the Deputy Secretary to me after September 11 was, "Are we prepared?" Interestingly, while preparing for congressional hearings, I noted that within a 24-hour period the Secretary of the Department of Homeland Security was quoted in the lay press as saying "yes," whereas a *New York Times* article quoted university researchers as saying "no." How do we reconcile these apparently contradictory statements? We do so by recognizing that they are incomplete responses to the fundamental question – *prepared for what?* Although some work has moved us toward an answer, there remains a lack of standardized and well-accepted benchmarks or performance measures to assess true preparedness. The field of disaster medicine is in its infancy, yet world events are forcing us to operationalize preparedness measures concurrent with their development.

If we consider the idea that a "disaster" requires resources beyond current capacity, an issue related to preparedness is the concept of "surge capacity." Although "capability" refers to a fixed competence (e.g., the hospital has an angiography suite and is therefore "capable" of performing cardiac catheterizations), "capacity" implies a time-sensitive, current ability (e.g., at this very moment, there exists equipment, staff, and infrastructure such as electricity to operate the angiography suite). When something is preventing current capacity (i.e., lack of staff, supplies and equipment, a building, or organizational management structure), surge capacity is needed. This is a relatively new term that needs further definition and discussion. In addition, there is an urgent need to develop a "crisis standard of care" appropriate to the situation in which resources are insufficient at a certain point in time. Triggers to shift from standard operations to this crisis mode should be developed and key personnel must be educated in their use. We must also build resiliency into our emergency management systems.

FORMAT OF THE BOOK

This book is unique in many ways. We are taking a multidisciplinary approach and collaborating with well-respected academicians and researchers from around the world. In some cases, there is lack of agreement on how to describe or approach the challenges of disaster medicine. Rather than present only one view, we provide a balanced approach with the best science to support each perspective. Within this construct, to the extent possible, we present global (rather than U.S.-centric) perspectives and use a comprehensive emergency management, all-hazard approach philosophy to include a hazard vulnerability analysis. We do not include chapters about every conceivable type of event (e.g., stampedes, wildfires, civil unrest, and so forth); rather, there should be something unique about the topic for it to warrant a separate section. In addition, we emphasize the multidisciplinary nature of the emerging field of disaster medicine and draw heavily from the sociology literature (e.g., the concept of "disasters by design") in addition to other relevant fields.

Chapters are divided into three sections: Overview, Current State of the Art, and Recommendations for Further Research. Hence, we not only provide current information but also look to the future and lay the research agenda for this emerging field, much of which could be considered "translational research" – an area receiving strong emphasis from the U.S. National Institutes of Health, or "transformational research" as promoted by the U.S. National Science Foundation.

THE TIME IS RIGHT

In 2006, the Disaster Medicine Certification Board was formed. Although visionary, it is perhaps premature to offer a certification in a field in which we have not yet proven a unique body of knowledge. To quote an esteemed colleague, "Our teaching must be based on *knowledge*, not on what we *believe*." Too many times, in the early days of disaster medicine, presentations and publications dealt with personal observations and perceptions, and well-meaning presenters showed photographs of the most recent disaster response and told the audience what happened and what they did. Although a beginning, this is not true science. I am convinced that there is a unique body of knowledge that underlies the discipline of disaster medicine, but we do not yet have the data to support this belief.

Too often, a major disaster must occur before a responsible entity begins to provide sufficient resources toward improving medical and health outcomes. Disaster grant money frequently represents a government's reaction to a devastating event and the need to "do something." The interest of healthcare providers in preparing wanes as time passes after a catastrophic event. With global warming and the effects of climate change, we can only expect an increase in worldwide disasters. Developing a formalized academic specialty is an important step in providing resiliency with sustainable interest, funding, and readiness.

The time is now right, and Cambridge University Press is the right publisher to give the appropriate academic credibility to the project. In addition, I can think of no one more qualified and committed to join me as coeditor than Dr. Carl Schultz. Please enjoy this book and use it as a springboard to further academic discussion and debate as we move forward together to create and codify the rapidly emerging field of disaster medicine.

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Part I

Conceptual Framework and Strategic Overview

1

Disaster Research and Epidemiology

Megumi Kano, Michele M. Wood, Judith M. Siegel, and Linda B. Bourque

OVERVIEW

Defining Disaster

There is no single, agreed-upon definition of disaster either within or across disciplines. Definitions used in practice and research vary widely, reflecting differing objectives and interests in regard to the causes, consequences, and processes involved in disasters. In the Preface, Koenig presents a terminology for describing disasters that focuses on the functional impact of disasters to the healthcare system. This chapter discusses research methods and findings in the context of the broader spectrum of processes involved in disasters including, but not limited to, the impact on the healthcare system, the short- and long-term effects on people's health and livelihoods, and the behaviors of individuals, groups, and organizations in relation to disasters.

Accordingly, a disaster is "any community emergency that seriously affects people's lives and property and exceeds the capacity of the community to respond effectively to the emergency."[1] For instance, Hurricane Katrina was a category 5 hurricane at its peak, which made landfall as a category 3 hurricane in the Gulf Coast region of the United States on August 29, 2005. Its accompanying storm surge overwhelmed the local flood protection system, flooded entire communities, led to mass evacuation, caused multiple human casualties, and significantly disrupted people's livelihoods. It overwhelmed the response capacity of the community at the individual, household, and organizational levels. Thus, studies of this disaster legitimately go beyond its impact on the healthcare system.

The term disaster is often used interchangeably with the terms "emergency" and "hazard," although there are formal distinctions. An emergency is a threatening situation that requires immediate action but may not necessarily result in loss or destruction. If an emergency is managed successfully a disaster may be averted. A hazard is a possible source of danger that, upon interacting with human settlements, may create an emergency situation and may lead to a disaster. For the purposes of this chapter, all three terms will be used, and the distinctions in meaning will be maintained.

Historical Overview of Disaster Research

Historically, disaster research has been dominated by exploratory research designs, whereas epidemiological research emphasizes the importance of explanatory designs.[2–8] Exploratory studies usually focus on examining new areas of research or the feasibility of conducting more structured research, with an emphasis on developing hypotheses, often with qualitative methods of data collection. Descriptive and explanatory studies, in contrast, start with hypotheses and emphasize minimizing bias and maximizing external validity, with explanatory studies also attempting to infer causality. (State of the Art section II of this chapter provides greater detail on study design.)

The perceived need to enter the field immediately after a disaster encouraged disaster researchers to utilize exploratory study designs rather than more structured descriptive designs. Researchers thought they were dealing with perishable data that had a limited time frame for collection. Information was thought to be unavoidably fleeting, vanishing quickly after a disaster because of memory decay, removal of debris, and other activities. Furthermore, it was assumed that disaster-associated in- and out-migrations were rapidly changing the target population and their communities in ways that could not be captured by the research. Consequently, early research on disasters relied on data obtained through semistructured interviews with selected informants after quick entry into a community, immediately postimpact. Over time, this perceived need to enter the disaster area immediately has been referred to as the "window of opportunity" and has been adopted by practitioners and policymakers, as well as other research disciplines, including engineering, seismology, medicine, and public health.

Disaster researchers trained in the social sciences have been concerned with the applicability of social theory to the study of disasters and, in reverse, the contributions that disaster research can make to the development of theory, primarily sociological theory. References to theory in the early disaster literature are oblique, however, and often are a statement about why theory cannot be applied or that it will emerge inductively from the research. In contrast, and with the exception of concerns about biological plausibility, epidemiological research is largely theoretical. One popular introductory epidemiology textbook contains no reference to theory in its index.[3]

Early Disaster Research

Samuel Prince's Columbia University dissertation,[9] which examined the impact of the collision and explosion of two ships in the inner harbor of Halifax, Nova Scotia, in 1917, is recognized as the first scholarly study of a disaster.[10] With a few exceptions, other systematic studies of disaster were not undertaken until World War II. Table 1.1 organizes the milestones in disaster research linearly by date, initiating agency and funding sources, primary disciplines conducting the research, research strategies, contributions to the field, and key sources for accessing disaster research. In the United States, through 1959, all of the early research was initiated and funded by the federal government, often the military.

The United States Strategic Bombing Surveys (1944–1947) examined the effect of U.S. strategic bombing and the resultant physical destruction on industry, utilities, transportation, medical care, social life, morale, and the bombed population's will to fight in Germany and Japan. Fritz[11] noted, "people living in heavily bombed cities had significantly higher morale than people in the lightly bombed cities [and] that 'neither organic neurologic diseases nor psychiatric disorders can be attributed to nor are they conditioned by the air attacks.'" In other words, the problems that were anticipated did not emerge, including social disorganization, panicky evacuations, criminal behavior, or mental disorders. In fact, morale remained high and suicide rates declined. These findings were not widely disseminated and were at variance with prewar expectations and prevailing views on the behavior of people under extreme stress.[12,13]

With the advent of the Cold War, federal government agencies, ignorant or unaware of these findings, expressed concern about how people might react to new war-related threats. A second set of studies, funded by the U.S. Army Chemical Corps Medical Laboratories and conducted at the National Opinion Research Center (NORC) at the University of Chicago (1949–1954), hypothesized that disasters cause extreme stress, which in turn results in social disorganization, the breakdown of social institutions, and the manifestation of antisocial and psychotic behavior by individuals and groups. Field studies were conducted following disasters, with a major objective being to use these situations as surrogates for what might occur during an invasive war of the United States and the Americas. "Comparing the state of knowledge prior to the NORC studies with the new field research, it became clear that previous studies . . . were sorely deficient [and], except for a few notable exceptions, the literature was loaded with gross stereotypes and distortions."[11] Researchers compiled the NORC disaster studies into a three-volume report.[14]

In 1952, the U.S. National Academy of Sciences–National Research Council established the Committee on Disaster Studies (later the Disaster Research Group) at the request of the Surgeons General of the Army, Navy, and Air Force to "conduct a survey and study in the fields of scientific research and development applicable to problems which might result from disasters caused by enemy action."[11] This third set of studies refined theories about human behavior in disasters and improved the methodologies. Exploratory field studies conducted in the immediate aftermath of a disaster focused on how individuals behaved in crisis.

The general theoretical structure brought to this research, although not always explicitly stated, was developed from the theories espoused by Mead[15] and Cooley[16] of symbolic interaction and theories of collective behavior, particularly those specific to crowd behavior and the development of emergent groups. It was hypothesized that the norms that determined social interaction might be challenged as a result of a disaster. Different social norms might evolve either temporarily, while the environment stabilized, or permanently, leading to different forms of social organization. Disasters were seen as triggers that disrupted the social order. Of interest was the behavior of individuals, groups, and organizations during either a brief or prolonged period of normlessness.[17,18]

> Societies are composed of individuals interacting in accordance with an immense multitude of norms, i.e., ideas about how individuals *ought* to behave. . . . Our position is that activities of individuals . . . are guided by a normative structure in disaster just as in any other situation. . . . In disaster, these actions . . . are largely governed by *emergent* rather than established norms, but norms nevertheless. (Drabek as cited by Perry[19])

Consistent with the interests in emergent norms and in behavior during and immediately after a disaster, the research conducted between 1949 and 1960 gradually identified an underlying time line in the natural history of a disaster, starting with preparedness and proceeding through warning, evacuation, impact, and response and recovery periods. The early studies focused on the middle four stages, with little attention paid to preparedness or recovery. The stages enumerated have changed over time, but an underlying time line is assumed, whether stated or not, in most contemporary disaster research.

The establishment of the Disaster Research Center (DRC) in 1963, first at Ohio State University and later at the University of Delaware, by Russell Dynes and Enrico Quarantelli, was a natural extension of this early research. DRC continued to conduct field studies immediately after disasters, focusing on the behavior of formal, informal, and emergent groups rather than the behavior of individuals. Early disasters studied included the Indianapolis Coliseum explosion (1963), the Baldwin Hills (Los Angeles) dam collapse (1963), a nuclear weapons accident in San Antonio, Texas (1963), and the Alaskan earthquake (1964). Although primarily studying disasters within the United States, field studies were also conducted in a number of foreign countries.

Most studies were exploratory in design and continue to be today,[20–23] but some investigations were conducted using descriptive designs, including those following the Wilkes-Barre floods (1972) and the Xenia tornado (1974).[24] The Defense Civil Preparedness Agency (precursor to the Federal Emergency Management Agency [FEMA]) funded most of the research, with the focus on major community organizations involved in disasters, such as police, fire departments, hospitals, and public utilities. Some funding was received from the National Institute of Mental Health and the Health Resources Administration to examine the delivery of physical and mental health services.[25]

Gilbert White established the Natural Hazards Research and Applications Center (NHRAC) at the University of Colorado in 1976. With primary funding by the National Science Foundation as part of the National Earthquake Hazards Reduction Program agencies, the center served as a catalyst for bringing social scientists, physical scientists, academic researchers, practitioners,

Table 1.1: Milestones in Disaster Research

Dates	*Primary Research Agency/ Funding Source*	*Primary Disciplines Conducting Research*	*Research Strategies*	*Contributions to Disaster Research and Knowledge*	*Key Sources*
1920	Doctoral dissertation	Sociology	Exploratory case/field study	Recognized as first scholarly study of a disaster[9,107]	
Nov. 1944–Oct. 1947	U.S. War Department, Army and Navy	Civilian and military experts headed by a civilian Chair	Exploratory and descriptive research using field observations, archival data, and personal interviews	Countered prevailing views that extreme stress lowers morale, causes mental disorders and social disorganization[108–110]	U.S. National Archives and Records Administration, Records of the United States Bombing Survey [http://www.archives.gov/research/guide-fed-records/groups/243.html]
1949–1954	National Opinion Research Center at the University of Chicago; funded by the U.S. Army Chemical Corps and Medical Laboratories	Social science; Psychology	Exploratory field studies	Laid the groundwork for the study of human behavior in disasters[111]	
1952–1959	Committee on Disaster Studies (1952–1957), Disaster Research Group (1957–1959), National Academy of Sciences-National Research Council; requested by Surgeons General of Army, Navy, and Air Force; funded by the Armed Forces, Ford Foundation, National Institute of Mental Health, Federal Civil Defense Administration	Social science; Psychology; Medicine	Exploratory and descriptive research involving field studies, experiments, clinical, economic and demographic studies	Showed that routine crises are qualitatively different from large-scale disasters, although there are similarities in human responses across disaster types. Also shed light on the positive outcomes of disasters[11,14,57,112–114]	
1963–present	Disaster Research Center at Ohio State University and later at the University of Delaware; funded by Office of Civil Defense, FEMA and other federal agencies	Sociology	Exploratory field studies during immediate aftermath of a disaster, and descriptive surveys	Generated sociological disaster research over four decades. Remains one of the main academic centers for disaster research in the U.S.	Disaster Research Center [http://www.udel.edu/DRC/] *International Journal of Mass Emergencies and Disasters* [http://www.ijmed.org/] *Mass Emergencies* [http://www.massemergencies.org/]
1970–present	Center for Disease Control, and later, the Centers for Disease Control and Prevention (CDC)	Public health, especially epidemiology	Descriptive and some explanatory epidemiology	The first epidemiological study of a disaster is published[26] *MMWR* becomes the main source for epidemiological disaster research in the U.S.	*MMWR* [http://www.cdc.gov/mmwr/]

(*continued*)

Table 1.1 (***continued***)

Dates	*Primary Research Agency/ Funding Source*	*Primary Disciplines Conducting Research*	*Research Strategies*	*Contributions to Disaster Research and Knowledge*	*Key Sources*
1973–present	Centre for Research on the Epidemiology of Disasters at the School of Public Health of the Université Catholique de Louvain in Brussels, Belgium	Epidemiology	Descriptive and explanatory epidemiology. Emphasis on applied research	Established an academic center for the study of disaster epidemiology. Maintains database on disasters worldwide and their human and economic impact by country and type of disaster	*Bulletin of the World Health Organization* [http://www.who.int/bulletin/en/] *Disasters* [http://www.blackwellpublishing.com/journal.asp?ref = 0361–3666&site = 1] *Epidemiologic Reviews* [http://epirev.oxfordjournals.org/] *Lancet* [http://www.thelancet.com/]
1976–present	Natural Hazards Center at the University of Colorado; funded by a consortium of federal agencies and the Public Entity Risk Institute	Geography; Sociology; Economics	Various research objectives and strategies. Promotion of interdisciplinary research	Brought together hazard researchers and disaster researchers. Increased interaction across disciplines, and between researchers, practitioners and policy makers both in the U.S. and internationally	Natural Hazards Center [http://www.colorado.edu/hazards/] *Natural Hazards Review* [http://www.colorado.edu/hazards/publications/review.html]
1976–present	World Association for Disaster and Emergency Medicine	Emergency medicine	Exploratory and descriptive research utilizing case studies and surveys	Marked emergency medicine's entry into disaster research	*Prehospital and Disaster Medicine* [http://pdm.medicine.wisc.edu/]
1977–present	Numerous grants awarded by the National Science Foundation, U.S. Geological Survey, National Institute of Science and Technology, FEMA, and the National Oceanic and Atmospheric Administration through the National Earthquake Hazards Reduction Program	Geography; Sociology; Political science; Psychology; Economics; Decision science; Regional science and planning; Public health; Anthropology	Various research objectives and strategies	Expanded the diversity in and quantity of disaster research[115]	

and policymakers together in multidisciplinary research projects, yearly workshops, and training programs. It encouraged the merger of disaster and hazard research. Interestingly, it was not until the last decade that the workshops drew participants from medicine, emergency medicine, epidemiology, and public health.

Epidemiology, Public Health, and Emergency Medicine

The first disaster research by investigators who identified themselves as epidemiologists was a study of the East Bengal cyclone of November 1970, by Sommer and Mosley.[26] They showed that death rates were highest for children and the elderly and that females fared poorly relative to males. A decade later, in the first article published on disaster research in *Epidemiologic Reviews*, it was noted, "research on the epidemiology of disasters has emerged as an area of special interest."[27] The authors observed that a few university groups in the United States were conducting extensive research on disasters (e.g., DRC and NHRAC) and that there was the Center for Research on the Epidemiology of Disasters at the School of Public Health of Louvain University in Brussels, Belgium. They described the work being done as focusing on the immediate postimpact period, with emphasis on surveillance for outbreaks of infectious and communicable diseases and on increased mortality directly attributable to the disaster. Importantly, they also recognized three "controlled long-term health studies," the 1968 floods in Bristol, England; the 1974 Brisbane, Australia, floods; and the 3- and 5-year follow-up of the 1972 Hurricane Agnes floods in Pennsylvania.

In 1990, a discussion of the epidemiology of disasters appeared as a brief update in *Epidemiologic Reviews*.[28] Many of the disasters discussed occurred outside the United States. Notably, the public belief about the high prevalence of communicable diseases postdisaster was countered. Unlike the earlier review, however, there was no cross-referencing to studies conducted by social scientists or others traditionally associated with disaster research. In 2005, *Epidemiologic Reviews* devoted a full issue to "Epidemiologic Approaches to Disasters." Included were original reviews of research conducted following cyclones, floods, earthquakes, and the Chernobyl disaster and of the development of posttraumatic stress following disasters.

Disaster epidemiology concentrates on estimating the short- and long-term, direct and indirect incidence, and prevalence of morbidity or other adverse health outcomes, with the objective of developing surveillance systems and prevention strategies and estimating the public health burden caused by the disaster.[29] Ideally, studies would be population based and longitudinal in design. Case-series, and cross-sectional, case-control, and cohort designs are all represented in the epidemiological studies of disasters, but where field studies are common in other disciplines, the case-series predominates in the epidemiological disaster literature. The U.S. Centers for Disease Control and Prevention (CDC) and others have encouraged and sometimes funded the conduct of postdisaster, rapid-assessment surveys, using modified cluster sampling,[30] but a substantial number of epidemiological studies are restricted to coroners' reports and the description of persons who present at emergency departments and other points of service. Many of these studies make no effort to describe the "denominator population" from which the dead, the injured, and the sick were drawn. A further complication is the lack of agreement on what constitutes a disaster-related death, injury, or disease.[31] With the exception of one article, none of the contributions to the special issue of *Epidemiologic Reviews* makes any reference to theory, and most of the articles end by describing a need for more rigorous methodology in epidemiological studies of disasters.

The authors of this chapter conducted systematic, although not exhaustive, searches for disaster-related research articles in the epidemiological literature published between 1987 and 2007 in the *Morbidity and Mortality Weekly Report* (*MMWR*), *Epidemiology*, *Epidemiologic Reviews*, and *American Journal of Epidemiology*. Not surprisingly, the majority (more than a hundred since 1987) of epidemiological disaster studies were published by the CDC in the *MMWR*. These articles examine the full range of disasters and disaster-associated morbidity, mortality, service delivery, and needs assessments. Like the early field research conducted by social scientists and psychologists, the majority of studies are case series or field studies, which lack denominator data or information about the population they represent.

In contrast, *Epidemiology*, the journal of the International Society for Environmental Epidemiology, published fewer than 40 disaster-related articles between 1987 and 2007, with most published since 2000, and the majority of which were conference abstracts rather than full articles. In addition to the literature noted previously, *Epidemiologic Reviews* published review articles on psychiatric distress from disasters, pandemic influenza, toxic oil syndrome, and heat-related mortality. Fewer than 20 articles on disasters have been published in the *American Journal of Epidemiology* during the same time period, where the emphasis has been on mortality, morbidity, injuries, and psychological distress.

The establishment of the World Association for Disaster and Emergency Medicine by Peter Safar and other leading international experts in resuscitation/anesthesia in 1976 and the establishment of the American Board of Emergency Medicine as a conjoint specialty board in 1979 mark emergency medicine's entry into disaster research.[32] Originally an "invitation only" group called the Club of Mainz, membership was eventually broadened in 1997. In 1985, Safar founded the journal *Prehospital and Disaster Medicine*. Much of the disaster research conducted in emergency medicine is published in *Prehospital and Disaster Medicine*, but very few articles contain references to disaster research conducted outside of medicine or before 1985.

Using a broad definition of "disaster research" and "nonmedical citations," 23 recent issues of *Prehospital and Disaster Medicine* were reviewed for articles on disaster research. Seventy-one articles were identified, which included a total of 92 citations to nonmedical sources; extra-medicine references are found in only a limited number of articles. Most references are to other emergency medicine or medical journals, including the *Annals of Emergency Medicine*.

These findings suggest that the many disciplines engaged in hazard and disaster research remain self-contained, with limited knowledge of research conducted in other areas and minimal contact across disciplines.

CURRENT STATE OF THE ART

This discussion of the state of the art focuses on three aspects of disaster research: methodology, vulnerability, and estimates of morbidity and mortality. The first portion provides an overview of key methodological issues pertinent to disaster research, ranging from disaster research settings to ethical considerations. The second portion explores the concept of vulnerability, focusing on different approaches to determining who might be most vulnerable to the impact of a disaster. The last section is relevant to the impact and aftermath of a disaster. It reviews the factors that influence estimates of disaster-related morbidity and mortality.

Disaster Research Methods

There are multiple scientific perspectives involved in disaster research, and the methods used to study disasters are just as varied. The appropriateness of one methodological approach over another is determined by the specific question that the researcher is trying to answer, and the discipline in which the researcher was trained. A number of books provide expert guidance on disaster research methods.[4,33–35]

Disaster Research Objectives

The objective of a disaster research study can be exploratory, descriptive, or explanatory. Exploratory studies are the least structured type of research endeavor, often examining new areas of research or the feasibility of conducting more structured research. The emphasis is on *developing* hypotheses, frequently involving in-depth data collection from a relatively small group of purposively selected research subjects. It should not be assumed that exploratory studies are easier to conduct or less time consuming simply because they tend to be performed on a smaller scale or without the use of large sets of quantitative data.

Descriptive studies, in contrast, start with formal hypotheses or research questions and seek to obtain accurate estimates of the distribution of variables (e.g., disease occurrence by person, place, and time) or associations between variables and theoretical constructs in a population. Like descriptive studies, explanatory studies start with formal hypotheses or research questions. The goal of explanatory studies is to explain the "true" causal relationship between variables. Explanatory research is also referred to as analytic, as opposed to descriptive, research in epidemiology.[36] In both descriptive and explanatory studies, emphasis is placed on selecting samples that are representative of the population being studied and minimizing bias in data collection.

Disaster Research Settings

The study of disasters can occur in many different physical and temporal contexts. Among disaster health researchers and epidemiologists, data collection activities have been focused largely in "hot spots" where disaster victims are likely to congregate, such as emergency departments. Research conducted in these settings captures the "numerator," that is, the number of people with different health afflictions who present themselves in these settings. This approach provides no information on the larger community from which these individuals emerged (denominator) or the extent to which they represent the range and severity of disaster-related morbidity. For example, Peek-Asa and colleagues[37] examined coroner and hospital records following the 1994 Northridge earthquake and found that when compared with their systematic, individual medical record review, initial reports overestimated disaster-related deaths and hospital admissions by overattributing deaths and injuries that presented for care during the disaster window. Population-based studies, in contrast, enable researchers to estimate the number of individuals in a community who were afflicted in some manner because they focus on the "denominator," or the entire community at risk. For example, following the 1994 Northridge earthquake, three waves of population-based data collection provided information about the proportion of the population affected by disaster, levels of community preparedness, physical and emotional disaster-related injuries within the community, utilization of healthcare and other disaster relief services, and the cost of damages to physical structures, among other things.[38]

Disaster research may also occur in different temporal contexts. An organizational structure for disaster planning, response, and research conceptualizes disaster events as occurring in a cycle. There are slight variations in the way different researchers divide and label the critical periods, but three phases are common to all schemas.[39] These are the "preimpact," "transimpact," and "postimpact" periods, also described as the "disaster preparedness," "emergency response," and "disaster recovery" periods. The U.S. National Research Council recommends that cycles typical of hazards on one hand, and disasters on the other, be integrated in recognition of the importance of collaborative cross-disciplinary research.[40]

The preimpact period is the time frame leading up to a disaster event. Vulnerability reduction, hazard mitigation, and emergency preparedness planning and research may be conducted during this phase. Baseline disaster data and information about disaster readiness may be collected as well. The transimpact period focuses on warning, evacuation, immediate response, and disaster relief activities. The postimpact period revolves around disaster recovery. It is important to note that these divisions serve as an organizational scheme and are neither fixed nor absolute. In fact, they may blend together depending on the outcome of interest.

More recently, studies have been conducted during all phases of the disaster cycle, extending the window of postimpact data collection and using longitudinal designs (comparing data before and after a disaster) when appropriate baseline data are available. The notion that disaster-related memory is stable over time is supported by research conducted in three successive time periods following the 1994 Northridge earthquake in California.[41]

The stages of the "disaster cycle" can be related to the different levels of morbidity and mortality prevention. Within the field of epidemiology, the term "prevention" is broadly used to understand the spectrum of efforts to eliminate or reduce the negative consequences of disease and disability.[42] Traditionally, the term has been defined in levels of primary, secondary, and tertiary prevention to help delineate different healthcare foci. Primary prevention involves individual and group efforts to protect health through activities such as improving nutrition and reducing environmental risks. These efforts are made before disease or disability occurs, and they are the focus of public health. In terms of the health threats posed by disasters, primary prevention efforts represent individual and group disaster mitigation and preparedness activities. Secondary prevention consists of measures that facilitate early detection and treatment, such as health screening, to control disease or disability and reduce the potential for harm. In terms of disasters and their health consequences, secondary prevention can be likened to early warning systems, evacuation efforts, and immediate disaster response and relief because these efforts are designed to reduce later harm in the face of a newly introduced health threat, that is, disaster. Tertiary prevention strives to reduce the long-term impact of disease and disability by eliminating or reducing impairment and improving quality of life. These efforts are generally the focus of rehabilitation. Tertiary prevention of disaster-related health effects might be understood as disaster recovery efforts, in which the goal is to eliminate impairment caused by a disaster and rebuild communities and infrastructures. Figure 1.1 integrates the temporal

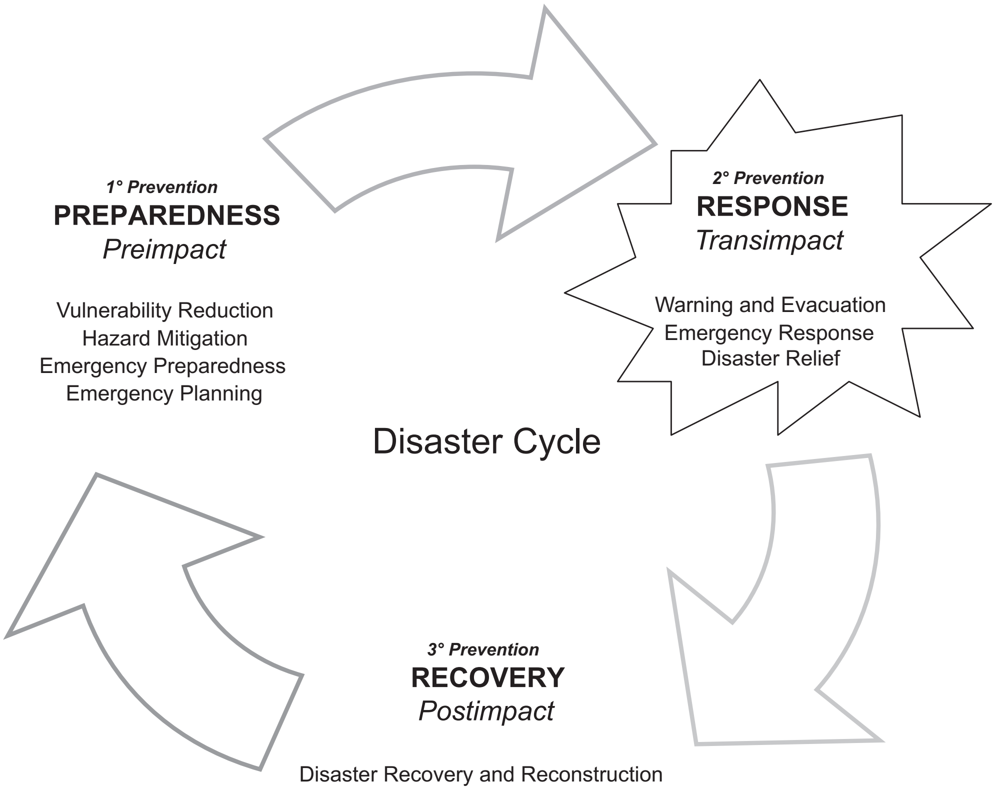

Figure 1.1. The disaster cycle.[39,40,42]

stages of disaster, levels of prevention, and disaster-related activities.

Disaster Research Variables

Regardless of the phase of the disaster cycle that is being studied, the choice of research variables requires careful consideration. This selection is guided by the researcher's disciplinary or theoretical background as well as by the unit of analysis (i.e., individuals, groups, organizations, or communities). Variables that are expected to have an effect on the outcome of interest are the independent variables. For example, demographic characteristics are often considered independent variables that affect people's experiences in disasters. Another key independent variable that is studied in disaster research is the level or dose of exposure to a disaster. Disaster exposure can be measured in various ways, such as the intensity of shaking experienced in an earthquake, the extent of personal loss due to a disaster, or the amount of information about a disaster that a person received through the media.

The range of possible outcomes or dependent variables in disaster research is extremely wide due to the multidimensionality of the disaster phenomenon and the corresponding multidisciplinary nature of disaster research. The major disciplines involved in disaster research today include geography, geology, engineering, economics, sociology, psychology, public policy, urban planning, anthropology, public health, and medicine.

Geographers and geologists study the relationship between human settlements and hazards (e.g., earthquake faults, hillsides, and floodplains), or the "hazardscape," and engineers examine the extent of structural damage that can be caused by a disaster. Economists assess the economic and financial impact of disasters, sociologists and psychologists study the behavioral responses to disasters and disaster risk, and health professionals are primarily interested in the effect of disasters on people's health and the healthcare infrastructure. Depending on when (i.e., during which part of the disaster cycle) the dependent variables are measured and how the study is designed, researchers can forecast the amount of loss and damage that might be done or prevented, measure the actual impact of a disaster, assess the effectiveness of interventions in mitigating disaster impact, and predict the course of long-term recovery, each in terms of the dependent variables of interest to the researcher.

As the number of disasters increases worldwide, the field of disaster research grows, with new disciplines being added or previously minor disciplines becoming more prominent. These changes affect the dependent variables that are studied in disaster research. For example, since September 11, 2001, the study of terrorism has grown dramatically within this field. Studies have assessed different outcomes of terrorism, including the public's response to terrorism and the health impact of terrorism events. Similarly, bioterrorism, pandemics, and public health preparedness (or lack thereof) are emerging as critical areas of study.

Disaster Research Study Designs

The appropriate study design depends on the research objectives, whether it is exploratory, descriptive, or explanatory/analytic (as described earlier), and the feasibility of the study given available resources. The study designs described here are frequently used in the social sciences and in epidemiology to study a wide range of both disaster-related and nondisaster-related phenomena.

Experimental studies involve comparing outcomes between those who receive a certain "treatment" and those who do not, holding all other known factors constant. A treatment can be any independent variable that is expected to have an effect on the dependent variable. In experiments, the researcher controls the levels of the independent variable or exposure in an attempt to isolate its effect. Experiments involve random assignment of subjects to treatment groups (i.e., randomization) to increase the likelihood that the groups will be comparable in regard to characteristics other than the main independent variable that may affect the outcomes. Truly experimental designs can offer evidence with the highest internal validity (i.e., evidence of causality) and, thus, are suitable for explanatory research. As an example, researchers tested the effectiveness of a behavioral treatment for earthquake-related posttraumatic stress disorder by randomizing a group of survivors of the 1999 Turkey earthquake with a clinical diagnosis of posttraumatic stress disorder into treatment and nontreatment groups.[43] This study identified significant effects of the behavioral intervention at weeks 6, 12, and 24, and 1–2 years posttreatment. Experiments might also be conducted in which human subjects are not involved, for example, to test whether certain structural designs mitigate damage in an earthquake. They are not used, however, to investigate how people are affected by or respond to disasters because it is unethical and, in most cases, impossible to manipulate exposure to a disaster.

Quasiexperiments are frequently used in the social sciences for explanatory research. There are many natural social settings in which the researcher can approximate an experimental design without fully controlling the stimuli (determining when and to whom exposure should be applied and randomizing the exposure) as in a true experiment. Collectively, such situations can be regarded as quasiexperimental.[44–46] In the absence of an actual disaster, the independent variable can be exposure to disaster "risk" instead of exposure to the disaster itself. For example, researchers conducted a study of the causal sequence of risk communication and preparedness behavior in response to an earthquake prediction in three central California communities with varying degrees of earthquake risk:[47] a community 25 miles from the predicted epicenter that had experienced a devastating earthquake in 1983, a community also 25 miles from the predicted epicenter but with no recent earthquake experience, and a community 75 miles from the predicted epicenter with no recent earthquake experience. Results showed that the relationship between information seeking and earthquake mitigation and preparedness behavior was essentially the same in all three communities, regardless of their levels of "risk exposure."

In epidemiology, study designs that are not experimental are called observational studies.[36] That is, subjects are studied under natural conditions without any intervention by the researcher. Only naturally occurring exposures and outcomes are examined in these types of studies. A cohort study is one of the typical designs used in epidemiology in which the researcher identifies a group of exposed individuals and a group of nonexposed individuals, or individuals with varying degrees of exposure, and follows the groups to compare the occurrence of outcomes of interest. In disaster research, for example, long-term health outcomes could be compared between groups of residents of the same disaster-affected community based on their level of exposure to the index disaster or between residents of a disaster-affected community and residents of a similar community not affected by a disaster.

Another common study design in epidemiology that could be applied to disaster research is the case-control study. As with cohort studies, this design is appropriate for explanatory research aimed at understanding the association between exposure and outcomes. In contrast with cohort studies, however, instead of determining exposure status first and then observing outcomes, a case-control study begins by identifying groups of people who naturally have or do not have the outcome of interest (i.e., cases and controls) and then retrospectively determining their exposure status. For example, researchers would first identify the cases (e.g., people who exhibit certain symptoms of psychological distress), match them with controls (e.g., people without symptoms but who are comparable to the cases in other respects), and compare the extent to which cases and controls were exposed to the index disaster.

Epidemiologists are often interested in identifying dose–response relationships, that is, the relationship of observed outcomes to varying levels of exposure. A dose–response relationship strengthens the internal validity of the research findings. Quasiexperiments, cohort, and case-control studies can all offer relatively high internal validity. They can also maximize external validity, or generalizability to a larger population, if population-based sampling is used. One of the major challenges to using these designs is defining disaster exposure. For example, one might posit that everyone in the United States was exposed to the September 11, 2001, attacks on the World Trade Center and Pentagon, even though most people were not proximal to the disaster sites. Rather, they may have experienced it vicariously through the media, their friends, or family.

Observational study designs are also appropriate for descriptive studies, in which the objective is to describe accurately the distribution of variables or associations between variables in a population. Nonexperimental designs have low internal validity but can have a high degree of external validity if they are conducted with a probability sample of the population. The greatest challenge in conducting population-based studies in disaster research is identifying the population to which the study results can be generalized, or, in other words, establishing the denominator for population estimates. This is not a major problem when a disaster does not result in large demographic shifts. In fact, very few disasters in the United States have resulted in mass casualties or population displacements. Catastrophic disasters, however, complicate population-based sampling because the population from which data can be collected after a disaster is likely to be unstable or different from what it had been before the disaster due to disaster-associated in- and out-migrations, deaths, and alterations in procedures used to compile various types of administrative records.[48,49]

A nonexperimental, observational study design that is suitable for in-depth, exploratory research is the case study (or a case series). In this type of study, cases are purposively selected for the study and are not statistically representative of a population, thus compromising external validity. Internal validity is also low because systematic comparisons between cases and noncases are not performed. The main benefit of case studies is that they lead to a better understanding of rare or new phenomena and the development of hypotheses. Much of the early disaster research in the social sciences used case studies (see earlier section on Historical Overview of Disaster Research). Case studies are also used in disaster medicine and epidemiology to describe the unique characteristics of deaths, injuries, illnesses, and other health outcomes associated with disasters.[50]

In addition to the distinction between experiments, quasiexperiments, and observational designs, there is a difference in study designs in terms of the frequency of data collection over a study period. When data are collected at only one point in time, it is called a cross-sectional or prevalence study. It is best used to describe the state of a population at a given time. For that reason, the analogy of taking a snapshot is often used to describe the nature of cross-sectional studies. Cross-sectional designs can also be used to identify causal associations between variables, where the evidence for causation is based on the application of theory and inferential logic rather than time sequence.[51] That is, because all variables are measured at the same time, theoretical models determine whether the hypothesized independent variable logically precedes the dependent variable. Thus, although cross-sectional designs are most naturally used for descriptive research, they are also used in explanatory designs.

Cross-sectional studies conducted before a disaster occurs can provide valuable baseline data on health status, knowledge of risks, attitudes toward preparedness, and actual preparedness behavior at the individual, organizational, or community level. In reality, most disaster studies using a cross-sectional design are conducted after a disaster has occurred to assess the impact of a disaster. Examples of these kinds of studies include the postdisaster, rapid health surveys routinely conducted by the U.S. CDC as well as by local public health officials. Results of postdisaster, cross-sectional studies must be interpreted with care, especially when baseline data are not available. Although it is tempting to associate postdisaster observations (such as elevated blood pressure) with the index disaster, it must be recognized that findings from a postdisaster, cross-sectional study reflect conditions that existed before the disaster as well as conditions that arose during or after the disaster. Not all cases or conditions identified in a postdisaster, cross-sectional study are new (i.e., incident cases). Rather, some may have existed before the disaster. The cases identified in a cross-sectional study, including both old and new, are referred to as prevalent cases.

Even new cases that occur after a disaster may have little or no causal association with the disaster itself. Among the prevalent cases identified after a disaster, errors are frequently made in distinguishing between incident cases (or conditions) caused by the disaster, incident cases unrelated to the disaster, preexisting cases that were exacerbated by the disaster, and preexisting cases that were unaffected by the disaster. Chronic conditions are especially prone to such classification errors, although a carefully designed study can allow researchers to make causal attributions to the index disaster. For example, a nested case-control study, which is a case-control study conducted within a cohort study, was used to assess the long-term mortality and morbidity associated with exposure to the 1988 earthquake in Armenia.[52] New cases of heart disease and other chronic conditions were matched with controls within a cohort of earthquake survivors that had been followed for 4 years since the earthquake. The analyses revealed a dose–response relationship between exposure to the earthquake (i.e., loss of material possessions and family members in the earthquake) and the risk of developing heart disease within 4 years after the earthquake.

When data are collected more than once over a longer period of time, the studies are called longitudinal. This design is used less frequently than cross-sectional designs because it typically requires more resources and a longer-term commitment to the study. It has the advantage, however, of allowing researchers to examine trends and changes over time. It can also provide stronger evidence for causality because temporal ambiguity is reduced or eliminated. In disaster research, longitudinal designs are often used for documenting a community's course of recovery from a disaster or for observing changes between periods interrupted by a disaster (i.e., pre- and postdisaster).

Examples of longitudinal designs include repeated cross-sectional studies, in which *new samples* of the population are studied each time, and cohort studies, which are also referred to as panel studies or repeated-measures studies, in which data are collected at multiple times from the *same group* of subjects. Repeated cross-sectional designs are especially useful when predisaster data are available for a population that was later affected by a disaster. To illustrate, a study was conducted to estimate the impact of Hurricane Katrina on mental illness by comparing results of a posthurricane survey with those of an earlier survey.[53] The populations from which the probability samples were drawn were comparable (although the posthurricane population frame was limited to survivors) and the measures used to assess outcomes were identical. Results showed that the estimated prevalence of mental illness doubled after the hurricane.

Although repeated cross-sectional studies have the advantage of being able to study samples that are representative of the population at each time of data collection, panel studies allow for the examination of change over time *within* a group. For instance, respondents to a survey conducted after the 1994 Northridge, California earthquake were reinterviewed 4 years later to determine if their prior experience affected their response to another anticipated disaster, a slow-onset El Niño weather pattern.[54] This study found that emotional injury experienced as a result of the earthquake both facilitated preparedness, in terms of number of hazard mitigation activities performed, and predisposed people to a subsequent emotional injury. Cohort studies, however, often suffer from loss to follow-up (i.e., respondents who intentionally or unintentionally drop out of the study). In the El Niño study, of the 1,849 households originally interviewed after the earthquake, 1,353 (73%) agreed to a follow-up interview, but less than half of them, 632, could be contacted at the time of the follow-up study. Ultimately, 414 agreed to participate in the follow-up study, yielding a 22.4% response rate of those interviewed at baseline. Loss to follow-up is expected to be high in areas where the population is very mobile, such as in large urban areas.

A further aspect of study designs is the timing of data collection in relation to the outcome of interest associated with the index disaster. In a concurrent design, both exposure and outcome data might be collected at the time the event occurs, or shortly afterward. In a prospective design, which is only possible in a longitudinal design, exposure data are collected from the target population before the event (in this case, the disaster) has occurred, and outcome data are collected afterward. In these instances, the study may be initiated for other purposes but can be adapted to the disaster researchers' needs. Last, in a retrospective design, data are collected on events or conditions that have occurred in the past by using archival data or recalled information. An example here is reviewing hospital records after an index disaster. Case-control studies are retrospective by design because prior exposure data are collected after cases are identified. Although most observational studies can use any one of these designs, or a combination of them, experiments by definition can only be concurrent or prospective because it is impossible to go back in time to manipulate study variables.

Some study designs have been underutilized in disaster research. Case studies using laboratory simulations were used in early disaster research,[55,56] but have not been used in recent times, perhaps because of the difficulty of simulating the complexities of a disaster. Moreover, the external validity, or generalizability, of results from laboratory simulation studies might be compromised because of the highly artificial and decontextualized nature of a laboratory setting. It has been noted, however, that disaster simulation exercises in the field, which are routinely conducted to train emergency management personnel, are underutilized opportunities for disaster research.[7]

Retrospective designs have generally been disregarded especially because of the emphasis on the "window of opportunity" immediately following a disaster. These include retrospective case studies, which involve the historical analysis and reconstruction of events that occurred in the past,[10] historical cohort studies, which involve the analysis of data on cohorts that were followed up in the past, and case-control studies. Case-control studies are appropriate for studying rare outcomes and, thus, would be suitable for studying disaster-associated phenomena.

Disaster Research Data Collection

Disaster research, as with most other types of research, utilizes both qualitative and quantitative data. Qualitative data are often collected through field observations, in-depth interviews, focus group discussions, and archival research. They offer very detailed information about a specific individual or group, place, time, and/or phenomenon that is of interest to the researcher. Qualitative data collection methods are frequently used in exploratory or descriptive studies in which the objective is to investigate an issue or describe a phenomenon about which there is little existing information. A historical example of qualitative disaster research is Form and Nosow's 1958 study of community response to a tornado in Michigan.[57] A more recent study examined the experiences of hospital evacuation after the 1994 Northridge, California, earthquake by using structured interviews with physicians, nurses, administrators, and other staff who were on duty during the evacuation.[58] These and other examples of well-performed qualitative disaster research demonstrate that despite a common misperception that qualitative studies are less scientifically rigorous than quantitative studies, they are indeed important and have been published in prominent journals.

Quantitative data complement qualitative data by expanding the breadth of knowledge about a particular issue. The most popular and efficient method for collecting quantitative data is the use of surveys based on representative sampling. Surveys can be of individuals, households, institutions, or communities, and data in surveys can be collected with questionnaires and record reviews. Surveys of individuals are typically conducted using questionnaires that are self-administered by the respondent or administered by interviewers over the telephone or in person. For surveys of households, organizations, or communities, a representative of the group can be designated to participate in the survey instead of all members of the group.

Survey topics that are common in social science research include predisaster knowledge, attitudes and behaviors, immediate emotional, and behavioral responses to a disaster, and the course of postdisaster recovery. Commonly perceived limitations of the use of surveys in disaster research include disaster victims' reluctance to discuss their experiences with researchers and the lack of reliability of self-reports, although these concerns have been refuted by several researchers.[41,59,60] Another obstacle to using surveys for disaster research is the general decline in participation rates in household surveys in recent years.[61]

Surveys of individuals, healthcare providers, and healthcare organizations are heavily utilized in disaster epidemiology to obtain quantitative data about the health status of a population and possible associations between disaster exposure and health outcomes. These data are critical for assessing the immediate and ongoing healthcare needs in a population during and following a disaster. In addition to direct surveying of members of the population, epidemiological disaster surveys often collect aggregated data from healthcare providers, emergency response agencies, coroners, and other relevant sources, either prospectively or retrospectively. Public health officials might survey emergency shelters on a weekly basis by reviewing medical records to enumerate shelter residents diagnosed with acute respiratory and gastrointestinal illnesses to detect possible outbreaks of infectious disease among sheltered evacuees.

Standardization of the data collection method is especially important with quantitative data because researchers want to compare data across different events, populations, settings, and times. In this respect, postdisaster rapid health surveys frequently suffer from inconsistencies in sampling methods, data reporting periods, the use of different criteria for establishing disaster-relatedness of health outcomes, and incomplete information in records for determining if an injury or medical condition is disaster related. Lack of standardized definitions and survey instruments is one of the major challenges to quantitative data collection in disaster research.

Mixed Method Disaster Research

With increased awareness that qualitative and quantitative methods and data complement each other, a mixed methods approach might become more popular in disaster research. Mixed methods is broadly defined as research in which the investigator collects and analyzes data, integrates the findings, and draws inferences by using both qualitative and quantitative approaches or methods in a single study or a program of inquiry.[62]

The Multihazard Mitigation Council of the National Institute of Building Sciences recently concluded a mixed method disaster research study[63] to determine the future savings gained from FEMA's investments in hazard mitigation activities. Future savings based on losses avoided because of earthquake-, wind-, and flood-related hazard mitigation activities funded by FEMA through three large hazard mitigation grant programs were measured in two interrelated studies by using different methods to address the common question: What is the ratio of hazard mitigation benefit versus cost? The first study component used benefit/cost ratio analyses and a statistically representative sample of FEMA mitigation grants so that findings in the sample could be applied to the entire population of FEMA mitigation grants. In the second study component, eight communities were selected using purposive sampling to examine if, why, and how mitigation activities percolate through communities. Field studies were conducted in each community by using semistructured telephone interviews with informants, field visits, and the collection and review of documents. Findings suggest that natural hazard mitigation activities funded by the three FEMA grant programs between 1993 and 2003 were cost effective and reduced future losses from earthquakes, wind, and floods; yielded significant net benefits to society as a whole; and represented significant potential savings to the federal treasury. Specifically, the quantitative benefit/cost analysis found that on average, every dollar spent on natural hazard mitigation saves society approximately 4 dollars. The community studies suggest that the 1:4 cost/benefit ratio may be an underestimate because federally funded hazard mitigation often leads to an increase in nonfederally funded mitigation programs.

Geographical Information Systems and Disaster Research

The application of Geographic Information Systems (GIS) technology is growing in the field of disaster research. Dash[64] and Thomas and colleagues[65] have written chapters on the use of GIS technology in disaster management and research. There have also been discussions on the utility of GIS-based spatial analysis in health research and epidemiology.[66,67] The main strength of GIS technology is its ability to integrate geographical data with other information, such as demographic data, extent of physical damage caused by a hazard, morbidity and mortality rates, and access to resources. It also has the capability to analyze data as well as to generate maps and other visual summaries of the data.

FEMA has developed a software program, HAZUS-MH, which uses GIS technology to map and display hazard data and also produce estimates of potential losses (i.e., physical damage, economic loss, and social impact) from earthquakes, floods, and hurricane winds. GIS-based risk assessment tools such as these are extremely useful to disaster management officials and policymakers who are responsible for developing and implementing disaster mitigation, preparedness, and response strategies for geographically defined areas.

The most common application of GIS technology in disaster epidemiological research is to facilitate postdisaster rapid assessment surveys, which frequently use cluster–random sampling. The cluster–random sampling design, which was originally developed to estimate immunization coverage in a population, allows investigators to obtain expedient and accurate population-based information at relatively low cost.[68] GIS is used to aid the random selection of households, field navigation, data management and analysis, and presentation of results. For example, less than 3 weeks after Hurricane Katrina struck Hancock County, Mississippi, the CDC was asked to conduct a rapid assessment of public health needs. Using GIS, they cluster–random sampled 200 households, and, using global positioning system technology to navigate to those locations, they physically surveyed 197 households and completed interviews with 77 of them in 2 days.[69] The results of the assessment, which indicated a need for water, trash/debris removal, and access to health services, were provided to the state health department and emergency management to guide relief and recovery operations.

There are other applications of GIS in disaster epidemiology, which involve more extensive data collection and spatial referencing. Peek-Asa and others[70] used GIS to link data on the geophysical characteristics of the 1994 Northridge, California earthquake (i.e., shaking intensity, strong ground motion, and soil type), individual characteristics of people who were injured in the earthquake (i.e., physical address and demographics), and building data (i.e., damage state, year of construction, structure type), each obtained from a different source. Their analyses indicated that a person's age and sex, intensity of ground motion, and multiunit building structures independently predict heightened risk for injuries in an earthquake.

GIS has the potential to facilitate data collection, analysis, and presentation for describing or predicting the geographical distribution of various disaster-relevant variables. The usefulness of GIS to disaster research, and especially disaster health research, depends on the quality and availability of spatial data. Health data generally lack spatial attributes unless they were collected specifically for use in GIS. In addition, there is a legitimate concern about preserving individual confidentiality within spatial information. Researchers have shown, for instance, that a map of Hurricane Katrina–related mortality locations in Orleans and St. Bernard Parishes published in a local newspaper could be reengineered to reveal the actual addresses associated with the points, even though the original map included very little secondary spatial data.[71]

So far, GIS has primarily been utilized as a decision-making tool for disaster management or for applied disaster research. Its application to theory-oriented disaster research has been very limited, such as in studying the spatial patterns of social vulnerability to disaster.[72] GIS has yet to be widely used in scientific disaster research for the advancement of theory.

Ethics in Disaster Research

As in any research, ethical considerations are integral to disaster research. The central concern is whether the research activity could, directly or indirectly, harm the research participants and the wider community. For example, field observations and interviews of evacuees and emergency responders during or immediately after the disaster might impede the progress of relief operations. Likewise, interviewing disaster victims about their experiences has the potential to cause emotional stress and pain, compounding that already caused by the disaster, which might not be justified by the expected benefits of the study. Other ethical considerations include the ability of researchers to maintain a neutral stance. This situation might emerge when grave human suffering seemingly is attributable to social injustice and an incompetent response by the organizations that are responsible for protecting people's welfare. Despite a sense of urgency to get into the field postimpact, disaster researchers must consider these and other ethical issues in designing their study and before having contact with research subjects. Readers are referred to Chapter 5 of this book, as well as to writings by Stallings,[4] Fleischman et al.,[73] and Collogan et al.[74] for further discussion about the ethical issues involved in disaster research.

Disaster Vulnerability

There is a general consensus within the disaster community that vulnerability interacts with the physical hazard agent to produce disaster risk.[75–77] Vulnerability is conceptualized as, "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of natural hazards."[77] Thus, greater vulnerability of an individual or group is associated with more risk for a given level of disaster exposure. In many instances, estimations of who might be most vulnerable to a disaster can be formulated before a disaster, although disasters often function to bring attention to underserved segments of the population.

Health professionals may be most familiar with conceptualizing "vulnerable" populations as those that are physiologically vulnerable because of their age and/or physical and mental health conditions, such as children, the elderly, pregnant women, and people with disabilities. Physiological vulnerability can indeed affect people's ability to withstand external shock (such as the physical force of an earthquake, tornado, or hurricane), survive trauma injuries, and cope with short- or long-term disruptions in regular living conditions, including food, shelter, and access to healthcare. It is widely recognized, however, that disaster vulnerability is multidimensional, in that there are many other factors that contribute to people's capacity to anticipate, cope with, resist, and recover from the impact of hazards. The most commonly mentioned dimensions of vulnerability in disaster research are physical, economic, political, social, and psychological.[78–81]

Physical vulnerability refers to the physical proximity to the hazard and/or inadequate physical and structural resistance to hazards.[81–83] Physical vulnerability is important for high physical force disasters, such as in earthquakes and tornadoes, in which the potential for damage to physical structures is increased.

Economic vulnerability can be conceptualized at the macro level, in terms of international and national economic practices and conditions, but is more often conceptualized at the micro, or household level, in terms of livelihood conditions (e.g., income opportunities, job characteristics).[84] The nature of economic vulnerability is different for disasters with a rapid onset and short duration, such as earthquakes, than for those of a slow onset and/or long duration, such as droughts. In rapid-onset disasters, economic vulnerability is defined by the ability to withstand short-term social and economic disruption and the ability to finance reconstruction and repairs of structural damages. In contrast, economic vulnerability to slow-onset/chronic disasters depends on the flexibility of the economy to adjust to prolonged disaster situations (e.g., importing food stock, creating jobs for farmers), the availability of assets at the household level, and the diversity of income-producing opportunities.[85] Extended exposure to adverse conditions, including food scarcity, mass population movement, and psychological stress, can lower immunity levels and increase risk for infectious diseases, as well as exacerbate any preexisting health conditions. Although the risk for communicable diseases is actually quite low for any major disaster,[86] these concerns are relevant in chronic disaster situations, like droughts and famines.

Political vulnerability encompasses having little or no political power, representation, or autonomy.[78,80,87,88] Political values and priorities determine which hazards will be addressed, the relative emphasis on and support for hazard mitigation, and the ability to meet the needs of divergent groups in the aftermath of a disaster. Political vulnerability, like psychological vulnerability described later, is relevant to any type of disaster. Political power affects the likelihood that an individual or a community will receive social protection from governments or have the resources and resilience to take measures to protect themselves. Those who are marginalized in society tend to live in the least safe areas and have the greatest exposure to hazardous conditions. Political vulnerability is particularly relevant for disasters in conflict situations, where political or military motivations by warring parties determine who receives the most aid and protection.[89] The philosophy that increasing political clout is the key to reducing overall vulnerability, including vulnerability to disasters, underlies individual and community empowerment efforts.[88]

Social vulnerability includes the formal institutional structures that marginalize certain groups and individuals based on their socioeconomic[81,83] or other characteristics, such as race or ethnicity. Informal social relations with friends, family and others[78] are included here as well. A community is socially vulnerable when people feel victimized, fatalistic, or dependent,[79,80] often resulting in apathy and a low sense of personal responsibility.[87] This global sense of alienation can become immersed in a broader cultural system of beliefs and customs and may manifest itself in disaster-relevant behaviors, such as low levels of motivation and/or knowledge about implementing preparedness measures.

There has been some effort to quantify social vulnerability to disasters, despite the lack of consensus in the research community on which dimensions should be incorporated. The Social Vulnerability Index[72] was developed using factor analysis and provides a score for each county in the United States. The index measures 11 independent factors reflecting *social* inequalities and *place* inequalities. Social inequalities are factors that influence the susceptibility of various groups to harm, and govern their ability to respond. Place inequalities are characteristics that contribute to the social vulnerability of places, such as the level of urbanization, growth rates, and economic vitality. Preliminary data show that the index is not correlated with presidential disaster declarations, thus providing limited evidence for construct validity. Nonetheless, the concept is a promising one; research studies on this and other indices that attempt to quantify social vulnerability are worth pursuing.

Psychological vulnerability is studied at the level of the individual in terms of the psychological characteristics that influence the individual's ability to cope with disaster stress and their likelihood of experiencing an emotional injury or distress from disasters.[90] In the extant literature, previous mental health problems are the most robust and consistent predictors of postdisaster distress.[91] Contrary to popular belief, psychological effects of nonterrorist disasters tend to be mild and transitory in the general population, rarely resulting in psychopathology.[92–94] Severe levels of psychological impairment are more likely to occur in disasters involving mass violence compared with other types of disasters.[95] Thus, psychological vulnerability is a more prominent factor in exposure to intentional disasters, and individuals with previous mental health problems would be anticipated to fare the worst.

The notion of dimensions of vulnerability is a convenient schematic but it should be recognized that these dimensions mutually interact, and the distinctions among them are often blurred. For example, the 2005 hurricanes Katrina and Rita affected areas that were physically vulnerable because of the levee construction (physical vulnerability). Political factors (political vulnerability) determined the low priority given to levee repairs and upgrades before the disaster and the inadequate governmental response as the disaster unfolded. The low socioeconomic and marginalized status of many of the individuals affected by the hurricanes influenced their ability to cope with and recover from the disaster, both in the short term and the long term (economic and social vulnerability). The hurricane-associated deaths were predominantly among the elderly (physiological and social vulnerability).[96] As a function of the long-term disruption in social networks, the ongoing stressors associated with the disaster, and what might be perceived as an intentionally unresponsive rescue and recovery effort, psychological disorders have emerged (psychological vulnerability). Focusing on the interplay among the dimensions of vulnerability is compatible with an ecological approach that emphasizes the mutuality of nature and human activity.[97–100] According to this approach, disasters occur when the social and cultural systems of a population fail to provide adequate adaptation to the environmental conditions that surround it or when these systems themselves produce a threat to the population.[99]

Disaster Morbidity and Mortality

The discussion of disaster morbidity and mortality describes how these estimates are derived, as well as the many factors that can influence their accuracy and introduce variability across studies.

Patterns of Morbidity and Mortality by Disaster Type

The health impact of a disaster varies by the physical characteristics of the hazard that triggers an abnormal event, the physical, social, and political environment in which the hazard event occurs, and the characteristics of the population that is affected. For instance, the number of people who die or suffer from physical or mental health problems as a result of an earthquake depends on (among other factors): the intensity of the ground shaking, the duration of shaking, and the intensity and frequency of aftershocks and the soil type (i.e., hazard characteristics); the population density and proximity of human settlements to the areas where the greatest shaking occurs, common construction types, the emergency response and healthcare infrastructure in place (i.e., physical environment); cultural norms regarding earthquake awareness and preparedness, common human activity at the time of the earthquake occurrence and political will and capacity to mitigate against and respond to earthquake disasters (i.e., social and political environment); and the age, preexisting health conditions, and socioeconomic status of the population (i.e., population characteristics). This is why earthquakes of a similar magnitude, as measured on the Richter scale, result in vastly different outcomes in regard to human casualties. To illustrate, official reports indicate that the 2001 Seattle/Nisqually, Washington earthquake (M6.8) resulted in one death and 407 injuries; the 1994 Northridge, California earthquake (M6.7) 57 deaths and 1,500 injuries (Note: A thorough county-wide screening of hospital admission records and a review of relevant medical records and coroner's reports in Los Angeles County verified 33 fatalities and 138 hospital admissions due to injuries caused by the Northridge earthquake[37]); the 1988 Armenian earthquake (M6.8) 25,000 deaths and 130,000 injuries; and the 2003 southeastern Iran earthquake (M6.6) 26,200 deaths and 30,000 injuries.[101]

Differences in reports of morbidity and mortality also reflect variability in the methods used to estimate the health impact. These methods are reflective of the infrastructure for systematic data collection that exists before the event, and the extent to which damage and disruption caused by the event interfere with postdisaster data collection. Thus, it is important to recognize this multifactorial nature of both the actual and reported morbidity and mortality in disasters. When possible, researchers should attempt to put the numbers into context by accounting for the various factors that could have influenced estimates of morbidity and mortality.

Hazard type is a common classification scheme for disaster-associated morbidity and mortality.[91,102] The CDC, especially through the *MMWR*, is the main source for disaster-attributable morbidity and mortality data in the United States. The amount of knowledge or research that is available about the health effects of a particular hazard depends on several factors including how frequently events involving that hazard occur, whether there is a clear beginning and end point to the hazard event, thus, making causal attributions less ambiguous, whether the hazard tends to cause multiple human casualties, and whether there have been especially devastating or dramatic events that surround the disaster.

There is an accumulation of literature and knowledge about the health impact of hurricanes (and floods associated with them) and tornadoes in the United States, both of which are seasonal hazards that occur annually. Earthquakes also have been well studied internationally and in California (even though they are infrequent events) because there is little ambiguity about when an earthquake begins and ends, and because large earthquakes may cause numerous deaths. In comparison, relatively little research has been devoted to the health impact of volcanoes, wildfires, tsunamis, and droughts, due to one or more of the reasons noted previously, and including infrequent events, ambiguous event thresholds, and low human impact. Concomitant with recent interest in the effects of global warming,[117] there has been a recent rise in the number of studies of heat-related health consequences, with a greater willingness to conceptualize extreme temperatures as a disaster. The occurrence of a catastrophic event can reenergize or completely change the research activity in these areas. The Indian Ocean tsunami in December 2004 has spawned an unprecedented amount of research on the morbidity, both physical and psychological, and mortality associated with tsunamis.

Among the hazards that are not "natural," *unintentional* releases of hazardous materials caused by industrial accidents have been studied the most. In regard to *intentional* events, the effects of terrorism, usually involving explosive devices, have been well documented also, especially the occurrences in 1995 in Oklahoma City and in 2001 in New York City. In contrast, there have been very few opportunities for conducting research on the intentional use of biological, radiological, or chemical agents. The medical or physical health consequences of direct exposure to these hazards are perhaps better known than those resulting from exposure to other hazards, however, partly because exposure can be defined more clearly.

The psychological morbidity resulting from disasters is known to be less differentiated by the type of hazard and more affected by whether a disaster was due to unintentional or intentional causes, with the latter causing greater psychological distress to victims who are aware it is intentional. Posttraumatic stress disorder is by far the most common disorder studied, followed by depression, anxiety, and panic disorders.[103,104] Most studies reveal a significant drop in symptoms over time.[103,105]

Consistency of Estimation Methods

Lack of consensus on what constitutes a disaster, exposure to disaster, and a disaster-related death, injury, or disease complicates disaster research. One focus of disaster research is classifying types of disasters by types of health outcomes. Although a number of schemes for classifying health outcomes do exist, there is no standard method for classifying exposure to a disaster. Despite efforts to develop standardized procedures, disaster researchers continue to develop and use their own definitions and classification protocols, often with little regard for prior research. The sprawling disciplinary landscape of disaster research contributes to this tendency.

The definition of what constitutes a death or injury that has been caused by a disaster varies, not only within, but also across, disaster types. The U.S. CDC has attempted to develop a protocol for classifying outcomes attributable to disasters based on the time the death or injury occurs relative to the disaster and also based on whether the event is directly or indirectly related to the disaster: "disaster-attributed deaths [are] those caused by either the direct or indirect exposure to the disaster. Directly related deaths are those caused by the physical forces of the disaster. Indirectly related deaths are those caused by unsafe or unhealthy conditions that occur because of the anticipation, or actual occurrence, of the disaster."[106] Although strong in theory, the schema is difficult to apply in practice, especially when estimating indirect effects.

Morbidity estimates are harder to ascertain than mortality estimates. In many cases, estimates of U.S. disaster-related morbidity are based on the "best guesses" of a public health employee who contacted the Red Cross and local hospitals in an affected area for their estimates of the number of injured and ill individuals served in emergency departments. It has been established that most of the injured and sick do not utilize emergency departments, and persons staffing emergency departments are not necessarily aware of or knowledgeable about which injuries are attributable to a given disaster.[37] Thus, morbidity estimates often include a fairly substantial margin of error, including both under- and overreporting. Careful review of emergency department logs and admission records is essential and will improve estimates but cannot eliminate ambiguity in every case.[31,91]

RECOMMENDATIONS FOR FURTHER RESEARCH

Despite the common belief that disaster and hazard research is an emergent discipline, the formal study of disasters has a long, multidisciplinary history. As outlined in the historical overview section, disasters are an established focus of research within the fields of medicine, public health, sociology, psychology, engineering, economics, geology, and geography, among other disciplines. The multidisciplinary approach to the study of disasters is not accidental. The interacting societal problems caused by disasters benefit greatly from and, in fact, demand the multiple methodological and theoretical lenses provided by the disciplines represented in disaster research.

Given the diversity of research perspectives, it is not surprising that communication between disaster researchers from different fields remains an ongoing challenge. Consequently, researchers sometimes conduct parallel and redundant lines of research, without knowledge of pertinent contributions to the disaster literature made by researchers outside their own discipline. With the broad history and nature of disaster research in mind, several recommendations for improving the quality of and access to disaster research are offered.

One strategy for improving the quality of disaster research is to design, fund, and conduct mixed method studies that involve collaboration across disciplines. Such efforts would improve communication across fields and contribute to the integration of methods and theoretical frameworks for understanding disasters. Stimulating cross-disciplinary work should maximize the likelihood that researchers will be knowledgeable about disaster research outside their discipline and minimize the chance of repeating or reinventing what has already been done. Conducting mixed method studies could, for example, capitalize on both the rich tradition of qualitative disaster research in the social sciences and the quantitative analytical techniques that are predominantly used in epidemiology.

In addition to active promotion of cross-disciplinary work, it will be beneficial to encourage collaborations between local experts and individuals with training and experience in the broader study of disasters. Local emergency management experts have community-specific knowledge, whereas "career" disaster researchers are more broadly trained, experienced, and familiar with the extant literature and emerging disaster knowledge base.

Ensuring adequate training of incoming professionals is another important strategy for improving the quality of disaster research. High-profile events, such as the 9/11 World Trade Center attacks and Hurricane Katrina, tend to cause a convergence of disaster researchers, both old and new. Newcomers who are attracted to disaster studies may not be well grounded in the accumulated knowledge in the field, the methods that are appropriate for disaster research, or the unique ethical considerations for conducting this type of research. Training centers and grants that provide infrastructure to support new researchers through fellowships, mentoring programs, and other training activities are appropriate and can help mitigate these challenges.

The quality of disaster research can be improved by supporting research strategies beyond those based in traditional health settings, such as hospitals and emergency departments. Population-based studies, for example, can provide information about the impact of disasters on the population as a whole rather than only the subset of individuals who sought treatment at a particular hospital. Although there is often competition among researchers to be the first to report results, it is both possible and desirable to expand the disaster time line, before *and* after disaster impact. Collecting data in communities at risk can help establish a predisaster baseline, provide information about individual and community preparedness and hazard mitigation, and potentially, provide the relevant information to study the relationship between preparedness and later disaster experiences. Longitudinal research can provide data on the rate and level of disaster recovery over time and study some of the changes that are secondary to the disaster event. Regardless of the research methods used, consistency of estimation methods can greatly improve the quality of disaster research. Establishing consensus on the definitions of what constitutes a disaster, exposure to disaster, and a disaster-related death, injury, or disease would improve the validity of findings. The same is true for the particular methods used to estimate morbidity and mortality associated with disasters.

One approach to enhancing data collection is to classify injuries and illnesses that arise from officially declared disasters as reportable diseases. Identifying these outcomes as reportable will facilitate efforts by public health personnel to obtain critical information on disaster victims. The public health community has a long history of obtaining such information effectively, while protecting the confidentiality of those exposed to the disaster. This approach will facilitate research across disciplines and make analyses more efficient, in that each group of researchers will not be repeating the process of independently collecting data. In addition, the recommended change will improve rapid access to data that may be lost over time or difficult to obtain, secondary to various governmental regulations.

A separate challenge within the field of disaster medicine is that published research frequently lacks the structure necessary to enhance scientific development of the specialty. In 2003, an international task force released recommendations to standardize the manner in which disaster medical research is reported.[116] The group modeled their approach after the Utstein style for reporting out-of-hospital cardiac arrest research. This work is constructed primarily around the medical and public health aspects of Disaster Medicine and consists of three major sections, each provided in a separate volume: 1) conceptual framework; 2) operational framework; and 3) research templates. The three volumes combine to form a structure that defines the development, implementation, and evaluation of the processes that produced the disaster. In addition, they provide standards for evaluation of the effectiveness, efficiency, costs, and benefits of any interventions. Using the structures provided, it is possible to compare similar and dissimilar disasters and any intervention provided. Use of this structure will facilitate the development of the science of Disaster Medicine that is essential for the identification and codification of best practices and standards upon which education, training, credentialing, and accreditation must be based.

Underlying efforts to advance the quality of disaster research is the need to improve access to research strategies and findings. These efforts should be directed to disaster researchers and to consumers of disaster-related information. Particular attention should be paid to countering disaster-related myths. It is well established that dead bodies pose minimal risk for epidemics and that mass panic and widespread social disorder typically do not occur in disasters. Emergency management policies and practices should be informed by such empirical research findings. One means of improving access to disaster-related research findings is to support the integration of search engines on which pertinent publications are indexed to help make the task of reviewing the disaster literature less daunting. Improving access to and dissemination of disaster research findings will likely yield better-informed disaster researchers, practitioners, and policymakers, thereby increasing the likelihood that disaster-relevant policies are evidence based.

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2

Disaster Education and Training: Linking Individual and Organizational Learning and Performance

Peter W. Brewster

OVERVIEW

The purpose of this chapter is to identify the principles and practices for training those who respond and provide care to victims of disasters. To understand adequately the scope of disaster education and training, it is first necessary to have an appreciation of its interdisciplinary nature, the health and medical operational system, and how education and training fits within the broader organizational learning context. This discussion is limited to conveying an overview of the process used to develop and deliver education and training to support organizational performance in emergencies and disasters. What follows is a discussion of important background concepts and the basic theory used in instructional design, with examples of disaster education and training for various medical and health target audiences. At the conclusion of this chapter, the reader will be able to

- Explain the overall context for disaster health education efforts
- Describe the Instructional System Development (ISD) approach to developing education and training programs
- Identify various examples of disaster health education and training programs for various audiences

STATE OF THE ART

Disaster Health

Disaster education and training is interdisciplinary by nature and addresses all hazards. In October 2004, a World Association for Disaster and Emergency Medicine seminar was convened to discuss disaster education and training. As reported by Murray and others, the group defined "disaster" as "a major event which actually or potentially threatens the health status of a community." They recognized these major events could be the result of any type of hazard. The term "disaster health" was chosen to replace "disaster and emergency medicine" because it was more inclusive of the variety of disciplines that would become involved in a response. Bradt's visual depiction of this "disaster health" framework included clinical and psychosocial care, public health, and emergency and risk management as three interrelated core domains (see Figure 2.1).

Operational System

Students in disaster health education and training programs need to have an understanding of the operational system within which health and medical services are provided in disasters. Integration of out-of-hospital medicine, public health, acute care medicine, and mental health into a medical and health functional group called an Emergency Support Function (ESF) was first described in the U.S. Federal Response Plan in 1992.[2] Table 2.1 illustrates the variety of ESFs in the 2009 version of the National Response Framework and shows the specific activities conducted under ESF 8, Public Health and Medical Services. This framework (or a similar one) is also found in state and local government emergency operations plans (EOPs) across the United States.

Although EOPs reflect the desired integration between health and medical entities and between levels of government, reality may be somewhat different. Barbera and Macintyre note

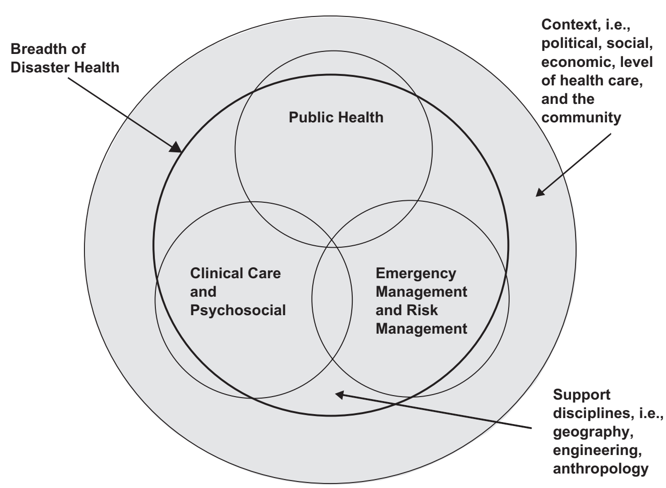

Figure 2.1. A framework for disaster health[1]

Table 2.1: Emergency Support Functions of the National Response Framework and the Specific Activities Under ESF 8, Public Health and Medical Services

Transportation
Telecommunications and Information Technology
Public Works and Engineering
Firefighting
Emergency Management
Mass Care, Housing, and Human Services
Resource Support
Public Health and Medical Services (ESF 8)
- Assessment of Public Health and Medical needs
- Health Surveillance
- Medical Care Personnel
- Health/Medical Equipment and Supplies
- Patient Evacuation
- Patient Care
- Safety and Security of Human Drugs and Biologics
- Blood and Blood Products
- Worker Health and Safety
- Food Safety and Security
- Agriculture Safety and Security
- Behavioral Healthcare
- Public Health and Medical Information
- Vector Control
- Protection of Animal Health
- Technical Assistance

Urban Search and Rescue
Oil and Hazardous Materials Response
Agriculture and Natural Resources
Energy
Public Safety and Security
Community Recovery, Mitigation, and Economic Stabilization
Emergency Public Information and External Communications

healthcare facilities have traditionally engaged in preparedness activities as independent entities, not as part of a larger system. Public health agencies have not been well integrated into the first response/public safety system on an operational level, and they have not been effectively linked to acute care medicine or mental health. Furthermore, they saw preparedness efforts being aimed at individual problems, such as patient tracking, by individual disciplines without first defining the overall response system.

To improve operational level integration, the U.S. government has mandated the use of the Incident Command System (ICS).[3] ICS provides a standardized management structure and process that allows disaster health education and training efforts to clarify the role an individual plays within an organization's EOP. Revised in 2006, the Hospital Incident Command System provides one approach to integrating the various departments

Table 2.2: Operations Section: Hospital Incident Command System

- Medical Care
- Infrastructure
- Hazardous Materials
- Security
- Business Continuity

Table 2.3: Operations Section: MaHIM System

- Epidemiological Profiling
- Prehospital Care
- Medical Care
- Mental Health
- Hazard Containment
- Mass Fatality Care

and services within a healthcare facility for responding to disasters.[4] An example of such integration within the Operations Section is listed in Table 2.2. What is notably different from previous versions (Hospital Emergency Incident Command System or HEICS) is the broader focus of hospitals beyond simply providing medical care in emergencies.

At the local jurisdiction level, another model, the Medical and Health Incident Management (MaHIM) System, describes how the various medical, public health, emergency management, and support disciplines are integrated within an ICS structure (see Table 2.3).[5]

Finally, the publication, *Medical Surge Capacity and Capability* provides an overall system description that explains how the various levels or tiers operate and coordinate within a national system (see Table 2.4). This guidance currently serves as a foundation for health system preparedness efforts.[6]

Emergency Management Program Development Cycle

The relationship among an organization's operational procedures, education, training, implementation, evaluation, and corrective actions is an import context. Education and training programs need to communicate the organization's EOP, standard operating procedures, job action sheets, and checklists to the variety of staff, as appropriate to their roles. Although this seems obvious enough, many times exercises, whose purpose is to "test" the organization's emergency operations procedures, are designed around a high-profile scenario and not tied to the procedures. Organizational performance can only be improved if the procedures exist and training is provided prior to validation occurring through a well-designed exercise program. Rather than starting with full-scale exercises, it is highly recommended to begin with orientation seminars, tabletop discussions, and functional exercises leading to the full-scale events. Evaluation tools should be designed from exercise objectives and produce impartial data identifying where improvement is needed (e.g., procedures, training, and equipment). Table 2.5 illustrates the role of education and training within the overall development cycle of an emergency management program.

Table 2.4: Tiers within the Medical Surge Capacity and Capability Management System

- Individual Healthcare Asset
- Healthcare Coalition
- Local Jurisdiction
- State Response and Coordination of Intrastate Jurisdictions
- Interstate Regional Management and Coordination
- Federal Support to State and Local Jurisdictions

Table 2.5: Steps in the Emergency Management Program Development Cycle[7]

- Establish an Advisory Committee
- Develop an "all-hazard" EOP that incorporates the ICS
- Conduct a hazards vulnerability analysis to identify priority hazards, threats, and events
- Write incident-specific operational procedures for priority hazards, threats, and events
- Maintain ongoing mitigation and preparedness efforts
- Coordinate with external entities
- Provide education and training to staff on their roles and responsibilities
- Implement the EOP/ICS and incident-specific guidance during actual disasters and exercises
- Review performance and identify recommendations for corrective action to the Advisory Committee

Developing a Disaster Education and Training Program

Terminology is the foundation for education and training efforts. Because disaster health is interdisciplinary by nature, the establishment of an integrated compendium of terms, acronyms, and definitions is an important first step. A glossary developed by The George Washington University's Institute for Crisis, Disaster and Risk Management to support a major health system's emergency management education and training program is available in the public domain. Selected terms from the Institute for Crisis, Disaster and Risk Management glossary that are important to this discussion are presented in Table 2.6.

The basic theory that supports the development of education and training programs is called ISD. The ISD process, originally developed by the U.S. military[9] involves five phases (see Figure 2.2)

- Analysis of training needs and identification of requirements for each target audience, including regulations, standards and accepted practices
- Design of the education and training program and schedule, individual activities, and delivery methods
- Development of content and instructional resources
- Implementation of the education and training program
- Evaluation and improvement activities

ANALYSIS

Reviewing the organization's records will provide information on the topics, target audiences, frequency, recertification cycles, and attendance at past training. Evaluation forms or discussions with staff who helped deliver and who attended the events are good sources that will help to determine the focus, direction, and usefulness of past efforts. It is also important to look at the annual schedule of education and training offerings to see whether they were sequenced to support development of organizational procedures and exercises. For U.S. hospitals, the Joint Commission standards require healthcare organizations to conduct at least two exercises per year, separated by 4 months.[10] The requirements for these exercises include use of the organization's operational procedures for priority hazards, and a corrective action process.

Regulations and standards that need to be incorporated within any disaster education and training program include

Table 2.6: Key Terminology that Supports Emergency Management for Healthcare Systems[8]

Competency: A specific knowledge element, skill, and/or ability that is objective and measurable (i.e., demonstrable) on the job. It is required for effective performance within the context of a job's responsibilities and leads to achieving the objectives of the organization.

Education: Education is instruction, structured to achieve specific competency-based objectives, that primarily imparts knowledge. This may be general knowledge or it may be job specific but extend to "higher order" knowledge (e.g., understanding the "big picture," or working under stress) not specifically included in the job description but of great value during emergency management activities. Educational material should be competency based and specify a level of proficiency that relates to the competencies ("awareness, operations, or expert").

Training: Training is instruction that imparts and maintains the skills (and abilities such as strength and endurance) necessary for individuals and teams to perform their assigned system responsibilities. Training objectives should also be competency based and specify a level of proficiency that relates to the relevant competencies ("awareness, operations, or expert"). As much as possible, training should address skills that will function under the conditions likely when the skill must be conducted.

Exercise: A scripted, scenario-based activity designed to evaluate the system's capabilities and capacity to achieve overall and individual functional objectives and to demonstrate the competencies for relevant response and recovery positions. The purpose of exercise evaluation is to determine a valid indication of future system performance under similar conditions and to identify potential system improvements.

Organizational Learning: A systems-based process for assessing proposed changes to the system and incorporating accepted proposals to effect lasting change in system performance. This is accomplished through alterations to system structure, process, competencies, facilities, equipment, supplies, and other parameters. This process is accessible to the whole organization and relevant to the organization's core mission and objectives.

(in U.S. terminology) the ICS (as part of the National Incident Management System), hazardous materials, and worker health and safety (Occupational Safety and Health Administration).[11] The National Fire Protection Association Standard 1600, the standard for Disaster/Emergency Management and Business Continuity Programs, recommends that each entity assess the training needs and develop a curriculum to support implementation of the program. The frequency and scope of the training should be identified and training records maintained.[12]

For U.S. hospitals, additional Joint Commission requirements specify that staff, including volunteers and licensed independent practitioners and volunteers, will be oriented and

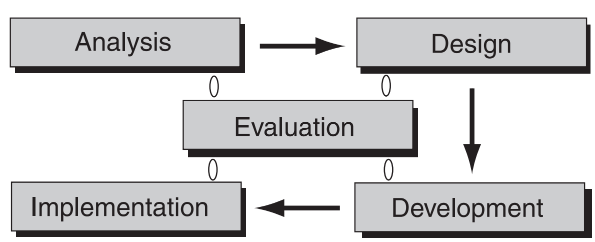

Figure 2.2. The phases of the ISD model.

trained on their assigned roles in the EOP.[13] National Fire Protection Association Standard 99, Chapter 12, Health Care Emergency Management, recommends that each organization implement an educational program that includes an overview of the emergency management program and ICS. Education concerning the staff member's specific duties and responsibilities needs to be provided at the time of joining the organization and annually thereafter.[14] The American Society for Testing and Materials, in its Hospital Preparedness and Response standard designation E 2413–04, also requires education and training for staff response to myocardial infarctions, psychosocial impacts, managing information, documentation, and principles of coordination.[15]

Also important for those involved with patient admission and tracking is the Health Insurance Portability and Accountability Act (HIPAA), enacted by the U.S. Congress in 1996 (see Chapter 10). Title I of the Act protects health insurance coverage for workers and their families when they change employers or lose their jobs. Title II addresses the security and privacy of health data, through the establishment of national standards for electronic data transactions. Protected health information is individually identifiable health information. Protected health information can be shared for the purposes of preventing or controlling disease, injury, and disability or for other public health and law enforcement purposes.[16]

The organization's role in the community's emergency response system should be incorporated into education and training. The local government's EOP should be reviewed to ensure the programs clarify the organization's role and responsibilities.

Education and training should be competency based; in other words, instructional activities are guided by learning objectives designed for the particular target audiences and linked to training drills and exercises of the EOP.[17]

Identifying target audiences must occur before any further design and development occurs. The Veterans Health Administration, in developing its Emergency Management Academy, identified its target audiences as staff belonging to one of several "job groups" (see Table 2.7).

Competencies for disaster education and training relate to the role played by a particular target audience in emergency response and recovery, recognizing the importance of the organization's emergency procedures and ICS[18] (see Table 2.8). After the target audiences and competencies are identified, learning objectives can be developed for the overall program and for each individual lesson. The use of "levels of proficiency" (awareness, operations, and expert) is common in education and training courses. Awareness-level proficiency would involve having the basic knowledge or understanding of the topics, usually to prevent injury. Operations-level proficiency entails the knowledge, skills, and abilities of a topic to safely perform any tasks involved. Expert-level proficiency is the operations-level, plus the knowledge, skills, and abilities to apply expert judgment necessary to solve complex problems.[18]

Proficiency levels were first identified in the regulations developed to guide training for those who respond to releases of hazardous materials (see Table 2.9).[19]

Table 2.7: Job Groups Used to Define Target Audiences in a Healthcare System

- All personnel (with responsibilities in the EOP)
- Facilities and Engineering
- Police and Security
- Clinical Support
- Patient Care Providers
- Emergency Program Managers
- Health System Leaders

Table 2.8: Sample Emergency Response and Recovery Competencies

All Personnel Job Group – Includes all personnel with assigned job positions within the EOP and supervisory staff who may be required to perform the duties of an initial Incident Commander. The competencies within this group are referred to as core competencies necessary as a base for every position within the organization. Emergency response and recovery competencies for this job group include

- Utilize general ICS/Incident Management System principles during incident response and recovery (operations level)
- Recognize situations that suggest indications for full or partial activation of the healthcare facility's EOP, and report them appropriately and promptly (operations level)
- Participate in healthcare facility mobilization to transition rapidly from day-to-day operations to incident response organization and processes (operations level)
- Apply the organization's core mission statement to actions taken during emergency response and recovery (operations level)
- Apply the organization's Code of Ethics during emergency operations (operations level)
- Execute personal/family preparedness plans to maximize availability to participate in the facility's emergency response and recovery (expert level)
- Respond with a prepared and maintained personal "go-kit" to maximize the ability to perform and maintain the assigned role during response and recovery (expert level)
- Follow the occupant emergency procedures and assist others (e.g., personnel, patients, and visitors) as necessary to accomplish the directives (operations level)
- Perform specific roles and responsibilities as assigned in the facility's EOP (operations level)
- Follow the communication plan and reporting requirements as outlined in the facility's EOP and the specific Incident Action Plan for an emergency event (operations level)
- Follow and enforce safety rules, regulations, and policies during emergency response and recovery (operations level)
- Follow and enforce security measures consistent with the nature of the incident that has prompted the EOP activation (operations level)
- Utilize or request (as appropriate) and integrate equipment, supplies, and personnel for the employee's specific role or functional area during emergency response and recovery (operations level)
- Follow demobilization procedures that facilitate rapid transition to recovery operations for the healthcare facility (operations level)
- Follow recovery procedures that ensure facility return to baseline activity (operations level)

DESIGN

In this phase, the content and delivery methods are identified and matched to the target audiences, competencies and desired levels of proficiency. The development of learning objectives and an instructional outline begins this process. An instructional outline with learning objectives for a course on weapons of mass destruction (WMD) is found in Table 2.10.

Table 2.9: Proficiency Levels for Hazardous Materials Training

Level 1: First Responder Awareness
This is the person who witnesses or discovers the release of hazardous material and notifies the proper authorities. Training includes recognition and identification of hazardous materials, notification procedures, and the employee's role in the emergency response plan.

Level 2: First Responder Operations
These individuals are persons who respond to release of hazardous substances without trying to stop the release. They require Level 1 competency and 8 hours of additional training in basic hazard and risk assessment, personal protective equipment (PPE) selection, containment and control procedures, decontamination, and the emergency release plan (ERP).

Level 3: Hazardous Materials Technician
Persons trained to this level respond aggressively to stop a release. This level requires 24 hours of Level 2 training and competencies in detailed risk assessment, toxicology, PPE selection, advanced control, containment, and decontamination procedures, air-monitoring equipment, and the ICS.

Level 4: Hazardous Materials Specialist
The specialist has advanced knowledge of hazardous materials and responds with and provides support to hazardous materials technicians. Requirements are 24 hours of Level 3 training and proven competencies, along with advanced instruction, on all specific hazardous material topics.

Level 5: On-site Incident Commander
This individual assumes control of the incident. Level 5 requires 24 hours of training equivalent to Level 2 with competencies in the ICS and ERP, hazard and risk assessment, and decontamination procedures.

Unless specified by the standards or regulations, it can be difficult to determine which staff members require which education and training topics. The job groups and key aspects described earlier can be used to begin this "curriculum mapping" process. One approach for recommending which ICS courses are appropriate for various staff positions is found in Table 2.11.

Deciding how to deliver disaster education and training programs will depend on the desired target audience(s), topic(s), and level of proficiency. Members of a decontamination team, patient reception team, hospital emergency response team, or incident management team will require an operations- or expert-level proficiency. For these groups, traditional face-to-face methods are best for practicing hands-on skills, such as triage or the use of specialized equipment, with a limited number of students who require the ability to perform some type of procedure. For awareness level proficiency, the number of students increases and the focus of the activity is primarily imparting knowledge. Many technologies exist to provide content and the desired level of interaction. Information in electronic documents, videos, and DVDs, that support instructional activities or entire courses are increasingly available from government, university and private sector sources. Web-based courses, satellite broadcasts, and videotapes are practical methods for delivering this information to all except those who require an operations or expert level of proficiency.

Adult learning principles should be used, particularly when designing site-specific training. These characteristics include encouraging self-direction; reinforcing and building on prior experiences; providing training in small groups; and offering a supporting and challenging environment.[22]

Table 2.10: Sample Instructional Outlines for a Hospital WMD Course[20]

1.0 Event Recognition
- Use surveillance systems
- Recognize a possible terrorist attack
- Report WMD-related information to the appropriate person(s)

2.0 Unified Incident Command/Management Structure
- Use a unified system of command

3.0 Response Support
- Provide the necessary logistical support for victim care, responders, and the response as a whole

4.0 Safety and Protection
- Select and work effectively in PPE
- Demonstrate behaviors that help ensure personal safety

5.0 Decontamination
- Decontaminate victims at an incident site, medical facility, or other areas as needed

6.0 Isolation and Containment
- Appropriately isolate and contain victims of each type of WMD event

7.0 Evidence Preservation
- Use appropriate techniques for preserving possible at an incident site or medical facility

8.0 Psychological Effects
- Prepare for, recognize, and treat the psychological impacts of a WMD event on victims and healthcare professionals

9.0 Communication and Agency Interaction
- Maintain and help facilitate effective communication during a WMD incident response
- Interact effectively with appropriate agencies and organizations involved in responding to an incident

10.0 Triage
- Perform effective triage of victims of specific types of WMD incidents involving a variety of agents

11.0 Treatment
- Perform effective assessment, stabilization, diagnosis, and treatment of victims of specific types of WMD incidents involving a variety of agents

12.0 Transportation
- Transport victims as required, considering potential contamination risks, resource shortages, and communication needs

13.0 Recovery Operations
- Complete recovery operations, including reports and debriefings

14.0 Fatality Management
- Appropriately handle human remains, addressing safety, psychosocial, and forensic needs

DEVELOPMENT AND IMPLEMENTATION

In these phases, the course materials, instructional strategies, and methods are finalized. Many commercial and governmental sources of education and training products exist that address personal and family preparedness, occupant life safety, and the

Table 2.11: Matrix of Courses Required Under the National Incident Management System to Staff Positions[21]

Position/Employee Group	*IS-100*	*IS-200*	*IS-700*	*IS-800*
Headquarters Staff with Disaster Responsibilities			X	X
Regional Director			X	X
Regional Safety Manager/ Industrial Hygienist	X	X	X	X
Medical Center Director			X	X
Medical Center Associate Director			X	X
Medical Center Chief of Staff			X	X
Key Operations Managers	X		X	
Emergency Preparedness Coordinator	X		X	X

ICS. Others are designed to fulfill specific standards and regulations, such as those promulgated by the U.S. Occupational Safety and Health Administration and HIPAA. Programs on WMD and medical surge capacity and capability topics are widely available.

EXAMPLES OF DISASTER EDUCATION AND TRAINING PROGRAMS

Public

In the United States there are several programs that involve training the public to support formal response efforts in disasters. These include: the Citizens Corps, the Medical Reserve Corps (MRC), and the Community Emergency Response Team (CERT). Table 2.12 contains additional information on each of these programs.

Table 2.12: Public Education and Training Programs

A new cabinet level Department of Homeland Security was formed after the terrorist attacks in the fall of 2001. In collaboration with the U.S. Department of Health and Human Services, this department promulgates programs that are designed to organize the general public into effective volunteers. These programs include the Citizens Corps, MRC, and CERTs. They provide instruction on improving preparedness at home, in the workplace, and in the general community. As a result, participants can assist the formal emergency response system during disasters by performing such activities as house-to-house welfare inspections, providing basic first aid, and giving assistance to neighbors.

Citizens Corps

"Are You Ready?" is the slogan for the Citizens Corps program.[23] This program provides guidance to individuals, families, and businesses in developing emergency plans. Successful implementation of these plans will reduce injury, mitigate damage, and increase the ability of all citizens to assist others during disasters.

Medical Reserve Corps

This organization enables healthcare professionals (including retirees) to augment effectively local health officials' capacity to respond to an emergency. MRC units are community-based and function in a way to locally organize and use volunteers who want to donate their time and expertise to prepare for and respond to emergencies and to promote healthy living throughout the year. MRC volunteers supplement existing emergency and public health resources. MRC volunteers include medical and public health professionals such as physicians, nurses, pharmacists, dentists, veterinarians, and epidemiologists. Many community members – interpreters, chaplains, office workers, legal advisors, and others – can fill key support positions.

MRC training topics are organized under the following three general competencies.

Health, Safety, and Personal Preparedness
- Introduction to disasters
- Are you ready?
- Family and workplace preparedness
- Standard precautions and respiratory hygiene
- Psychological first aid

Roles and Responsibilities of Individual Volunteers
- Introduction to the ICS
- Hospital ICS

Public Health Activities and Incident Management
- Public health 101

CERTs

The CERT program supports local government responders by training volunteers to organize themselves and spontaneous (convergent) volunteers at the disaster site, to provide immediate assistance to victims, and to collect disaster intelligence to support responders' efforts when they arrive. CERT training consists of

- Disaster Preparedness
- Fire Safety
- Disaster Medical Operations
- Light Search and Rescue Operations
- CERT Organization
- Disaster Psychology
- Terrorism
- Disaster Simulation

FIRST RESPONDERS

The National Domestic Preparedness Consortium[24]

The National Domestic Preparedness Consortium is the principal vehicle through which the U.S. Department of Homeland Security, Office of Grants and Training identifies, develop, tests, and delivers training to state and local emergency responders. The following is a brief description of each member and their expertise:

- *Center for Domestic Preparedness*: The center provides hands-on specialized training to state and local emergency responders in the management and remediation of WMD incidents. Located at the former home of the U.S. Army Chemical School, Fort McClellan, the Center for Domestic Preparedness conducts live chemical agent training for the nation's civilian emergency response community. The training emergency responders receive at the center provides a valid method for ensuring high levels of confidence in equipment, procedures, and individual capabilities.
- *National Energetic Materials Research and Testing Center at the New Mexico Institute of Mining and Technology*: This center offers live explosive training including the use of field exercises and classroom instruction. The National Energetic Materials Research and Testing Center is the lead National

Domestic Preparedness Consortium partner for explosives and firearms, live explosives, and incendiary devices training.
- *Academy of Counter-Terrorist Education at Louisiana State University*: The academy provides training to law enforcement agencies and focuses its efforts on the delivery of the Emergency Response to Terrorism: Basic Concepts for Law Enforcement Course, and the development and delivery of the Emergency Response to Domestic Biological Incidents Course.
- *National Emergency Response and Rescue Training Center at Texas A&M University*: Texas A&M delivers a set of courses to prepare state and local officials for the threat posed by WMD. Courses are developed and designed to provide each specific segment of the emergency response community with the tools needed to accomplish its role in the event of a WMD incident. Additionally, Texas A&M has developed an Interactive Internet WMD Awareness Course for emergency responders. Texas A&M also provides technical assistance to state and local jurisdictions in the development of WMD assessment plans.
- *National Exercise, Test, and Training Center at the U.S. Department of Energy's Nevada Test Site*: This test site conducts large-scale field exercises by using a wide range of live agent simulants as well as explosives. The National Exercise, Test, and Training Center develops and delivers a Radiological/Nuclear Agents Course.

Collaborative Medical Readiness Initiative

The Center for Disaster and Humanitarian Assistance Medicine's Chemical, Biological, Radiological, Nuclear, and Explosive/WMD Collaborative Medical Readiness Training Initiative[25] is designed to provide healthcare practitioners with current health and medical information on WMD. The program includes a scenario-based, interactive program that follows a hypothetical healthcare provider responding to a mass casualty incident. As the scenario evolves, the course presents a series of lessons, discussions, and information sessions that address public health, medical, and emergency management issues.

Awareness

- Define the steps to conduct a threat assessment
- Describe the physics of radiation energy and pathophysiology of radiation effects on the human body

Management

- Recognize types of radiation injuries and describe how to manage their treatment
- Identify principles of triage and resource utilization to care effectively for numbers of patients that exceed the immediately available resources
- Define the steps to assess the level of exposure for the casualties and staff and identify necessary laboratory and diagnostic procedures that support the clinical management of contaminated casualties
- Identify surface decontamination principles for ambulatory and litter patients exposed to radiation and demonstrate principals of reverse isolation
- Describe how to protect staff, other patients, and facilities from secondary contamination and recognize the special inpatient considerations for the internally contaminated patient

Integration

- Describe the roles and responsibilities of the public health agencies and how providers must interact with them during a response; discuss evacuation, food safety, and veterinarian care considerations; and, recognize the need for using epidemiological tools
- Describe the presentation of acute stress disorders in responders and the interventions to mitigate them; discuss how to safely handle human remains, autopsy considerations, and the need to comply with legal standards for chain of custody and evidence collection
- Describe the roles of the ICS, hospital ICS, and the National Incident Management System (NIMS) and the response system at the facility, local, state, and federal levels; and describe the overall structure of the National Response Framework
- Discuss the importance of effective interactions with the media and the need for a unified public message; identify the principles and science of crisis and emergency risk communication; and describe the role of risk communication in response

Urban Search and Rescue[26]

Urban Search and Rescue (US&R) involves the location, rescue (extrication), and initial medical stabilization of victims trapped in confined spaces. Structural collapse is most often the cause of victims being trapped, but victims may also be trapped in transportation accidents, mines, and collapsed trenches.

US&R is considered a "multihazard" discipline because it may be needed for a variety of emergencies or disasters, including earthquakes, hurricanes, typhoons, storms and tornadoes, floods, dam failures, technological accidents, terrorist activities, and hazardous materials releases.

Medical Specialist training course units consist of the following.

- Introduction
- Medical Development
- Medical Team Responsibilities
- US&R Medical Problems
- Confined Space Medicine
- Task Force Canine
- Medical Skills Station
- Patient Care Scenarios
- Other US&R Operational Considerations
- Field Exercises

HOSPITALS AND HEALTHCARE SYSTEMS

There are six important dimensions that need to be addressed in a healthcare system's disaster education and training program.

PERSONAL AND FAMILY PREPAREDNESS

Preparedness for emergencies begins with the individual employee and his or her family. Staff whose roles are deemed essential must feel comfortable that their family members know what to do in the event of an emergency. This is even more important for staff who may deploy on response teams for 10–14 days. Family disaster planning information is available from the American Red Cross[27] and the Federal Emergency Management Agency (see Table 2.13).

Table 2.13: Family Disaster Plan

- Discuss the type of hazards that could affect your family. Know your home's vulnerability to storm surge, flooding, and wind
- Locate a safe room or the safest areas in your home for each hazard. In certain circumstances the safest areas may not be your home but within your community
- Determine escape routes from your home and places to meet. These should be measured in tens of miles rather than hundreds of miles
- Have an out-of-state friend as a family contact so all your family members have a single point of contact
- Make a plan now for what to do with your pets if you need to evacuate
- Post emergency telephone numbers by your phones and make sure your children know how and when to call 911 or the equivalent emergency services number
- Check your insurance coverage – flood damage is not usually covered by homeowners insurance
- Stock nonperishable emergency supplies and a Disaster Supply Kit
- Use a weather radio. Remember to replace its battery every 6 months, as you do with your smoke detectors
- Take First Aid, Cardiopulmonary Resuscitation (CPR), and disaster preparedness classes

OCCUPANT LIFE SAFETY

Fire and severe weather drills are a tradition within hospitals and public institutions. In the United States, "duck, cover and hold on" is taught to school-aged children in areas prone to earthquakes. The focus of this type of life safety education and training is ensuring building occupants understand the facility's alerting signals, notification procedures, and the appropriate actions to take (see Table 2.14). This type of education and training is driven by local ordinances, building codes and standards, and regional or national priorities.

INCIDENT COMMAND SYSTEM

The use of the ICS by federal, state, local and tribal governments and the private sector, including hospitals, became a priority with adoption of the NIMS following the terrorist attacks of September 11, 2001 in the United States (see Table 2.15).

A big part of the NIMS requirements is to incorporate ICS into the organization's existing EOP and procedures. Although the various NIMS-required courses described above are important building blocks necessary to understand the basic concepts and principles of ICS, major emphasis should be placed on providing education and training on the EOP, such as applying ICS to the organization.

Table 2.14: Sample Occupant Emergency Procedures

i. Emergency Evacuation Plan
ii. Reporting
iii. Emergency Response Procedures
  A. General
  B. Emergency Situations
    Fire
    Medical Emergency
    Bomb Threat
    Hazardous Materials
    Odor of Smoke/Burning
    Other Emergencies
iv. Emergency Teams
v. Building Information
  A. General Description
  B. Miscellaneous Information
  C. Special Circumstances
  D. Posting for Conference Rooms

Table 2.15: National Incident Management System[28]

- Organizational Adoption
- Command and Management
- Preparedness Planning
- Preparedness Training
- Preparedness Exercises
- Resource Management
- Communications and Information Management

ORGANIZATIONAL RESILIENCY

Resiliency relates to the capability of an organization to recover from the effects of a hazard impact. Developing procedures and processes for resiliency is a focus of the 2008 Joint Commission emergency management standards.

Continuity planning has long been a focus of emergency preparedness activities with government agencies and major corporations. This type of planning was solidified within the healthcare industry because of the "Year 2000" or Y2K, when manufacturers of computer chips that were used in a variety of medical devices and equipment could not guarantee their performance when 1999 changed to 2000. In the United States Department of Veterans Affairs (the largest integrated healthcare system), Y2K preparedness focused on "mission critical systems" (see Table 2.16) and developing contingency plans for maintaining continuity of patient care through the use of manual techniques and alternate systems.

INTERNAL MEDICAL SURGE CAPACITY AND CAPABILITY

The traditional focus of hospital planning, training, and exercise activities has been on creating "surge capacity" for mass casualties (see Chapter 3). Medical surge consists of two dimensions: surge capacity, which refers to the ability to evaluate and care for a markedly increased volume of patients; and surge capability, which refers to the ability to manage patients requiring unusual or specialized medical evaluation or care.[30] Education and training programs for medical surge are aimed at developing staff competencies in the treatment of injuries and illnesses generated

Table 2.16: Mission Critical Systems[29]

- Lighting
- Electrical Power
- Steam Distribution
- Heating, Ventilation, and Air Conditioning
- Room or Hood Exhaust
- Water Delivery
- Water Conditioning
- Waste Stream
- Critical Supplies
- Communications
- Computer and Information Management Systems
- Alarms
- Vertical Transport
- Central Medical Gases

Table 2.17: Resources and Activities that Support Medical Surge[31]

- Beds
- Isolation Capacity
- Healthcare Personnel
- Pharmaceutical Caches
- Personal Protective Equipment
- Decontamination
- Behavioral Health
- Trauma and Burn Care

by various hazardous agents and managing key resources and activities (see Table 2.17).

SUPPORT TO EXTERNAL SYSTEMS

Implicit in medical surge capacity and capability are the concepts of mutual aid and resource management. Healthcare facilities have long maintained sharing agreements for the purpose of relocating patients during events such as fires or loss of utilities. Historic events such as Hurricanes Katrina and Rita in the United States demonstrated that large-scale mutual aid efforts to support the care and evacuation of patients from damaged hospitals required more attention to pre-event resource identification, education, and training (see Table 2.18).

The U.S. federal response to south Florida after Hurricane Andrew in 1992 stimulated an effort to develop more effective mutual aid between states.[32] This effort has turned into the Emergency Management Assistance Compact, a nationwide mutual aid network consisting of all 50 States, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands as signatories.[33] The Department of Homeland Security is focusing efforts on strengthening the ability of counties and cities to provide mutual aid locally, through the Emergency Management Assistance Compact and under the National Response Framework.[34] The National Mutual Aid and Resource Management Initiative includes resource typing and credentialing of public health and medical resources. Healthcare staff who may deploy as part of these resources require additional education and training such as field living skills, use of communications equipment, intermediate ICS, and understanding of the National Response Framework.

In summary, all hospital employees should receive information on personal/family preparedness, and occupant safety procedures should be the basis for their training. All operating unit supervisors and managers should be provided additional information on organizational resiliency and the ICS. Operating units that provide or support patient care should also focus on medical surge capacity and capability topics. Finally, leadership should have additional information on support to external systems.

Table 2.18: Hospital Resource Categories Requiring Augmentation[35]

- Critical Care
- Medical/Surgical
- Behavioral Health
- Dialysis
- Laboratory
- Neonatal
- Infectious Disease
- Burn
- Obstetrics
- Operating Room
- Pharmacy (inpatient and outpatient)

Table 2.19: Masters–level Curriculum in Disaster Medicine and Public Health[38]

European Master in Disaster Medicine – The Master is intended to provide participants with a clear picture of current concepts and developments in the medical preparedness and management of disasters.

At the end of the course, participants are expected to

- Evaluate health risks in disaster situations
- Participate in medical disaster preparedness
- Direct the medical response team in case of disasters
- Organize and manage evaluation and debriefing sessions
- Provide introduction and awareness to disaster management for medical response personnel
- Conduct research on the medical aspects of disasters

GENERAL MEDICAL AUDIENCES

National Disaster Life Support Courses[36]

The National Disaster Life Support family of courses are designed for physicians and other health professionals to respond to mass casualty events caused by terrorist acts as well as from explosions, fires, disasters, and infectious diseases. The courses were developed by the American Medical Association in collaboration with the National Disaster Life Support Education Consortium partners: Medical College of Georgia, University of Georgia, University of Texas Southwestern Medical Center at Dallas, and the School of Public Health in Houston. One of these courses is the Advanced Disaster Life Support Course, which includes lectures and skills stations on mass triage; PPE and decontamination; community and hospital disaster planning; media and communications during disasters; and management of mass fatalities. This material is widely available and undergoes internal review by the National Disaster Life Support Education Consortium; however, it has not undergone independent review. In addition to the material produced by the American Medical Association, there are multiple other sources of education that include courses taught at medical schools and national and international conferences.

UNIVERSITY PROGRAMS

In the United States alone, there are at least 20 colleges and universities with degree programs in emergency health and medical services.[37] Tables 2.19 and 2.20 provide examples of postgraduate degrees in public health or disaster medicine.

EVALUATION

Evaluation of education and training is both formative and summative. Formative evaluation relates to whether the educational activity itself reached its stated goals and objectives. An example of this is a course evaluation form that is completed by

Table 2.20: Master of Science in Disaster Medicine and Management[39]

Philadelphia University School of Science and Health – The program is a 36-credit, 12-course curricula to be completed in 1–3 years depending on the course load taken by the student.

Master of Science in Disaster Medicine and Management Courses

- Principles of Disaster Medicine and Management
- Hazardous Materials and Industrial Safety
- Natural Disasters
- Weapons of Mass Destruction
- Principles of Terrorism
- Organization Management and Communication in Disasters
- Psychological Aspects of Disasters
- Disaster Exercises and Drills
- Public Health Implications of Disasters
- Disaster Emergency Planning
- Applied Research Methods and Statistics
- Capstone Experience
- Master's Writing or Research Project
- Internship
- International Experience

attendees. Summative evaluation is an analysis of whether the outcomes of the activity produced the expected improvement to the organization's emergency management capability.

Disaster education and training events are designed to improve individual and organizational performance during emergencies. The degree to which this is accomplished involves the design of the operational system description (the organization's EOP and procedures); the education and training activities; and the evaluation process. It is standard practice to complete evaluation forms or After Action Reports whose purpose is to document performance in exercises and actual emergency responses. Issues identified in the After Action Reports will almost certainly have an education or training component. Before issuing recommendations based on the input from these forms, it is important to take into account the types, frequency, participation, and evaluations of previous education and training events and the degree to which these events reflect revisions to the organization's procedures over time.

The use of ISD concepts may involve one or more of the following levels of evaluation[40]

- *Reaction*: Student and instructor satisfaction with the course
- *Learning*: Student mastery of course objectives
- *Behavior*: Translation of the instructional experience to improved job performance
- *Results*: Alignment of instructional activity to the organizational goals and objectives

Recommendations for Further Research

In December of 2001, the U.S. Agency for Healthcare Research and Quality published a report that reviewed the literature on the most effective ways to train clinicians for public health events relevant to bioterrorism.[41] Although the purpose of the report was to address the topic of bioterrorism, the findings can apply to many disaster-related subjects. Some of the summary information is presented in Table 2.21.

Table 2.21: What Is Known About the Most Effective Ways to Train Clinicians for Public Health Events

The most common educational methods found in the literature surveyed were lectures, discussion, audiovisual aids, and written materials. More than half of the studies combined more than one educational method. The ability to correlate results from these education and training methods is limited because of differences in learning objectives, setting, targeted clinicians, and methods.

The Agency for Healthcare Research and Quality report acknowledged there is a lack of well-designed published studies on the most effective methods to train clinicians for bioterrorism preparedness or in management of public health events relevant to bioterrorism preparedness. Particular attention should be paid to the design of evaluation methods, such as an increased use of pretesting and posttesting and in the linkage of outcomes to course objectives.

Aside from improving the quality of research into determining the most effective methods to deliver disaster education and training, other studies are needed to address

- Whether implementation of the ICS by the medical and health disciplines under the NIMS requirements improves their integration within the larger emergency management system and by incorporating ICS into operational procedures are education, training, and evaluation simplified through the use of this standardized management system
- The use of competencies as a basis for course design rather than topics. Currently, the majority of disaster education and training courses are developed around comprehension of specific subject matter, not around target audiences. Job group competency frameworks describe the knowledge, skills, and abilities necessary for response and recovery to all hazards across a broad group of target audiences. Functional group competencies more specifically focus on performance of a particular function within the response system
- How information technology can improve coordination between individuals and organizations. Part of the coordination problem during disasters is due to the lack of a universal management system, although implementation of the NIMS should help to alleviate this. Another part of this problem is the infrequent nature of exercises. Use of the Internet and software to create realistic simulated disasters in which personnel from a variety of departments, agencies, and/or levels of government could interact more routinely would improve understanding of the overall response system and cooperation
- What is the real value of exercises? Are disaster drills and tabletop exercises cost-effective educational methods for training clinicians in how to respond to a bioterrorist attack or other public health event?
- Duration and extent of certification and refresher cycles. How often does clinicians' knowledge about preparedness for bioterrorism or other public health events need to be reinforced?

Summary

Disaster education and training programs must be designed to reflect the interdisciplinary and intergovernmental nature of the emergency management, public health, public safety, and medical systems. The use of the ISD model can improve the efficacy of these programs, emphasizing the emergency management program development cycle. Understanding the critical relationships among operational procedures, education and training programs, implementation activities (exercises and actual events), and the corrective action process is necessary to ensure individual and organizational learning.

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3

Surge Capacity

Donna Barbisch, Josef Haik, Ariel Tessone, and Dan Hanfling

> "On March 11th, 1918 – an Army private reported to the camp hospital before breakfast. He had a fever, sore, throat, headache . . . nothing serious. One minute later, another soldier showed up. By noon, the hospital had over a hundred cases; in a week, 500 . . . Over 11,000 people would die in Philadelphia alone that October . . . In 31 shocking days, the flu would kill over 195,000 Americans. It was the deadliest month in this nation's history".[1] It was not only happening in the United States, it was happening all over the world.

Developing the capacity and capability to handle a rapid increase in demand for patient care and public health services related to disasters or significant events impacting the healthcare community has become known as medical surge. The need for surge capacity is characterized by a mismatch between patient care needs and the capability and/or capacity to fill those needs during a catastrophic medical event. Figure 3.1 demonstrates a national response. Health and medical needs rise sharply after an event. Local response rises to meet the demand but becomes exhausted and begins to degrade after 24 hours. Preincident capacity for routine services is reduced in the immediate aftermath of a disaster. National and other external resources are activated and arrive after approximately 72 hours. The gap in requirements or needs compared with the capability is the surge requirement.

Significant effort has been placed on developing concepts to build medical surge capacity. The World Health Organization (WHO) identifies capacity building within the public health infrastructure as a global responsibility for all countries. In the 2005 Global Health Report, WHO outlined core capacity requirements that all countries must meet to detect, assess, notify, and report events covered by the International Health Regulations.[2] Capacities identified in the Global Health Report include

- Components such as building or strengthening national public health institutes
- Ensuring that national surveillance and response systems use internationally recognized quality standards
- Strengthening human resources capacity through training programs in intervention epidemiology, outbreak investigation, laboratory diagnostics, case management, infection control, social mobilization, and risk communication
- Using WHO indicators to conduct regular assessments of core capacities to monitor progress and assess future needs

The complexities and interdependencies of the healthcare environment present considerable challenges in developing a viable and cost-effective, sustainable medical surge solution. Limited evidenced-based data exist on the efficacy of proposed interventions. Standard healthcare practice based on individual care does not transition easily to population-based best outcomes decision making; the approach to surge requires a change in perspective on healthcare management. Understanding the essential elements in developing surge capacity and developing a system to balance the rapidly increasing demands given the limited resources available is critical. A comprehensive approach will build resiliency into the healthcare system and optimize outcomes when patient care needs exceed capacity. A focus on resiliency in healthcare management will not only facilitate best outcomes during the event, it will develop the ability to maintain nonevent-related essential services during the surge and promote rapid recovery in the aftermath of the disaster to restore pre-event healthcare services. A comprehensive surge system consists of well-balanced capacity and capability in personnel (staff), supplies and equipment (stuff), and physical structure and management infrastructure (structure).[3–4] This 3S Surge System will be described in detail in this chapter.

OVERVIEW OF THE PROBLEM

When the numbers or types of patients overwhelm the medical system's capability, existing competence, or capacity, the time-sensitive ability to manage healthcare resources must surge to meet demand to optimize patient outcomes. In certain situations, some patient care capacity or capability may be underutilized whereas others are exhausted and overwhelmed. Balancing needs and resources to affect best outcomes is challenging.

Incidents requiring surge capacity fall into a spectrum of scenarios that may have low-complexity/high-numbers such as

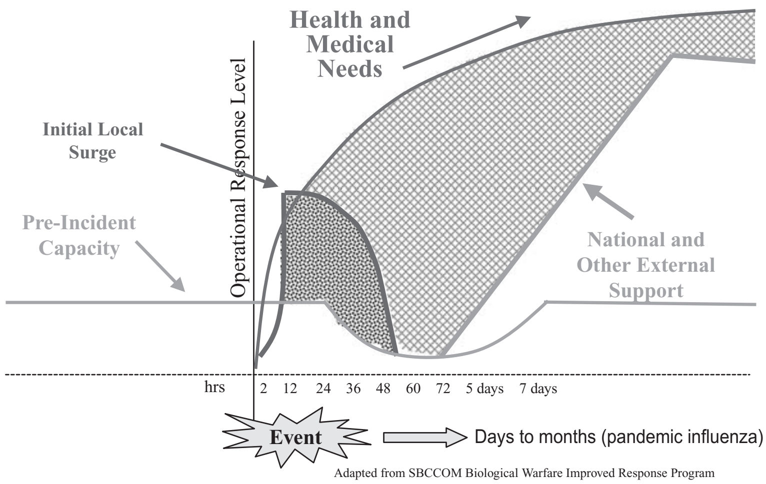

Figure 3.1. Medical surge.

some blast events, high-complexity/low-numbers such as motor vehicle collisions, or high-complexity/high-numbers as is projected in a pandemic influenza (Figure 3.2). "Complexity" in this context refers to the degree of difficulty in treating patient injuries. Many low-complexity/high-numbers events are characterized by a significant number of minor injuries that stress emergency triage capability. The event is localized and the majority of patients can be treated as outpatients. In high-complexity/low-numbers events there are fewer patients, but each patient requires intensive medical attention stressing critical care resources. In the preparation for mass burn events for example, although the numbers traditionally are relatively low (e.g., in Israel only ~9% of all terror and warfare injuries are burn related) the complexity of the injuries and the durations of stay are usually higher. Following detonation of an improvised explosive device, burn surge may move into the high-complexity/high-numbers category. In highly specialized treatment areas, required personnel, supplies, and accompanying expenses (e.g., imaging and laboratory studies) are increased compared with other mass trauma incidents or infectious outbreaks.[5] Hick et al., addressed the issue of specialized evaluation or interventions, a category under which most major burn patients will fall.[6]

In high-complexity/high-numbers events, such as pandemic influenza and other infectious diseases, the projected requirements stress multiple geographical areas simultaneously across a wide region of the healthcare community. Mutual aid agreements and the promise of support from governments and other entities capable of directing resources may be unavailable. Communities may be "on their own" to manage the surge in healthcare requirements. These complex events may be particularly challenging due to the shift in some systems toward managing fragile patient populations as outpatients with home health services that may include oxygen therapy, dialysis, and even in-home ventilatory support.

In prolonged or escalating events, an integrated approach is essential to coordinate and share resources. Even under "normal" conditions, some nations face extreme shortages of emergency resources. This includes developed countries like the United States where diverting patients to other hospital emergency departments due to crowding is common.[7] As disasters escalate it is imperative to recognize that medical and health needs will exceed healthcare resources.

In the management of surge, a transition is necessary from individual-based care to a population-based best outcomes approach. Healthcare professionals will be faced with ethical dilemmas in determining how to allocate scarce resources (see Chapter 5). Population-based triage protocols require shifting resources to achieve the "greatest good for the greatest number."

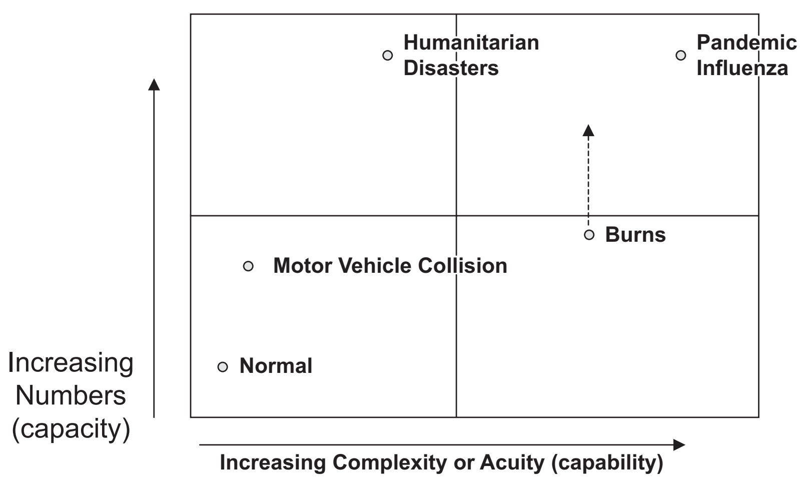

Figure 3.2. Spectrum of incidents requiring surge capacity.

This means that individual patients with little to no chance for survival may receive "comfort care" only and not be allocated resources for resuscitation.[8] Developing guidelines to support a shift in focus from optimizing individual to population outcomes is essential.[9]

Existing guidelines for building surge capacity (particularly over a prolonged time period) are limited. The State of California developed comprehensive surge capacity standards and guidelines in 2007–2008 with the input of a broad group of stakeholders from both government and the private sector. These experts addressed issues of worker liability, reimbursement, development and operation of alternate care sites, and surge plan templates for healthcare facilities and communities.[10]

The U.S. national planning effort has identified medical surge as one element of a Target Capabilities List.[11] The list, a companion to the U.S. National Preparedness Guidelines,[12] is contained within guidance from the Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response (known as "ASPR"). ASPR provides resources to eligible jurisdictions for medical surge capacity and capability to support, but not supplant local jurisdictions. Department of Health and Human Services also houses the Centers for Disease Control and Prevention (CDC), Public Health Emergency Preparedness Cooperative Agreement Program.

The Target Capabilities List is intended to cross-reference capabilities in the health and medical arena. The list of health and medical capabilities is not all inclusive; this can lead to critical points of failure when it is used as a sole planning document. The CDC and ASPR programs provide funding linked to surge capacity planning. The original U.S. Hospital Preparedness Program (HPP) focused on increasing hospital surge capacity by 500 beds per million population. The 2007 HPP identifies priorities associated with bed tracking, medical evacuation and facility management, rapid distribution and administration of medical countermeasures, effective utilization of mobile medical assets, interoperable communications systems, advanced registration of volunteer healthcare professionals, fatality management, alternate care sites, and decontamination and personal protective equipment.

The programs provide funding linked to objectives; however, the measurement of the objectives is highly subjective. The 2007 HPP provided funding of $415,032,000 to eligible jurisdictions[13] and the CDC awarded more than $896,000,000 for public health preparedness to improve national preparedness and strengthen medical surge and mass prophylaxis capabilities.[14] The public health emergency preparedness focus was on chemical events, laboratory readiness, improved coordination of public health and medical services, increasing proficiency of volunteers, and increasing the numbers of skilled and experienced physicians.

In 2004, the U.S. Government Accountability Office reported that public health response capacity was improving but much remained to be done.[15] To date, limited evidence-based data exist to determine whether the large amount of money expended in an effort to improve U.S. capabilities related to public health emergencies represent an investment that will improve outcomes.

Barbisch and Koenig describe a comprehensive approach to providing appropriate capacity or capability that takes into consideration the required supplies and equipment (stuff), the personnel (staff), and the physical space and management system (structure) to form a Surge System.[16] The system must be developed with evidence-based practice guidelines to achieve a seamless and scalable capability that will optimize outcomes in any given scenario whether of short or prolonged duration.

Defining Surge Capacity

The complexities surrounding surge capacity start with the myriad of definitions related to medical surge. In its broadest context, *Webster's* dictionary defines surge as "a sudden rise to excessive or abnormal value." Capacity is defined as the "facility or power to produce, perform, or deploy capability." In its generic form, it can be said that surge capacity is the ability to rise suddenly to an excessive or abnormal value to produce, perform, or deploy a capability. Surge definitions have evolved from a number of different perspectives. Surge can be defined relative to a practice setting, such as hospital, laboratory, emergency department, home health, and so forth; event type, such as blast, chemical, pandemic influenza, and so on; or magnitude of the requirements, such as daily surge or disaster surge. Daily surge is encountered regularly in chronically crowded emergency departments and some would argue that it is a predictable and manageable event and therefore the term could be considered a misnomer.[17] Disaster surge involves complex issues not encountered in daily situations. Disaster surge requires a shift from focus on best outcomes for the individual patient to a population-based best outcomes model.[18] Medical surge, in general, refers to an increase in patient flow above the norm and is characterized by an imbalance between resources and needs.

Kelen and McCarthy define surge as "a sizable increase in demand for resources compared with a baseline demand."[19] Related to healthcare, surge implies this increase in demand is for medical or public health resources. In addition to influx (volume rate), surge is further composed of the following components: event (type, scale, and duration) and resource demand (consumption and degradation). They define surge capacity as "the maximum potential delivery of required resources, either through augmentation or modification of resource management and allocation." Barbara et al., describe a tiered system of surge capacity focused on geographical integration. Barbara's model differentiates between capacity and capability, identifying capacity as the ability to evaluate and care for a markedly increased volume of patients that exceeds normal operating capacity, and capability as the ability to manage patients requiring unusual or specialized medical evaluation or care.[20]

The U.S. Targets Capability List defines medical surge as "rapid expansion of the capacity of the existing healthcare system in response to an event that results in increased need of personnel (clinical and non-clinical), support functions (laboratories and radiological), physical space (beds, alternate care facilities) and logistical support (clinical and non-clinical equipment and supplies)."[21]

The California Department of Public Health describes healthcare surge by stating that following a significant emergency or circumstances, "the healthcare delivery system has been impacted, resulting in an excess in demand over capacity in hospitals, long-term care facilities, community care clinics, public health departments, other primary and secondary care providers, resources, and/or emergency medical services."[22]

The multitude of efforts to define medical surge is indicative of the challenges in describing a comprehensive approach to managing the overwhelming medical needs in an escalating event. The common element in existing definitions refers to patient care needs exceeding medical and health resources at a

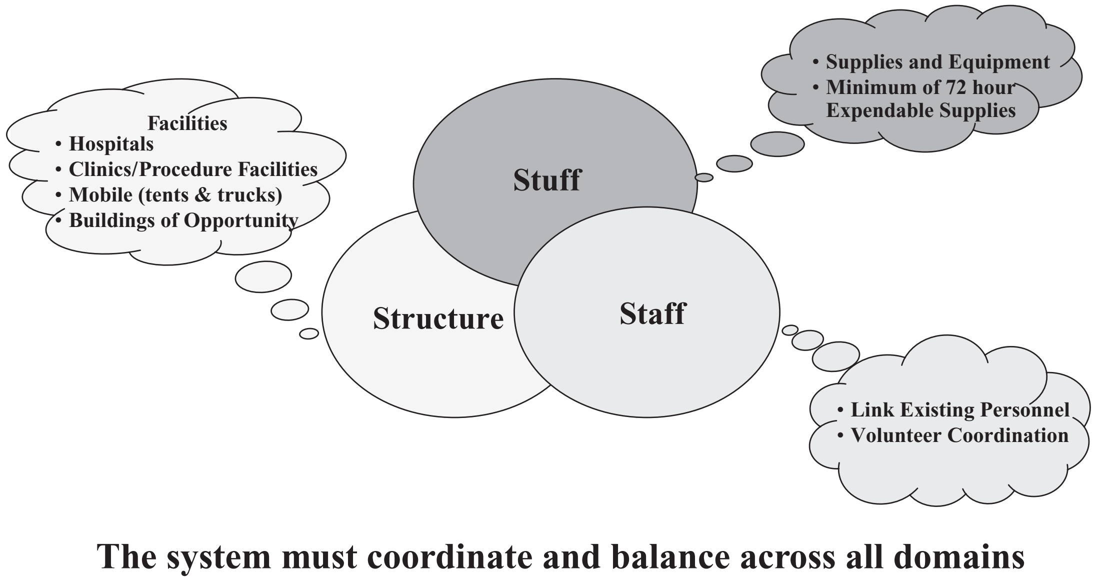

Figure 3.3. S-3 Surge System logistics management challenges.

given point in time. What is left to be determined is a consensus on how to meet those needs.

CURRENT STATE OF THE ART

Prepared for What?

In developing a resilient strategy to manage healthcare surge, the first objective is to gain an understanding of "prepared for what?" Because of the variety of events that could require a rapid increase in healthcare resources, it is critical to develop a comprehensive approach to "what" needs the preparations address. If the definition of "what" is limited to individual care associated with a specific event, or a specific capability, there is a risk of increasing capacity in one area and unintentionally disabling capacity in another as the event evolves. Consider a hospital plan that redirects home health staff into the hospital to increase the hospital's capacity to manage individual care. Although the shift in personnel may increase the in-hospital care capacity, if the needs continue to rise and the hospital must discharge patients to home healthcare, the overall system's patient care capacity will be reduced due to insufficient numbers of personnel working in the home health environment. Planning for one area without consideration of the impact in another area creates critical points of failure that reduce overall healthcare system surge capacity. The planning must be comprehensive, community based, and coordinated at the regional, national, or international level depending on the type and size of the event.[23] Hence the "what" can be defined as optimizing a population-based best outcome, scalable system.

Outcomes-based Planning

A lack of consensus exists on what is or what should be measured and what "population" is being served. Evidence-based data on the efficacy of proposed solutions to prepare for peak events at all levels (local, regional, national, or international) are incomplete. How can it be determined that plans will achieve the goals? Is the purchase of ventilators or a list of volunteers an adequate measurement of medical surge? It is not how much equipment is available, but rather how well the population is served that must be measured. Is it best outcome for the patient, the provider, the institution, or the population as a whole? The objective in medical surge must be best outcomes for the entire population.

Outcomes-based planning is a multidimensional process that starts with an accurate assessment of overall surge requirements, a realistic measurement of overall capability and capacity, and the potential impact to the overall system as a result of the interventions. Identifying the type of patient care required is not enough. A determination of how much care will be needed and how quickly it must be provided to be effective must be contrasted with what can reasonably be accomplished considering the available resources. Once the needs are identified, the timeline of delivery is critical and must match the rapidly escalating requirements.

Because surge capacity can be applied to numerous diverse scenarios with overwhelming requirements in both impact and complexity, solutions must transition from individual-based best outcomes to population-based best outcomes as limitations in resources escalate. Triggers to shift from an individual patient to a population-based focus are ill defined. Furthermore, in a prolonged event such as a pandemic, there may be multiple shifts back and forth between baseline operations and periods of time when allocation of scarce resources demand a population-based approach.

Koenig and Backer coined the term "crisis standard of care" to describe the clinical practice in the setting of a catastrophic disaster.[24] The shift to improving population-based outcomes occurs when healthcare needs exceed currently available resources. The mismatch occurs when any of the 3Ss of a surge system (staff, stuff, and structure) are insufficient (Figure 3.3). The lack of, or limited numbers of, qualified personnel (staff) in public health and specialty service (e.g., trauma, burn, or surgical services) or generalists in large-scale events can impact surge capacity. Limitations in surge capacity may be due to supply or equipment (stuff) shortages such as specific antidotes, respiratory equipment, or monitors. The mismatch can also be due to limitations in the physical space available for patient care and related services (structure) such as the number of functional hospitals or alternate care sites in an area, the capacity of the laboratory infrastructure to process specimens, or the mismatch of facilities designed for specific needs such as critical care or burn care, or nonacute and long-term care facilities. The most critical element is the system itself, which is used to manage all of the resources. Ventilators without personnel to operate them or a mass care arena without pharmaceutical support lack the ability to improve outcomes. Effective surge capacity requires a systems approach and a process to transition between differing surge numbers and complexity levels.

Given the interdependency of the various elements of the healthcare environment, a significant challenge exists. A rapid increase in demand superimposed on existing healthcare shortages, just-in-time inventory, projected breakdowns in the supply chain, personnel shortages and capability mismatch, and the dire consequences of limitations in healthcare make the concept of healthcare surge capacity extraordinarily complex. If not considered, these interdependencies can lead to critical points of failure resulting in a total systems breakdown. Proposed solutions in one area often create cascading untoward effects in other practice settings or parts of the surge system. Surge concepts are generally defined relative to the needs of a specific practice setting such as a hospital or the public health community, or specific elements within those communities: emergency departments, intensive care settings, home health, hospice, and so forth. Other surge concepts have been developed relative to the type or cause of injury or illness, for example trauma, burn, and infectious diseases. If uncoordinated, multiple entities can be competing for the same resources rather than complementing each other.

Consider the assumptions used to decide where to manage a critical care patient when both the emergency department and the critical care unit of a hospital are filled to capacity. There is an understanding in both environments that the patient will not get optimal care if the appropriate stuff, staff, and structure are unavailable and if the system is not coordinated to provide all of the patient's necessary services. In some cases, patients are placed in hallways without essential requirements while awaiting appropriate care environments. The practice begs the questions: Which environment will create the best outcomes for the patient, for the other patients, for the staff, and overall for the hospital? Depending on the goal, the answer may change. In a true scarce resource environment, the goal will be to optimize outcomes for the entire population of patients rather than for each individual patient.

Challenges associated with complex issues that have incomplete, contradictory, and changing requirements can be characterized as "wicked problems."[25] Defining best outcomes in wicked problems requires understanding the environment and assumptions of all stakeholders, acceptance of differing perspectives, and a comparison of the impact of actions that may not be optimal for each individual stakeholder, but deliver best outcomes for the community at large. Using the wicked problems approach, enduring processes can be developed to link the seemingly disparate influences in the health and medical environment with the desired outcome.

Assumptions in Surge Capacity Planning

Contributing to the challenges in developing evidence-based planning are commonly held assumptions in healthcare such as that the number of hospital beds is a reflection of capability or that stockpiling ventilators is a measure of readiness. Beds and ventilators are important elements of the "stuff" component of the 3S Surge System; however, equipment does not take care of patients by itself.

Some experts suggest that field and mobile hospitals are too little, too late and cost ineffective because they arrive from 2 to 5 days after impact, well after the last casualties are evacuated in sudden impact disasters.[26] Additional reports indicate that field hospitals may undermine efforts to restore services to baseline because they divert staff, supplies, and patients away from regular services in the aftermath of the disaster.[27] Any plan to use field hospitals should clearly identify the types of services provided as well as the time required before the capability is operational. In addition, these resources should be as self-sufficient as possible so as not to drain resources from existing local supplies. Operational plans must also specify at what point the field hospital mission will be completed because it is often uncertain when to withdraw these outside resources, particularly if their presence has provided a higher level of care than the affected population was receiving at baseline.

Measuring capacity and capability requires a review of the continuum of healthcare and the throughput of patients from the time they enter the healthcare system until they are no longer in need of care. It is incorrect to assume that if there are sufficient hospitals or hospital beds, the healthcare system is prepared. Projections for pandemic influenza suggest 30% of the U.S. population will be ill; 50% of those will need outpatient services; more than 10% will require hospitalization; 1.6% will require intensive care; 0.8% will require mechanical ventilation; and 2% will die.[28] Historical data from 1918 suggest the majority of illnesses will occur in a 1-month period. Figure 3.4 provides the numbers for a 1918 and a 1957-like pandemic. Several questions arise. What is "hospitalization" if hospitals are not available? How many victims will actually receive hospital care? If not managed in a hospital, where will care take place? Who will provide the care? Will appropriate triage occur to dedicate scarce resources to those who are expected to live? If not, will more suffer and die?

Using assumptions that not only project level of care but correlate the level of care with what will realistically be available is critical. Data on the influenza pandemic of 1918 within the U.S. show that the death rate escalated from 14/1,000 to 44/1,000 in October. It then immediately declined to 24.9/1,000 in the following month, returning to nearly baseline in less than 2 months (Figure 3.5). With a surge in requirements of the magnitude seen in the 1918 pandemic, traditional healthcare will be unavailable. Planning therefore should address how to optimize patient outcomes by using nontraditional care.

Finally, developing realistic planning focusing on the number of lives that can be saved or the impact on positive outcomes is critical. The assumption that everyone can be saved is false. People will die in catastrophic events. The focus should be on maximizing lives saved and minimizing morbidity given the available resources. Resources should be directed to the portion of the population who, with appropriate intervention, has the most likely chance for recovery. Plans must be not only theoretical, but based in reality.

DYNAMIC CAPABILITIES IN SURGE CAPACITY

Defining Surge Requirements

Defining evolving requirements is critical when managing an event. Several predictive models can assist planners in describing

Medical Planning Assumptions

Population: 1,000,000

- **50% of ill persons will seek medical care***
- **Hospitalization and deaths will depend on the virulence of the virus**

	Moderate (1957-like)	Severe (1918-like)
Illness	**300,000 (30%)**	**300,000 (30%)**
Outpatient medical care	**150,000 (50%)**	**150,000 (50%)**
Hospitalization	**3,000**	**30,000**
ICU care	**429**	**4,800**
Mechanical ventilation	**216**	**2,400**
Deaths	**996**	**6,000**

* CDC

Figure 3.4. Medical Planning Assumptions.

the magnitude of the event. The Humanitarian Assistance in Disaster Situations: A Guide for Effective Aid recommends all countries should give high priority to the preparation of their own health and medical personnel to respond to the emergency needs of the affected population and that regional coordination planning should be a priority.[29] The first step in planning is to define projected needs or requirements. The following models provide communities with the ability to project needs.

THE HOSPITAL SURGE MODEL

The Hospital Surge Model estimates the hospital resources needed to treat casualties arising from biological (anthrax, smallpox, pandemic influenza), chemical (chlorine, sulfur mustard, or sarin), nuclear (1 KT or 10 KT explosion), or radiological (dispersion device or point source) attacks.[30]

PANDEMIC INFLUENZA ESTIMATE MODEL

FluSurge is a spreadsheet-based model which provides hospital administrators and public health officials estimates of the surge in demand for hospital-based services during an influenza pandemic. The FluSurge model estimates the number of hospitalizations and deaths from an influenza pandemic (whose length and virulence are determined by the user) and compares the number of persons hospitalized, the number of persons requiring intensive care, and the number of persons requiring ventilator support during a pandemic with existing hospital capacity.[31]

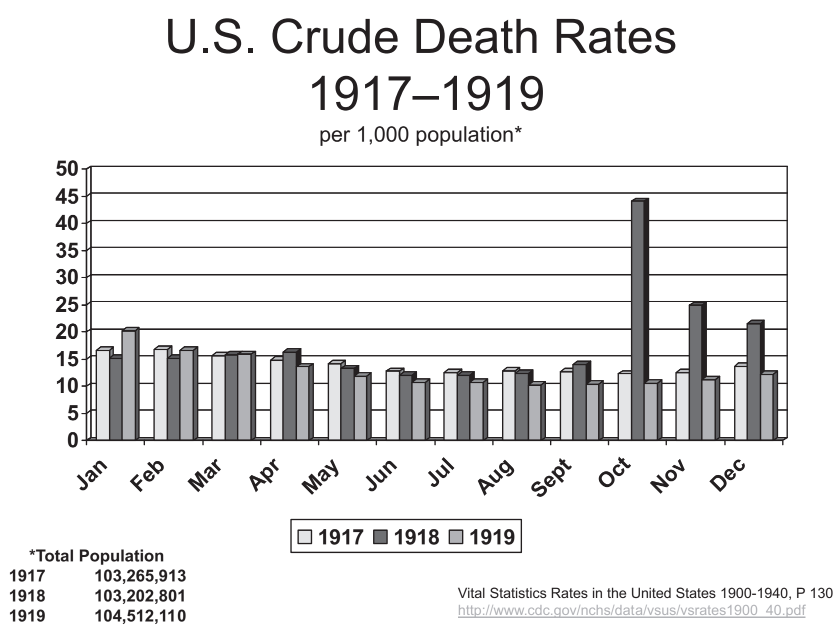

Figure 3.5. U.S. Crude Death Rates 1917–1919.

MASS EVACUATION TRANSPORTATION MODEL

The Mass Evacuation Transportation Model is designed for use before a mass casualty event or disaster to estimate the time required to evacuate patients and other evacuees from healthcare facilities and other locations and transport them to receiving facilities.[32]

At the international level, most programs focus on the coordination of resources at the local area of the disaster or those flowing into the impacted region. The United Nations' International Search and Rescue Advisory Group provides guidance relative to assets such as country specific Urban Search and Rescue teams.[33] Several evaluation tools exist. These include the Global Disaster Alert and Coordination System, a joint initiative of the United Nations and the European Commission. This system provides near real-time alerts about disasters around the world and tools to facilitate response coordination, including media monitoring, map catalogues and a Virtual On-Site Operations Coordination Center.[34] The Pan-American Health Organization supported the development of a Supply Management System database to facilitate the receipt, inventory, classification, and rapid distribution of key humanitarian supplies and equipment such as medicines, food, clothing, and blankets.[35]

While these templates exist, most have not been validated with respect to time sensitive delivery of resources. In many cases, the time to mobilize outside assistance exceeds that necessary to have a positive survival benefit and resources intended for response do not arrive until the recovery phase. Further research is required to develop evidence based approaches to identify which actions will deliver capability and capacity in an effective and timely manner.

According to the London Regional Resiliency Flu Pandemic Response Plan, the UK Department of Health will initiate a national 'FluLine' with access to algorithms that can assist in identifying protective actions for the general public. The UK plan advises symptomatic people to remain at home and "self care." The logistical support for managing self care in the home is not identified. Primary Care Trusts (PCTs) mobilize general practitioner and primary care resources supporting and monitoring the development of integrated health response arrangements, specifically antiviral collection points, the management of excess deaths, and social issues. The PCTs are also responsible for developing arrangements to maintain and support patients in a community setting and for ensuring that health plans account for the needs of vulnerable populations, closed communities such as care homes, military bases and prisons and other establishments that may require special planning.[36]

Within the US, many templates exist that primarily focus on the provision of necessary staffing, supplies, equipment and pharmaceuticals coupled with the structure and processes to integrate requirements to support a large scale disaster response. Due to their closer proximity, local and state resources will arrive to the disaster region before national assets. However local resources are limited and may be depleted by the event itself. This highlights the critical need for contingency planning. Local planners must recognize the need to meet surge requirements without the benefit of outside resources for a minimum of 72 hours. Examples of the type of planning and the resources available can be broken down into local, regional, national, and international efforts. The following are sample initiatives from the US system. Portions of these models may be applied to global preparedness efforts depending on country-specific resources and conditions.

Local Surge Planning and Coordination

Metropolitan Medical Response System

The Metropolitan Medical Response System (MMRS) is a locally managed emergency preparedness and response system that is integrated into state and federal programs. It is active in over 120 of the largest metropolitan regions in the United States. Originally formed in 1996 in the wake of the 1995 Oklahoma City bombing and the Tokyo Sarin gas attacks to focus explicitly on the traditional first responder approach to biological and chemical terrorist events, the program has evolved to be inclusive of all response disciplines, and has become a useful adjunct for support of surge capacity planning in local jurisdictions. The federal government provides funding linked to comprehensive plan development which is evaluated through a series of community wide exercises. These focus on medical surge response, mass prophylaxis distribution, chemical/biological/radiological/nuclear (CBRN) and other hazardous material responses and decontamination, medical supplies management and distribution, emergency public information and warning, interoperable communications, isolation and quarantine, fatality management and information sharing and collaboration. The MMRS integrates emergency response partners within communities and their surrounding regions to develop the collaboration that is critical in events of significant magnitude. Many MMRS communities have stores of personal protective equipment and caches of pharmaceuticals oriented towards CBRN response that complement other stocks of supplies and equipment. In summary, "the Metropolitan Medical Response System (MMRS) program assists designated localities to develop and maintain plans, conduct training and exercises, and acquire pharmaceuticals and personal protective equipment to achieve the enhanced capability necessary to respond to a mass casualty event during the first crucial hours of such an event, until significant external resources arrive and become operational."[37]

An expansion model related to the MMRS was initiated in Washington DC in 2007 designed to provide the tools to manage multiple capabilities within the region and identify timely integration of capabilities. The Seamless Emergency Medical Logistics Expansion System (SEMLES) established a program within the DC Department of Health to translate concepts into an integrated operational reality. The model provided a cost effective and integrated approach to synchronize parallel systems to create critical surge capacity for rapid and sustained response. The process requires extensive inter-organizational collaboration in assessing existing medical emergency capability, projecting needs in a variety of disasters and catastrophic events, and analyzing capability gaps. The program established a hub within the Department of Health to link resources into a modular expansion capability as needs grow. Regardless of the resource: prehospital, hospital; non-hospital healthcare; health related; or infrastructure support; SEMLES enables connectivity to optimize capability. It builds on MMRS to integrate all existing local, regional, and federal programs. Despite inevitable organizational, financial and political obstacles, SEMLES coordinates and synchronizes programs to provide a template to optimize surge capacity[38] (Figure 3.6).

Alternate Care System Development: The Stratification of Care Model

Increasing attention has been given to the need to broaden surge capacity planning to include the full spectrum of patient

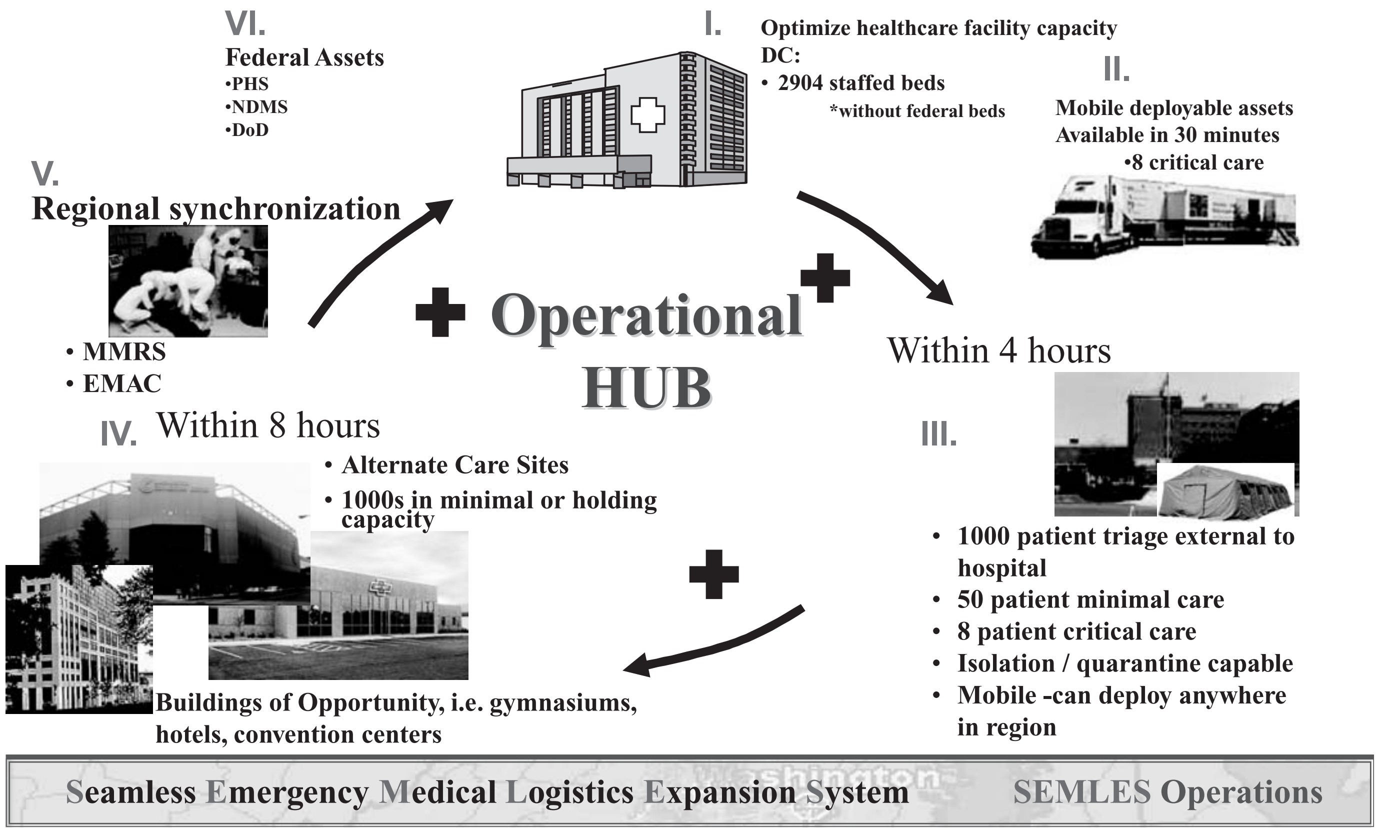

Figure 3.6. Modular/Phased Immediate and Sustained Capability.

care delivery capabilities in a disaster impacted community. Much of this work started with a focus on alternate care facility planning for extension of hospital-like services in an unregulated, non-healthcare setting. Examples include the establishment of Federal Medical Shelters (FMS) in the US during the responses to the multiple Florida hurricanes in the summer of 2004, Hurricanes Katrina and Rita (2005) and Hurricanes Gustav and Ike (2008). The initial concepts for such planning came from work conducted by the US Army Soldier Biological Chemical Command (SBCCOM), Biological Warfare Improved Response Program (BW-IRP) in the late 1990's. These efforts focused on a combination of out-of-hospital capabilities divided between Neighborhood Emergency Help Centers (NEHC) and Acute Care Centers (ACC).[39,40] The NEHC is intended to function as a community care station that provides functions including victim triage and distribution points for medical countermeasures. The ACC, similar to the FMS concept, serves as an out-of-hospital medical treatment facility for lower acuity patients not requiring a hospital critical care setting, but not well enough to be managed at home. Additional work in this arena continues to evolve, focusing on the spectrum of care delivery options and broadening the focus to a stratification of care model as elucidated in the *Mass Medical Care with Scarce Resources: A Community Planning Guide* publication in 2007.[41] Pandemic influenza planning has galvanized many communities to adopt such an approach to surge capacity planning, largely based on this theoretical framework.[42]

The US CDC adopted the framework for surge capacity planning, emphasizing the importance of coordinating public health and healthcare related planning for pandemic influenza under the umbrella of a Community Alternate Care Site (ACS), comprised of community partners who are essential to delivering care in the setting of a surge response to disaster (Table 3.1). The components of an ACS are built around the stratification of care model, with an important emphasis on developing consensus based community wide agreement on the use of triage algorithms, particularly those that relate to the ethical and legal implications of allocating scarce resources in a disaster event.

Healthcare Facility Surge Capacity

The implementation of surge capacity strategies in healthcare facilities requires a graded approach using a variety of strategies. There are a number of steps that healthcare facilities can take to expand capacity over discrete time frames. There are several steps that can be taken to augment the delivery of care for an increased volume of high acuity patients. Space to deliver care, clinical staffing availability, and the critical use of supplies must all be considered. A continuum of surge capacity implementation may be subdivided into conventional, contingency and crisis surge implementation.[43] In turn, these respective levels of surge will be accompanied by an equivalent conventional, contingency or crisis care process to maintain the standard of care. Such an approach is based upon the recognition that not all disaster events will require the same degree of response, thus requiring a scaled approach to surge capacity implementation in the hospital. Examples of methods to support conventional care that are outside the normal operations of daily patient care delivery

Table 3.1: Community Alternate Care Site Partners

Ambulatory Surgical Centers
Call Centers
Emergency Departments
Emergency Management
Emergency Medical Services
Faith Based Organizations
Home Health Agencies
Hospice Agencies
Hospital Administration
Law Enforcement
Legal Counsel
Local Government
Long Term Care Facilities
Medical Examiners Office
Non Profit Organizations
Pharmacies
Private Community Physicians
Public Health Department
Schools and Universities
Special Needs Agencies
Urgent Care Centers
Veterans Affairs Health Centers and Community Based Outpatient Clinics

include doubling of beds in single patient rooms and canceling elective surgical procedures. The other end of this spectrum, the delivery of crisis care, might involve the placement of patients in non-conventional treatment settings. In order to maximize the level of care delivered in a crisis care environment, there are a number of steps that can be taken to prepare to manage an influx in patients requiring critical care services.[44,45,46] Within the context of a surge response to a disaster event, the delivery of "emergency mass critical care" takes place in a crisis care environment. The pool of available critical care resources is limited by the disaster event, or because the total number of patients requiring such care exceeds that capacity that is normally available. A deliberate framework for planning to care for patients under these circumstances must be developed prior to the onset of an event. The framework must contain clearly delineated plans for the stepwise expansion of critical care services outside of the normal intensive care setting. These services must provide the highest level of care that can be sustained over an extended period of time. Essential components of emergency mass critical care include the use of mechanical ventilation; the administration of intravenous fluids, vasopressors, medications to treat specific disease conditions, and adequate sedation and analgesia; and other select practices that are known to reduce the adverse consequences of critical illness. Some experts recommend that hospitals with intensive care units should prepare to deliver such care for a daily critical care census that is three times their usual capacity, for up to 10 days of care delivery. Further research is necessary to validate this recommendation.

Examples of Local Level Resources and Tools

Hospital and Healthcare Facility Surge Options

Hospitals and other healthcare facilities must have plans to expand their capacity to manage a surge in the number of patients needing care during a disaster. The California Department of Public Health developed a comprehensive program of standards and guidelines, operational tools, and training materials to facilitate planning for healthcare surge.[47] Figure 3.7 reflects basic requirements for staffing when establishing an Alternate Care Site.

The US-based Joint Commission identified the following examples as options for consideration.[48] Detailed planning is required to integrate the comprehensive stuff, staff and structure to meet standard of care requirements in crisis care.

SHUTTERED HOSPITALS

Hospitals that have been closed may offer an option for surge capacity. The process of opening a facility that has been closed requires considerable attention to environmental safety. Planning is critical as the cost of improving the facility may be more than the cost of replacement. Recently closed facilities offer the most viable expansion solutions.

FACILITIES OF OPPORTUNITY

"Facilities of opportunity" are nonmedical buildings that can offer healthcare facility surge opportunities. Examples include veterinary hospitals, convention centers, exhibition halls, empty warehouses, airport hangars, schools, sports arenas, or hotels. Considerations such as staffing, ease of patient care, sanitary facilities, and food service should be considered. Facilities such as day surgery centers and other existing healthcare facilities may provide options for expansion with minimal cost and effort.

MOBILE MEDICAL AND PORTABLE FACILITIES

Mobile and portable facilities build on the military model of independent hospital facilities. Many models exist commercially that may offer expansion capability. As with other options, a cost benefit analysis along with assessment of the ability to deliver care in a timely manner is critical in developing the capability.

In 2007, the state of California engaged in a program to develop three mobile field hospitals designed to provide surge capacity of 200 beds each within 72 hours after activation.[49] The program provides facilities and an equipment package designed to maintain operations for 72 hours. Personnel are organized from existing resources within California. Each Mobile Field Hospital includes emergency/triage facilities, an operating room with two suites, two Intensive Care Units with a total of 20 critical care beds, 180 ward beds, mobile radiology, laboratory and pharmacy supply units. Locations for the care of special patient populations include pediatric care units, obstetrics/gynecology units, orthopedic and neurology units and a negative pressure isolation ward for highly contagious patients. The units require contractor support to maintain operations such as food services, potable water service, waste water removal, trash removal, medical waste removal, showers, toilets, laundry facilities, oxygen

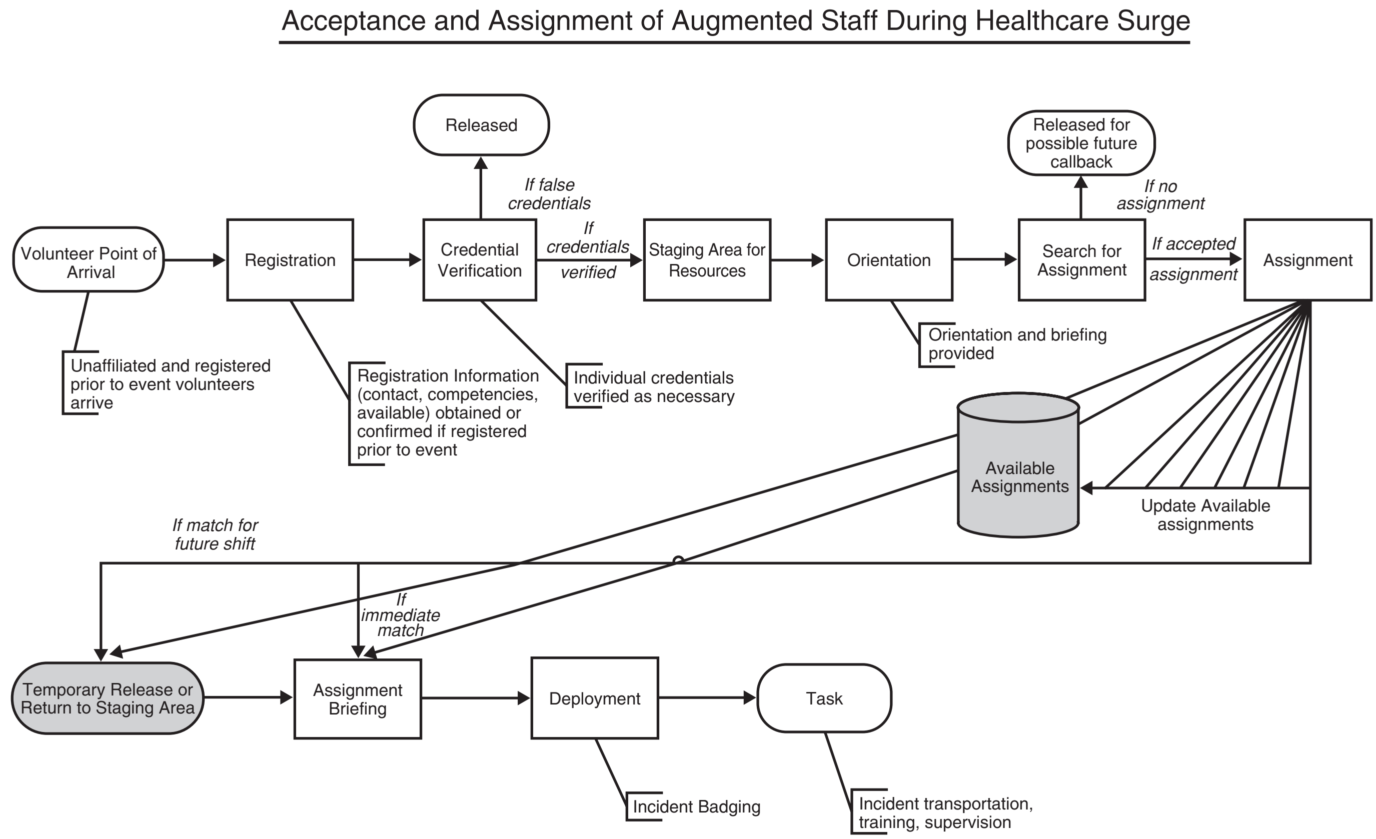

Figure 3.7. Considerations for Staff Support.

cylinder refill service and fuel delivery service for power generation systems. The program was designed to support services as needed to restore or replace available hospital capability during a disaster or public health emergency.

Local Staff Support Options

Staffing for surge capacity presents many challenges. Uninvited but well-meaning volunteers may converge on the disaster region. Often there is no plan to integrate these spontaneous volunteers into the local command and control structure and their management consumes resources that were programmed for the response. In addition to anticipating this group of volunteers, a better approach is to establish systems to coordinate volunteer resources prior to rather than during an event. Even with pre-event initiatives, there are difficulties related to confirming current qualifications, identifying sufficient providers who are not already committed to other responsibilities, and compliance with existing country-specific regulations. For example, in the US, multiple entities may have requirements for credentialing personnel including states and local healthcare facilities. These initiatives are focused on identifying health personnel who may be mobilized to help support the surge in demand for patient care service delivery. State based registry systems are being established under the Emergency System for Advance Registration of Volunteer Health Professionals (ESAR-VHP) program. Additional federal resources are being developed within the Medical Reserve Corps (MRC) program to identify local volunteers in the medical and public health arenas who can contribute their skills during times of disaster response. Nevertheless, significant controversy surrounds credentialing and management of volunteers. For example, Schultz and Stratton argue that all of the currently available credentialing options have serious limitations that would make it difficult for hospitals to use the health care workers provided by such entities. Most of these systems require significant time to activate and implement. In addition, they don't all provide volunteers with skill levels that hospitals can utilize. Hospitals require highly trained professionals within hours of a disaster. These two authors suggest a hospital-based credentialing system that is shared among local facilities within one jurisdiction. All credentialed healthcare providers at each hospital are listed in a database and this information is distributed to all facilities. Immediately after a disaster, hospitals can consult the database to verify the credentials of volunteers in the area. This system would permit rapid credentialing of qualified volunteers in the first hours and help to maintain hospital function.[50]

Expanding scope of practice under disaster conditions is another option under development. The State of California is developing guidance with the support of professional member organizations to identify professional skills sets that could be used during crisis care to expand capability in resource constrained environments. For example, State of California paramedics are trained to give injections, but not normally permitted to administer vaccinations. If regulatory relief and training were provided, prehospital personnel could assist with mass vaccination programs during exposures and outbreaks.

State Medical Assistance Teams are also being developed across the US to provide support within states rather than deploying to other states as has been the traditional focus. Mutual aid agreements may allow these resources to deploy to other states with approval of State leadership.

STATE MEDICAL ASSISTANCE TEAM (SMAT)

The North Carolina State Medical Response System developed a deployable State Medical Assistance Team (SMAT). Their level one team is designed to provide medical care in disasters or during special events, deploy a 150-bed alternate care facility, support a Strategic National Stockpile receiving site, establish drug distribution and immunization sites and establish a field medical station capable of treating 250 patients within a twenty-four hour period. The team deploys with 12 to 54 members depending on the requirements of the emergency.[51]

CalMAT TEAMS

California Medical Assistance Teams (CAL-MAT) are a state of California volunteer resource designed to respond across California during a state of emergency. California has three teams designed to deploy within 12 hours of notification and operate without resupply for 72 hours.[52]

Regional Support

Emergency Management Assistance Compacts

Another important source of surge response within the US is that provided by formal State to State requests and offers of support. After the delays in delivery of assistance experienced during Florida's Hurricane Andrew in 1992, the Southern Governors Association created a mechanism by which states could assist one another in times of disaster. This was the origin of the Emergency Management Assistance Compact (EMAC), a congressionally ratified organization that provides form and structure to interstate mutual aid. Through EMAC, a disaster impacted state can request and, when approved by the providing state, receive assistance quickly and efficiently. These process resolves two key issues: liability and reimbursement.[53] EMAC is a model that illustrates how to manage the response at the lowest level possible. It provides a process to request personnel and equipment more quickly that may be available through Federal programs.

Medical Reserve Corps

The MRC is a community-based program developed by the US federal government. It is designed to organize and engage volunteers to prepare for and respond to emergencies. The MRC supplements existing emergency and public health resources. The MRC identifies specific, trained, credentialed personnel and prepares them to respond to local disasters.[54]

U.S. National Planning for Surge Capacity

National Disaster Medical System

The National Disaster Medical System (NDMS) is a nationally driven, top down program designed to provide resources to local jurisdictions upon their request, in the event of a disaster. It was established in 1984 as a partnership between the Departments of Defense, Veterans Affairs, Health and Human Services, Federal Emergency Management Agency, and private hospitals. The program evolved from the Contingency Hospital System designed to provide medical care for military personnel returning from overseas conflicts. Originally focused on transport of patients and bed capacity at definitive care sites, the program expanded in 1997 to include deployable teams designed specifically for domestic emergency medical response. Lead responsibility resides in Department of Health and Human Services. The Homeland Security Act of 2003 transferred oversight for the NDMS to the Department of Homeland Security, however this authority was transferred back to the Department of Health and Human Services by the Pandemic and All Hazards Preparedness Act of 2006.[55]

NDMS constitutes the primary federal response mechanism for management of mass casualty events in the United States, with focus placed on three discrete areas of response (Chapter 9). The first is the provision of deployable teams designed to provide basic emergency healthcare support in the disaster affected area. The teams mobilize under federal authority to provide support as requested.[56]

The second component of NDMS is that related to patient transport and the provision of medical evacuation out of a disaster affected area. Transport management and coordination is a responsibility of the Department of Defense with the assistance of the Department of Veterans Affairs. This includes communicating onsite organization, coordination and transportation of evacuated patients from a mobilization center near the incident site (e.g., a designated airport facility) to a reception site (e.g., an airport in a non-affected region of the country). DoD (USTRANSCOM) estimates that dedicated assets will be able to transport 81 critically ill or injured patients over a 54-hour timeframe. A Civil Reserve Air Fleet (approximately 1400 aircraft including 45 Boeing 767s) provides additional transportation support. The conversion of civilian aircraft to a configuration capable of supporting the transport of disaster casualties takes a minimum of 60 hours. Additional private sector assets are under contract to assist in patient evacuation including those provided by the HHS private ambulance contract and the availability of approximately 800 civilian rotor wing assets.[57]

The third major component of NDMS is the provision of definitive care. About 1800 hospitals have signed agreements guaranteeing a minimal number of staffed and available beds for patient placement in the event of a catastrophic event requiring evacuation of patients out of a disaster stricken region. Theoretically, this provides a nationwide capacity for placement of approximately[58] 100,000 patients in unaffected regions of the US. For a widespread disaster that extends beyond a region or State or one that involves contagious or contaminated patients who cannot readily be transported to remote areas, this system would be problematic.

National Disaster Medical System Teams[59]

Table 3.2 contains a list of NDMS teams. A snapshot of capability of the most common teams includes:

DISASTER MEDICAL ASSISTANCE TEAM (DMAT)

DMATs are the basic team of the NDMS. As of 2009, there are 55 DMATs located across the United States, although only 24 are deemed to be operational, with demonstrated ability to deploy between 6 and 12 hours after activation. They are expected to arrive on site within 48 hours and maintain operations for 72 hours without resupply. Teams consist of 35 people who are capable of providing primary and acute care, triage,

Table 3.2: National Disaster Medical System Response Teams

55 Disaster Medical Assistance Teams (DMATs)
4 National Medical Response Teams (NMRTs)
5 Burn Teams
2 Pediatric Teams
1 Crush Medicine Team
3 International Medical/Surgical Teams (IMSuRTs)
3 Mental Health Teams
3 Veterinary Medical Assistance Teams (VMATs)
11 Disaster Mortuary Operational Response Teams (DMORTs)
1 Joint Management Team (JMT)
3 Nurse/Pharmacist National Response Team

initial resuscitation and stabilization, advanced life support and preparation of sick or injured for evacuation. DMAT members are capable of providing ambulatory care for up to 250 patients per 24-hour mission cycle, with limited laboratory point of care testing and bedside radiology services. They have the means to stabilize and hold 6 patients for extended treatment for up to 12 hours, and can support an additional 2 critical care patients for up to 24 hours. They can provide sustained ward care for 30 non-critical inpatients at NDMS designated facilities, and can augment staffing at alternate care facilities and assist with mass medical countermeasure distribution.[60]

DISASTER MORTUARY OPERATIONAL RESPONSE TEAM (DMORT)

DMORTs provide technical assistance and support for recovery, identification, and processing of deceased victims. Teams include medical examiners, coroners, funeral directors, pathologists, forensic anthropologists, medical records technicians and transcribers, fingerprint specialists, forensic odontologists, dental assistants, x-ray technicians, and other personnel. Stand-alone capability is available through Disaster Portable Morgue Units (DPMU).

VETERINARY MEDICAL ASSISTANCE TEAM (VMAT)

VMATs are designed to support veterinary services during disasters or emergencies. Their capabilities include support in assessing the medical needs of animals; medical treatment and stabilization of animals; animal disease surveillance; zoonotic disease surveillance and public health assessments; technical assistance to assure food and water quality; and animal decontamination. The teams are organized to support the specific event and include various members of the veterinary health management community.

NATIONAL MEDICAL RESPONSE TEAM (NMRT)

An NMRT is a 50-member specialized team designed to provide medical care following a nuclear, biological, or chemical incident. The team is capable of providing mass casualty decontamination, medical triage, and primary and secondary medical care to stabilize victims for transportation to tertiary care facilities in a hazardous material environment.

INTERNATIONAL MEDICAL SURGICAL RESPONSE TEAM (IMSURT)

IMSuRTs are designed to support the US State Department. They were implemented in response to attacks directed against the US embassies in Nairobi, Kenya and Dar es Salaam, Tanzania in August 1998. IMSuRTs provide worldwide deployable medical and surgical treatment capability.[61] They are supposed to deploy within 3 hours of notification. IMSuRTs are the only NDMS team with surgical operating room capability designed to provide emergency surgery, treatment, and stabilization. They deploy with all necessary equipment but are not designed to function in austere environments.

Strategic National Stockpile

The Strategic National Stockpile (SNS) is a program created in 1999 by the U.S. federal government designed to supplement and re-supply state and local governments with medical materiel supplies (Chapter 16). It contains antibiotics, medical supplies, antidotes, antitoxins, antiviral medications, vaccines and other pharmaceuticals. The SNS program coordinates governmental and non-governmental capabilities including the National Veterinary Stockpile, commercial business vendor managed inventory (VMI) process, and commercial carriers. The purpose is to integrate critical medical supplies for distribution in emergencies. The program also coordinates with the research and development community to acquire medical countermeasures for CBRN threats and to expedite access to drugs that are not commercially available for non-research purposes. The SNS maintains 12-hour push packs that are strategically located across the US near major transportation hubs as well as forward placed caches of chempacks that are integrated into local hazardous materiel response programs. A Technical Advisory Response Unit (TARU) is also available to support local authorities in receipt and coordination of distribution of the SNS. The SNS also maintains Federal Medical Stations designed to provide for 250 non-acute and special needs patients over three days. The medical stations increase in 50-bed increments and contain supplies for first aid, pharmaceuticals and housekeeping.[62,63]

VENDOR AND STOCKPILE MANAGED INVENTORY

In addition to the 12-hour push packages (Chapter 16), ventilators and vaccines, are stored and managed under a managed inventory program. This consists of either Vendor Managed Inventory (VMI) or Strategic Stockpile Managed Inventory (SMI). When specific supplies are known to be needed in order to support the medium to long term objectives of a disaster surge response, VMI or SMI will be used to supplement the initial shipments. VMI is maintained by the primary corporate vendor under contract with the federal government. VMI and SMI supplies are designed to arrive 24 to 36 hours following the initial receipt of the push packages. The process to request SNS assets requires a request from the affected state's public health authority through the governor's office to HHS. The request is evaluated and upon authorization will be released for shipment. HHS maintains authority for the SNS materiel until it arrives at the designated receiving and storage site where upon it is transferred to state and local authorities. State and local authorities will then begin the breakdown of the 12-hour Push Package for distribution. A Technical Assistance Response Unit (TARU), a team of medical logisticians, will deploy to assist state authorities in the breakdown and distribution of the stockpile.

Table 3.3: Federal Medical Station Types

Type I: Under development to provide advanced intensive care and operating room services
Type II: Under development to provide specialty care (e.g., infectious disease isolation)
Type III: Provide basic low acuity care in a ward like setting
Type IV: Provide medical shelter for patients with chronic medical conditions

CHEMPACKS

Unlike most biological incidents, treatment must be near immediate after a chemical agent release. To address this concern, the US government developed a forward deployed element of the SNS in 2003 in order. Healthcare facilities and other entities voluntarily participate in The Chempack Program and receive a cache of medications configured for either hospital or out-of-hospital usage.[64] The Food and Drug Administration's (FDA) Shelf Life Extension Program was developed to address the financial challenges of maintaining the program. The program was initially managed for the Department of Defense beginning in 1986, to permit select medications to be stored and used over a longer period of time than determined by the labeled expiration date.[65]

FEDERAL MEDICAL STATIONS (FMS)

The FMS is a federal resource designed to deploy and deliver primary healthcare services anywhere in the US. The team includes approximately 100 personnel primarily from the US Public Health Service (USPHS). The FMS provides resources for 250 stable primary care patients for three days using supplies from the SNS. FMS also may be used to support mass ambulatory vaccination services, prophylactic medication administration and prehospital triage and initial stabilization for up to 250 mass casualty patients. Facility requirements are the responsibility of the local jurisdiction and include an approximately 40,000 square feet structurally intact building with electricity, heating, air conditioning, ventilation, and clean water services, bathroom and showering facilities, billeting for staff, and contracted support for food, potable water, laundry, ice, medical oxygen filling, and biomedical waste disposal. They also require assistance of a 10-person set-up team. The FMS can be expected to arrive 48–96 hours from the time of request to delivery inside the continental US and takes an additional 12 hours to assemble. At the time of this writing, there are four types of FMS in various stages of development (Table 3.3).

THE CITIES READINESS INITIATIVE

In the context of biological terrorism response, the US government initiated the Cities Readiness Initiative (CRI) to support cities in increasing their ability to deliver antibiotics and medical supplies to their population with 48 hours of the decision that such mass medication distribution is required. The program began in 2004 and was expanded to prepare 72 cities across all 50 states. The CRI facilitates the development of Points of Distribution (POD) and the policies and processes to implement mass distribution. In several jurisdictions, the United States Postal Service is the key partner involved in the distribution of pharmaceuticals, relying on mail carriers to deliver antibiotics to the homes of selected zip codes.

Additional Staff Surge Capacity

The US Public Health Service Commission Corps

The US Public Health Service Commissioned Corps (USPHS) is one of seven uniformed services within the United States. It provides public health leadership and service for federal government agencies and programs and is the medical arm of the US Coast Guard. The USPHS consists of approximately 6,000 full-time public health professionals from all disciplines.[66] It has developed teams designed to augment state and local resources during emergencies.[67]

RAPID DEPLOYMENT FORCE (RDF)

The USPHS has five Rapid Deployment Force (RDF) teams, each with 105 multidisciplinary staff. They are designed to deploy within 12 hours of notification. The teams have numerous overlapping responsibilities providing capabilities such as mass care in the FMS, and reinforcing staffing at Points of Distribution and Casualty Collection Points. The RDF is also capable of conducting community outreach and assessments.

APPLIED PUBLIC HEALTH TEAM (APHT)

The APHT is designed to provide assistance in public health assessments, environmental health, infrastructure integrity, food safety, vector control, epidemiology, and surveillance. Their goal is to deploy within 36 hours of notification.

MENTAL HEALTH TEAM (MHT)

The MHT is designed to provide assistance in assessing stress and suicide risks within the affected population, manage responder stress, and provide therapy, counseling, and crisis intervention. Their goal is to deploy within 36 hours of notification.

US Department of Defense Surge Capacity Resources

The US Department of Defense (DoD) has a mission of Defense Support to Civil Authorities (DSCA). While the DoD has a wealth of capability, the assets are aligned with specific, primarily war fighting missions. Availability of assets is subject to national security priorities. All requests for DoD support are channeled through the National Response Framework processes. As the lead federal agency, the DHS has the responsibility for determining what agency has the ability to supply appropriate assets to the affected area. DoD acts in support of domestic emergencies and never in a lead role. They do not provide support without requests from DHS with the exception humanitarian assistance of immediate response to imminently life-threatening local situations.[68]

Burn Surge

Although a subset of overall surge systems, the issue of surge capacity for burn casualties has some unique features and deserves special attention. A review of the detailed planning in burn surge can assist in defining critical points of failure in surge planning. Burns surge has historically been a challenge. Figure 3.8[69] demonstrates the number of burn patients in several events. Burns fall into the high-complexity/low-numbers spectrum under normal circumstances but can escalate rapidly given different types of scenarios. Resources for the management of burn casualties are limited and, in many countries, a system of regional burn centers exists. Specially trained staff, burn-specific

- Café fire, Volendam, January 2001*
  - 245 casualties, mean TBSA 12%
  - of 182 admitted, 112 in ICU
  - 10 died, 78 transported abroad
- Night club fire, Rhode Island, February 2003**
  - 215 victims, 96 died at scene, 4 later
  - 64 sent to trauma center
  - 151 transported to 15 other facilities
- Matsa typhoon, 118 chemical burn casualties***

*Welling L. Burns. 2005;31:548-54.
**Mahoney EJ. J Trauma. 2005;58:487-91.
***Ma B. Burns. 2007;33:565-71.

Figure 3.8. Burn-related Disasters.

supplies (stuff), and specialized units (structure) are necessary to optimize outcomes for burn patients. In addition, a management system to distribute large numbers of casualties with burns is essential.

The first step in preparing for a burn surge event should be the identification of resources available for reallocation from traditional uses including: nonburn-specialized staff who can take part in the management of burn patients (e.g., general surgeons, anesthesiologists, intensivists, general surgery nurses, intensive care nurses, postoperative unit nurses); structure: hospitalization capability in departments other than burn units (e.g., plastic and general surgery, intensive care units, post operative units); and stuff: medical equipment, supplies, and medications (particularly large volumes of intravenous fluids and airway equipment).

The second step should be to define the systems component, that is, which of these resources should be used in each phase of the management of the event? Burn surge, as in other trauma, has three management phases – the first is the management at the scene or scenes of the incident; the second is hospital or alternate care facility management, such as further resuscitation and surgical interventions as indicated; and the third is the rehabilitation phase. During the planning phase, it is critical to define outcomes-based triage criteria by which patients would be distributed to nontraditional burn treatment areas. The first patients to be assessed are not always the ones that require hospitalization in a burn unit.

Kelen and McCarthy state "staffing for maximum known demand is not economically sound, because the physician or provider would be idle for considerable periods during lower demand times."[70] In addition, even if there were no fiscal constraints, until new learning technologies such as virtual reality are perfected, it would likely be difficult to provide adequate training to an unlimited number of staff. In resource-constrained environments, a number of small interventions can be reserved to the highest skilled providers, in this case, the burn surgeon if available. In the initial phases, estimation of burn size and initiation of fluid resuscitation, escharotomies where indicated, and the decision regarding admission to a burn unit or other care location should be conducted by an experienced burn provider. Ideally, a burn surgeon should perform daily evaluation of the wounds, decisions regarding the need for surgery, and the surgery itself. In the rehabilitation phase, a different type of specialist can provide services in consultation with a burn surgeon. In general, other physicians (e.g., general surgeons, emergency physicians, and anesthesiologists) can perform additional medical interventions. Thus, nonburn specialists with basic surgical skills can create surge capacity for burn patients by augmenting personnel resources. Although adjustments may need to be made in a scarce resource environment, if resources are sufficient, the following guidelines are useful in the hospital or definitive alternate care site setting

1) In the acute care phase patients should be divided into major burn patients and nonmajor/minor burn patients. Because every patient with more than 20% total body surface area (TBSA) burns requires fluid resuscitation and because escharotomies can be mandatory even in small deep burns restricted to one location, these are not optimal criteria for determining whether patients are in the "major" burn category. Rather, the criteria for a major burn patient should be – impending respiratory failure of need for mechanical ventilation; inhalation injury; hemodynamic, septic or other shock states; special body areas burned (e.g., genitalia, deep facial burns); greater than 30% TBSA; major accompanying trauma (e.g., head trauma or visceral injury); single- or multiorgan failure; underlying medical conditions that indicate major systemic diseases (e.g., ischemic heart disease, diabetes with target organ damage, malignancy); or disability (e.g., paraplegia, loss of hearing). All other patients are designated nonmajor/minor burn patients.
2) Nonmajor/minor burn patients can be managed with the resources of general and plastic surgery departments by the departments staff (physicians and nurses) with regular patient to caregiver ratio. Ideally, a burn specialist should perform daily patient assessments (a ratio of up to one burn physician to 30 patients is the goal).
3) Major burn patients should be managed in a burn unit or in an intensive care unit. Postoperative units are an alternative if burn unit capacity has been exceeded.
4) The ideal burn nurse to patient ratio for major burn patients is 1:1. Intensive care, general, and plastic surgery nurses can be trained to care for burn patients if staff surge capacity is needed. In this case, one of three nurses should be a burn nurse (daily dressing changes are usually performed in teams of three, therefore a team of three nurses can treat three patients). Taking all that into account, optimally each patient requires 4.2 full-time nursing equivalents 1.4 of which are specialized burn nurses. Another requirement should be that in each shift there will be at least one burn nurse per three patients. This requirement does not change the number of full-time nurses needed; however, it does require that patients are grouped into threes.
5) Exact guidelines for the rehabilitation phase are difficult to establish. Almost all major burn patients will require rehabilitation before discharge (and all will require rehabilitation after discharge). Because most major burn patients will be hospitalized for acute care for a few weeks, there is time to coordinate rehabilitation services.

Other Considerations

Staff

Augmentation of staff with expertise in burn care is a critical element for creating surge capacity. Planning should account for the fact that some personnel will be unable (e.g., due to injury, death, or lack of transportation infrastructure) or unwilling to report to work during a disaster. Therefore, double or triple the number of personnel expected to be needed should be provided. To prepare nonburn specialists (e.g., plastic surgery and general surgery nurses) to assist in a burn disaster, basic burn training coupled with a rotation in a burn unit at least every 2 years is desirable. Nurses from other departments who have experience in treating ventilated patients should also be considered for pre-event training in burn management. Surge plans should specify staff members who can be allocated to assist during a burn disaster. These staff members should be aware of their responsibilities and trained prior to the event. Just-in-time training after an event occurs may be a useful adjunct if additional personnel are required.

Outpatients

Most patients with injuries limited to burns can be managed as outpatients. Professional triage that complies with American Burn Association guidelines can identify patients who do not need acute care services thereby preserving staff, stuff, and structure for more severely injured patients. Community medical services should be capable of treating patients with burns of up to 15%–20% of TBSA in nonspecialized body regions.

Transfer

Because burn events fall under the "high-complexity/low-numbers" end of the spectrum, highly specialized multidisciplinary teams will be needed to manage patients from these types of disasters. If possible, patients should be transferred to an appropriate facility from the scene(s). In some cases, however, severely burned patients may require rapid transfer to a tertiary medical center after initial stabilization at a nonburn facility.

In addition to transferring patients out, resources can be brought in to augment capacity at a burn center. Local, regional, national, and even international resources may be needed in mass burn disasters. Local resources are most easily allocated and should be used first. A regional system should be in place for resource sharing. Physicians and nurses can be allocated for short periods of time based on a daily assessment of patient needs. National disaster management plans should state which backup resources are available and detail logistics for their movement to a burn center.

Duration of stay must be considered. Burn patients usually remain hospitalized well into the recovery phase of a disaster, especially when combined injuries are present. For example, in Israel 25.6% of terror-related burn casualties are still hospitalized 1 month after their admission.[71] Two major effects of this prolonged duration of stay are continuous demand for resources including personnel, hospitalization facilities, medical equipment, and medications; and shifts in management strategies (e.g., increased referrals or outpatient treatment) must be initiated to maintain capacity to care for nonevent-related patients.

Building Resiliency and Sustainable Surge Capacity

The responsibility to develop surge capacity does not always fall clearly within a single entity. Each part of the system (e.g., healthcare facilities, emergency medical services, public health, and all levels of government involved in providing healthcare) must develop surge capacity that enables maintaining its own critical functions during a disaster while simultaneously avoiding adding undue stress on other functions. In addition, the overall system of patient care needs surge capacity. A review of the patient care requirements from event through recovery is useful in determining how to build system resiliency and sustainable surge capacity. An outcomes-based, scalable system with capability across the continuum of care is needed along with the appropriate stuff, staff, and structure to support the surge. In addition, a process is necessary to transition between individual-based care and population-based best outcomes.

Healthcare can be divided into five basic elements that provide or support the continuum of care:[72] 1) emergency medical services (initial nonhospital care); 2) hospital care; 3) nonhospital healthcare (e.g., clinics, physician offices, nursing homes, home health, hospice, and rehabilitation facilities); 4) nonhospital health and medical assets (e.g., public health assets, laboratory, pharmacy, radiology, occupational health, and medical supply); and 5) assets that are not health or medical, but support health and medical operations (e.g., communications, power, water, security, and transportation). Catastrophic events will require increased capacity across all elements. Depending on the scenario, surge capacity may only be needed for a portion of these elements at any given time.

A solution for high-complexity/low-numbers events can produce the intended individual-based outcomes for those events but may fail the efficacy test for population-based outcomes in a high-complexity/high-numbers event. A transition strategy must be incorporated in the planning. As was identified in burn surge, a large part of the treatment can be provided by nonburn-specialized personnel, under the supervision of burn personnel.

With a clear understanding of patient throughput, incremental surge policies and procedures to provide capability and capacity in a timely and cost effective manner can be developed. A field or mobile hospital may represent significant capability if fully equipped and staffed with the appropriately trained personnel; however, if it cannot be fully operational until days after the event, it may not be useful or cost effective. If it uses personnel already engaged in other critical capability areas, it may not benefit the overall affected population. Only when the plans include a balanced and achievable 3S Surge System will the field hospital be a true asset.

Recommendations for Further Research

Evidence-based data on efficacy of interventions and best outcomes in surge capacity are limited. Modeling events that have not occurred can assist in validating assumptions. There are numerous areas of research and investigation that can add to the evidence-based data for operational planning, education of providers, and investigation into nontraditional methods of providing care. Additional research is required in healthcare management, finance, and the legal and ethical issues surrounding surge capacity.

Realistic timelines as to how quickly resources can be delivered must be developed. Further modeling of a balanced 3S approach will assist planners in developing achievable plans. A need exists for the development of triggers and transition strategies to assist in reallocation of resources as events escalate through the spectrum of scenarios. Further studies on the efficacy of interventions and their impact on individual-based versus population-based outcomes are needed.

The business of healthcare management and services provided should be reviewed to identify fiscal and legal issues. The California Standards and Guidelines developed in 2008 provide a good launching point to address the full spectrum of management.

Finally, a need exists to review current practices and to develop the evidence to support interventions that will improve outcomes. In May 2006, the Society for Academic Emergency Medicine convened a consensus conference entitled "The Science of Surge." The proceedings of this multidisciplinary, multinational meeting are available at http://www.blackwell-synergy.com/toc/acem/13/11. This early work raised important issues surrounding the concept of surge capacity. The development of realistic and sustainable solutions to create surge capacity for catastrophic disasters will require much additional research.

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4

International Perspectives on Disaster Management

Jean Luc Poncelet and Herman Delooz

OVERVIEW

For many years, disasters were perceived as unavoidable and only attributable to "natural" events. Over the last 30 years, however, professionals in the health field have begun studying the subject, realizing that there is potential to avoid the many negative consequences linked to such hazards. Public health and emergency medicine specialists were among the first groups to investigate these issues scientifically, examining ways to protect lives from the impact of disasters.

Pioneers in this new area of research included Professor Michel Lechat from the University of Louvain in Belgium, Professor Peter Safar from the University of Pittsburgh in the United States, and Professor Rudolph Frey from the University of Mainz in Germany. Professor Lechat established the Center for Research on the Epidemiology of Disasters in 1973, which subsequently became a World Health Organization (WHO) Collaborating Center for the Epidemiology of Disasters. Professors Safar and Frey founded the club of Mainz in 1976, which would become the World Association for Disaster and Emergency Medicine. Its focus was the improvement in the worldwide delivery of prehospital and emergency care during everyday events and mass casualty disasters.[1] The disciplines of public health and emergency medicine have both made substantial contributions to the field and are now intimately linked. Subsequently, a growing number of professionals have systematically investigated disasters from a multidisciplinary and multihazard perspective.

This chapter will provide an international perspective that focuses on the evolution of the approach health specialists have used to reduce the health consequences linked to disasters. It will highlight some of the main aspects of humanitarian disaster response training and disaster risk reduction. The first section explores how disaster management has evolved to its present status, whereas the latter section explores avenues for future growth. Examples of developments in emergency medicine education and research will also be discussed.

STATE OF THE ART

Thirty Years of Steady Improvement in the Approach to Preparedness

In 1976, a major shift took place in the field of humanitarian disaster response. Several disasters occurred in a relatively short period of time. The most significant of these were earthquakes impacting Peru in 1970, Nicaragua in 1972, and Guatemala in 1976. These caused significant devastation and loss of life, and the ministers of health in Latin America and the Caribbean subsequently called for changes in the international humanitarian response mechanism. Until that point, disaster response was mostly improvised both at the national and international levels.

Recognizing the shortcomings of an improvised disaster response, these ministers of health requested assistance from the Pan American Health Organization (PAHO), which is the regional office for the Americas of the WHO. In response, PAHO created a disaster preparedness program that improved the national capacity for responding to catastrophes. The resulting plan, passed as Resolution X at the PAHO 24th Directing Council, called on member states to, "develop plans, and, as necessary, enact legislation, set standards, and take preventive or palliative measures against natural disasters and disseminate these measures throughout the sectors concerned [with] coordinating their action with that taken by the corresponding services of the Pan American Health Organization."[2] Passage of this resolution represented a turning point in disaster response strategy, switching from an ad hoc response to a systematic preparedness approach.

In the field of public health, disasters are defined as situations in which the local health response capacity is overwhelmed to the point that external (often international) assistance is required. Typically, in these events, the number of injuries and deaths exceeds the level the emergency services can absorb. At the same time, the health system loses capacity because its infrastructure is seriously affected and healthcare personnel have suffered injuries and deaths or are unable to work.

Hence, disasters are situations in which a system can no longer meet the demands for health and medical services. The art of disaster response is to integrate all existing resources to increase capacity and address the needs that could not be met using standard operating procedures. The central objective of a disaster program is to prepare entities for coordination of necessary resources to reduce the disaster's negative impact on health. The funding needed for preparedness activities can be relatively small; what is most needed is the political support empowering the disaster management entity to assume the necessary leadership role to conduct the coordination function.

More recently, the concepts reflected in Resolution X have been applied not only to "natural" disasters but to all hazards. This preparedness methodology is now widely accepted and used to address any public health event of international interest, such as a possible influenza pandemic, as described in the International Health Regulations.[3] Professionals in the field of chemical and radiological disasters have also adopted similar preparedness approaches.[4–6]

The first pillars of preparedness began with simulations or tabletop exercises, and drills or live exercises that included the participation of several institutions through a multidisciplinary approach. Following suit, a number of countries started preparedness planning in their hospitals and later expanded activities to other institutions such as water systems.[7] Presently, a wealth of guidelines exist on the web covering a variety of topics, from establishing an Emergency Operations Center to describing the amount of water in liters that should be distributed to displaced populations or those in shelters.[8–10]

Training in disaster preparedness has mushroomed over these last few decades. According to a survey performed in 2003, 70% of the faculties of medicine in Latin America and the Caribbean were teaching at least a few hours of disaster management.[11] A sample of the most frequent topics included in such trainings is listed in Table 4.1.

Over the same time period, health and disaster legislation has also greatly improved.[12,13] In many countries, the progressive expansion of health and disaster-related standards and legislation resulted largely in response to the occurrence of disasters. These events helped governments identify problems and propose solutions. Based on these experiences, research activities, and field work, new standards and legislation were eventually created.[14] Some examples of these are found in countries where they form the basis of establishing hospital emergency committees and defining hospital construction standards. On a broader scale, subregional institutions, such as the Ministers of Health of Central America, the Ministers of Health for South American Andean Countries, or the South American Regional Trade Agreement also pass resolutions providing standards and defining the scope of regulations that form and implement a National Disaster Relief and Prevention System.

Table 4.1: Topics Frequently Included in Disaster Health and Medicine Curricula

Acute medical response	Prehospital emergency plans
Long-term medical support	Epidemiology
Surveillance	Hazard vulnerability analysis
Reconstruction of the medical and health system	Refugees
Disaster impact on public health	Sanitation
Transportation and communication	Water supply
Mental health	Nutrition and food supply
Hospital emergency plans	Shelter
Management of donations	Reconstruction of infrastructure
Mass casualty management	Disaster legislation

Although great progress has been made in preparedness, issues first identified in the 1980s remain as significant challenges. For example, nongovernmental organizations (NGOs), representatives from governments, and United Nations (UN) agencies met in Costa Rica in 1986 and established a series of specific recommendations to guide direct international donations (see Table 4.2).[15] Although these approved policy guidelines have been updated over time, relief agencies remain far from being compliant with the recommendations. Examples of such noncompliance are reflected in the continually perpetuated disaster myths and misconceptions of disaster management realities, which contradict these recommended standard procedures (see Table 4.3).

From Preparing the Response to Mitigating the Impact

In a perfectly designed health disaster preparedness plan, all existing resources, including those at the local, national, and international levels, are used in the most efficient way to minimize the number of lives lost, contain diseases, and limit disabilities; however, reality is frequently different. The Mexico City earthquake of 1985 illustrated the limits of preparedness, when one of the best-prepared medical response teams in the city was killed in a hospital collapse. Almost 20 years later, Hurricane Ivan struck Grenada in 2004 (a Caribbean island of 90,000 inhabitants). The country suffered such a level of destruction that no response could be generated from the island's resources, regardless of its previous preparedness level.

Table 4.2: Recommendations for International Donations

1. Donations of cash or credit provided to health authorities or international agencies should be used whenever possible.
2. Donations should be aimed at restoring the quality of healthcare to predisaster levels.
3. Perishables or short-life donations should only be made on request from, and with prior approval by, the National Health Disaster Coordinator or other Ministry of Health authority.
4. The World Health Organization's list of essential drugs and supplies should be used as a guideline by those wishing to donate.
5. Recipient countries should improve their distribution systems to ensure the best utilization of donated resources.

Table 4.3: Disaster Myths and Realities

Myth	*Reality*
Foreign medical volunteers with any kind of medical background are needed.	The local population almost always covers immediate life-saving needs. Only medical personnel with skills that are not available in the affected country may be needed.
Any kind of international assistance is needed, and it is needed now!	A hasty response that is not based on an impartial evaluation only contributes to the chaos. It is better to wait until genuine needs have been assessed.
Epidemics and plagues are inevitable after every disaster.	Epidemics do not spontaneously occur after a disaster and dead bodies will not lead to catastrophic outbreaks of exotic diseases. The key to preventing disease is to improve sanitary conditions and educate the public.
The affected population is too shocked and helpless to take responsibility for their own survival.	On the contrary, many find new strength during an emergency, as evidenced by the thousands of volunteers who spontaneously united to sift through the rubble in search of victims after the 1985 Mexico City earthquake.
Disasters are random killers.	Disasters strike hardest at the most vulnerable group, the poor – especially women, children, and the elderly.
Locating disaster victims in temporary settlements is the best alternative.	Temporary settlements should be the last alternative. Many agencies use funds normally spent for tents to purchase building materials, tools, and other construction-related support in the affected country.
Conditions are back to baseline within a few weeks.	The effects of a disaster last a long time. Disaster-affected countries deplete much of their financial and material resources in the immediate postimpact phase. Successful relief programs gear their operations to the fact that international interest wanes as needs and shortages become more pressing.

Source: PAHO/WHO.[16]

Those extreme situations define the limits that preparedness can achieve. If destruction is complete and only victims remain after a major disaster, there is little that a preparedness approach can offer, no matter how well developed it is. These types of situations require a different perspective and new approach. The new approach developed after the 1985 earthquake in Mexico is based on the concept of mitigation, emphasizing protection of infrastructure and the health system.

In 1987, the UN Assembly adopted a resolution launching the International Decade for Natural Disaster Reduction.[16] Its goal was to reduce loss of life, property damage, and social and economic disruption caused by disasters, especially in developing countries. The resolution establishing the International Decade for Natural Disaster Reduction was implemented in 1990.[17] The concept of mitigation was born.

Later, the mitigation approach helped produce the concept of risk reduction, which recognizes the importance of moving beyond preparedness. Risk is defined here as "a function of the hazard and vulnerability in which the hazard is a natural (e.g., earthquake or hurricane), technological (e.g., chemical or radiological accident), or political (e.g., war or civil strife) event." The essential idea of mitigation focuses on separating the hazard (an earthquake or biological agent) from the vulnerability of the institution or the system. If a building collapses, it is not attributed to the earthquake; rather it was a consequence of poor building design or failure to use appropriate shake-resistant construction techniques.

Since the late 1980s, an ongoing effort has existed in the health sector, especially in Latin America and the Caribbean, to protect health facilities so that life-saving functions can continue after a disaster. In the beginning, efforts centered on mitigating and refurbishing health facilities. Currently, the approach includes a more comprehensive vision, not just focusing on the construction aspects (structural and nonstructural dimensions – see Guidelines for Vulnerability Reduction in the Design of New Health Facilities), but also considering the functional (in this context "functional" refers to all organizational aspects) aspects of a hospital.[18,19]

Enormous progress has been achieved in the field of mitigation. For example, methodologies now exist that can produce a vulnerability analysis for buildings. This is the detailed study on how a building would perform if a maximum magnitude event (such as an earthquake or hurricane) occurs. The information generated by these analyses provides guidance on how to improve construction and revise existing building codes.

Mitigation can be a very efficient strategy. For example, some structures have been protected from collapse through targeted adjustments, such as retrofitting. The cost of the additional construction requires a relatively small financial investment compared with the overall value of the building. However, mitigation can be expensive when applied to existing facilities in poor condition and it frequently reaches the point at which it is too expensive to be considered. Hence, a lower cost approach is needed to reduce vulnerability.

From Mitigating to Integrating in the Development Process

In the late 1990s and early 2000s, the increasing engagement of financial institutions in risk reduction opened the door to considering new incentives and justifications for such activities in addition to the typical health-centered metrics such as lives saved. Participating institutions included the World Bank through its Global Facility for Disaster Reduction and Recovery and regional banks in Asia and Latin America.[20–21]

Increasingly, studies demonstrate that the perception commonly accepted 30 years ago, that it is too costly to make a society resilient to disasters, does not hold true. Contrary to earlier thoughts, if mitigation is part of the development process, it is not too costly to make a society disaster resistant. For example, when hazards are taken into account before construction begins, the increase in expenditures represents less than 4% of the total construction cost.[22]

Although cost is an essential factor in justifying risk reduction, it is not the only element. It would be unacceptable to construct a critical facility, such as one providing an emergency service, in so suboptimal a manner that it collapses during an earthquake simply due to financial considerations.

The integration of these financial and other technical considerations is an extremely positive step, as it allows development professionals to include "risk reduction" in their projects. The end result is an improvement in society without increasing the risk from disasters. For example, development professionals have begun to take into consideration locating critical services on higher ground, instead of flood prone areas. With these advances, it is possible to design technical tools and to train experts to conceive new development projects in such a way that they will remain functional even after a major event occurs.[23] The objective is no longer simple mitigation, but to build resiliency by considering vulnerability in a more comprehensive way through the risk reduction approach.

Although at the time of this writing the risk reduction approach is still in the initial stages of development, it has already generated some results. The World Bank established an online tutorial for "Strengthening essential public health functions,"[24] and one of these essential functions refers to disasters. This tool allows the user to estimate a country's level of preparedness and some aspects of risk reduction. Another example is the WHO/PAHO Hospital Safety Index.[25] This instrument allows trained local professionals to assess the safety level of health facilities. By applying this tool, government authorities should be able to identify the risks to which their hospital networks are exposed.

The UN launched a 2-year campaign in 2008 called "Hospitals Safe from Disasters" to ensure that these institutions are prioritized in reducing their vulnerability to hazards. Spearheaded by the WHO and the UN International Strategy for Disaster Reduction, "the campaign will focus on structural safety of hospitals and health facilities, on keeping health facilities functioning during and after disasters, and on making sure health workers are prepared when natural hazards strike."[26]

Shift in the Institutional Approach

Both governmental and regional institutions have significantly improved their disaster management efforts over the last 30 years. In a recent WHO survey report, 85% of the ministries of health globally have policies or programs related to disaster preparedness.[27] In Latin America and the Caribbean region, all countries with more than 20 million inhabitants have a formal disaster agency within the ministry of health and a national disaster coordination office.[28,29] The agency within the ministry of health is the designated entity for protecting health from the consequences of disasters. The national disaster coordination office's mission is to ensure the synchronization of all governmental disaster reduction efforts and to promote preparedness and risk reduction responsibilities across all sectors, such as a federal emergency management agency or other organizations that provide civil protection.

Although these figures represent a major step forward in national preparedness, the sustained improvement in quality and institutional continuity of these offices still relies on the frequent occurrence of disasters. In fact, the rate at which disasters occur has a substantial impact on institutional development of these agencies. Just as these national disaster programs and offices were established or significantly strengthened as the consequence of a disaster, they have also experienced reductions in their capacity or disappeared entirely when disasters do not occur for prolonged periods. This tendency has been noted in both wealthy and developing countries. In the latter, a change of government is another common reason for reducing the disaster preparedness investment or for assigning new personnel with no experience to these offices.

The absence of a disaster in such countries is a threat to institutionalizing preparedness and changes the nature of the roles and functions of these offices. With time, these agencies focus increasing attention on smaller events. When a government institution attends only to smaller emergencies, it loses its perspective and hence its capacity for cross-cutting coordination – its main function. Over time, the institution will isolate itself from other administrative entities and it will lose its close relationship with the top authority.[30]

On the international scene, similar progress and challenges exist. In 1974, the international community made a significant commitment with the creation of the UN Disaster Relief Organization (the precursor entity to the Office for the Coordination of Humanitarian Affairs [OCHA]) as a way to improve the international response to disasters. The reaction to the 2004 tsunami in Southeast Asia clearly showed that OCHA and many other agencies could successfully deliver aid, but also suggested that a stronger mechanism is needed to make the international response more efficient. Establishing a mechanism that attracts and coordinates more UN agencies (as is intended by UN humanitarian reform efforts) is an important step, but remains insufficient on its own.

Even in an ideal situation, in which all UN agencies and major NGOs agree to coordination using a single unified command structure, planners could not guarantee the most effective response. Instead, the efficiency of international assistance is mostly dependent on the recipient country's capacity to absorb, coordinate, and distribute the deluge of resources that could reach the affected population. Any international response effort that is not strictly and exclusively complementary with the national response will result in competition with, and disruption of, the country's relief activities. In other words, the best international humanitarian response is the one that complements the local response. The only exception to this is when no local organization exists or when the local authority is the reason for the chaos, such as in some complex public health emergencies (see Chapter 24). Even in those rare situations, when the local population relies primarily on an international response, the objective must remain to rebuild the local response capacity that existed before the disaster. International assistance cannot be considered successful if the recipient country is left with minimal institutional capacity when support is withdrawn.

Institutionalization of Knowledge

Three decades ago, disaster-related issues were viewed simplistically, primarily guided by the lack of resources and the limited number of professionals in the field. The decision-making process was also less complex, because those issues that could be addressed were solved quickly and efficiently because few people

Table 4.4: Sample List of International Disaster Medicine Journals

Publication	*Sponsoring Institution or Society*
Japanese Journal of Disaster Medicine	Japanese Association for Disaster Medicine (first published in 1996)
Prehospital and Disaster Medicine	World Association for Disaster and Emergency Medicine, editorial offices in the USA (first published in 1985)
Disaster Medicine and Public Health Preparedness	American Medical Association (first published in 2007)
International Journal of Disaster Medicine	Published by Taylor & Francis, editorial offices in Sweden (first published in 2004)
American Journal of Disaster Medicine	American Society of Disaster Medicine (first published in 2006)
Annals of Disaster Medicine (web-based journal)	Taiwan Society of Disaster Medicine (first published in 2002)

were involved. Today, with the availability of more human and financial resources, institutions are compelled to both raise and respond to more complex issues. As a consequence, this expansion of the field requires a lengthy and more sophisticated consultation process, through networks of various professionals and professional associations.

The knowledge base for the field of international humanitarian assistance increases everyday. This explosion of information is reflected not only in the number of experts in the field, but also in the number of related scientific and technical publications. A few examples are listed in Table 4.4. The U.S. National Library of Medicine has inventoried more then 30,000 publications related to disasters.[31] Disaster management, however, is still a relatively new field, and the majority of the technical "knowledge" is derived from anecdotes and personal experiences, rather than from scientifically rigorous studies published in peer-reviewed journals. Some information centers such as the Regional Disaster Information Center[32] have been compiling an inventory of gray (nonpeer reviewed) literature. More than 15,000 publications are now accessible on the web without cost through this resource.

Within emergency medicine, formal education and certification in disaster-related fields is also developing. The Department of Emergency Medicine at the University of Paris, France, in collaboration with the Paris Fire Brigade, introduced a "Capacité de Médecine de Catastrophe" in 1981. The name of the certificate (capacité), although a postgraduate diploma, clearly indicated it was not meant to be a specialty (Landstinget I Östergötland KMC. Personal communication).[33] This capacité was later organized in other French-speaking countries, such as Morocco. The European Center for Disaster Medicine was founded by the Council of Europe in the aftermath of earthquakes in southern Italy that occurred during the early 1980s. Since 1989, the Center has organized courses on emergency and disaster medical response, targeting mostly an Italian audience, but also countries from the Mediterranean basin. In the U.S., Johns Hopkins University in Baltimore, Maryland and the then Center for Disease Control (CDC) organized international workshops on earthquake injury epidemiology that mainly focused on mitigation and response.[34] Several other U.S.-based universities have developed postgraduate programs for trained emergency physicians. For example, in 2006, the University of California at Irvine founded its Emergency Medical Services and Disaster Medical Sciences Fellowship, a 2-year program that includes completion of a Masters degree.[35] Another example of postgraduate training is at the University of Linkoping in Sweden where they collaborated with the regional health authorities and founded a Center for Teaching and Research in Disaster Medicine and Traumatology. The Center introduced a certificate in Disaster Management, which subsequently was offered to international students. The university continued to expand its educational portfolio and in 2006 granted its first Doctor of Philosophy in disaster medicine.

In addition to individual institutions offering advanced degrees, international consortia of universities now exist creating a global educational effort. One example is a program initially developed in Europe called the European Master in Disaster Medicine (EMDM). In 1998, at the European Society for Emergency Medicine's first European Congress, organizers discussed the idea of an education platform for Disaster Medicine. The European Center for Disaster Medicine had offered training in Emergency and Disaster Medicine since 1989. Similarly, the Department of Emergency Medicine at the Catholic University of Leuven, Belgium had taught a postgraduate course on disaster medicine and management since 1988, in collaboration with the Medical Service of the Belgian Armed Forces. Integration of these two courses led to the establishment in 2001 of an educational program in which students could obtain a European Master in Disaster Medicine certification. All partners agreed that this certificate was meant to acquire the status of a university diploma, as soon as requirements listed in the European Directives on Higher Education were satisfied. In 2004, the diploma designated as the European Master in Disaster Medicine was established as a second level master's degree, (a master's degree obtained by an individual already holding a master's degree or equivalent), according to the Directives of the European Union. The two sponsoring organizations are the University of Eastern Piedmont, Vercelli, Italy, and the Free University of Brussels, Brussels, Belgium. The diploma is issued by the University of Eastern Piedmont on behalf of both universities. Subsequently, several institutions in the United States have formally affiliated with the EMDM and supply faculty; these include Harvard, Yale, and the University of California at Irvine.

The EMDM program emphasizes concept development and strategic thinking, with less weight placed on operational training. The basic content is offered in a modular format and the modules address all subjects commonly classified under the terms "disaster medicine" and "public health." The design of the EMDM consists of an electronic textbook with problem-based interactive simulation exercises, delivered via the Internet. This distance-learning component is combined with a residential session, a master's thesis, and a final examination also administered over the Internet. Student evaluation is continuous.[36] Due to the format chosen (Internet), the student population (between

Table 4.5: Global Cluster Leads

Sector or Area of Activity	*Global Cluster Lead Agency*
Agriculture	Food and Agriculture Organization
Camp Coordination/Management:	
Internally Displaced Persons (IDPs) from conflict	United Nations High Commissioner for Refugees
IDPs from disaster situations	International Organization for Migration
Early Recovery	United Nations Development Program
Education	United Nations Children's Fund Save the Children (in the United Kingdom)
Emergency Shelter	
IDPs from conflict	United Nations High Commissioner for Refugees
IDPs from disaster situations	International Federation of Red Cross and Red Crescent Societies
Emergency Telecommunications	United Nations Office for Coordination of Humanitarian Affairs/United Nations Children's Fund/World Food Program
Health	World Health Organization
Logistics	World Food Program
Nutrition	United Nations Children's Fund
Protection	
IDPs from conflict	United Nations High Commissioner for Refugees
Disasters/civilians affected by conflict (other than IDPs)	United Nations High Commissioner for Refugees/United Nations Office of the High Commissioner for Human Rights/United Nations Children's Fund
Water, Sanitation, and Hygiene	United Nations Children's Fund

Source: www.humanitarianreform.org

25 and 35 a year) is international in scope. Total enrollment to date represents all five continents and more than 50 countries. Although the EMDM is European, as it is based on European Directives and the title is issued by European Universities, it is global as far as the faculty and the students are concerned.

Broadening the Approach to Include Multiple Institutions

The central premise of health disaster response and risk reduction is management of resources for a *population's* health, as opposed to therapeutic measures applied to individual patients in an emergency medical situation. Not surprisingly, disaster response, preparedness, and vulnerability reduction rely not only on a multiplicity of institutions within the health sector (e.g., the ministry of health, the Red Cross and Red Crescent societies), but also require resources administered by organizations outside of the healthcare field. Involvement of other sectors including national disaster coordination entities, financial institutions, military, fire brigade, and meteorological centers is essential. However, determining the entity that can and should coordinate these multiple organizations remains the challenge.

Several countries have attempted to shift the national responsibility for disaster preparedness to agencies outside the ministry of health; however, marginalizing the ministry of health's role in disaster response has catastrophic results. It eliminates the health institutions' ownership of the process and creates an unproductive competition with entities outside the health sector. Experience has shown that the health sector must maintain a coordination function, as a complement to the national disaster coordination system.

The humanitarian reform movement has generated the concept of dividing humanitarian assistance into several topic-specific groups called clusters. Under this approach, one UN agency has been assigned to lead each cluster, as described in Table 4.5.[37] Although this approach has great advantages from a management perspective, it also raises new challenges as health-related topics such as nutrition, water quality, or sanitation are split among different clusters. Multiagency coordination at the international level must continue to be improved.

RECOMMENDATIONS FOR FURTHER RESEARCH

Striking the Appropriate Balance between International Response and National Preparedness

International institutions continue to improve their disaster response capabilities, and that rate of improvement could increase if another mega disaster occurs, such as a large tsunami. New mechanisms resulting from the humanitarian reform movement, such as the cluster approach, and new sources of funding like the UN Central Emergency Response Fund are signs of progress.[38] These and other developments are likely to stimulate further advances in international disaster response programs. However, coordination among multiple international responder entities remains a challenge. Another area of concern is that improving international institutional response capability will only be successful if the level of individual countries' national preparedness improves simultaneously.

In contrast to response efforts, national disaster preparedness receives much less international attention. The perceived failures in response coordination have been more visible than the contributing effects of inadequate national preparedness. As a consequence, analysts focus more on response issues when discussing deficiencies in disaster management. The conclusions that misattribute all the problems with disaster relief activities to failed response efforts frequently result from a lack of proper analysis. Although many failures in disaster response coordination exist, the root cause is primarily due to the lack of support for preparedness activities prior to the event.

This situation is of particular concern because disaster preparedness is the most efficient way to improve disaster response. Effective preparedness is also the only way to ensure cost-effective mobilization of national resources and cost-effective international assistance. Focusing on pre-event preparedness is a more challenging approach because the international community has no control over planning efforts of individual countries, and these nations must juggle the competing priorities of daily emergencies with planning for the "what if." In the long run, however, it is the only possible solution for true improvement in disaster management.

Strengthening Emergency Medicine

Progress is possible, as is exemplified by a WHO document produced during the Sixtieth World Health Assembly on May 23, 2007, which emphasizes improvements in national disaster preparedness. The document, entitled "Health systems: emergency-care systems," recognizes that "improved organization and planning for provision of trauma and emergency care is an essential part of integrated health-care delivery, plays an important role in preparedness for and response to mass-casualty incidents, and can lower mortality, reduce disability, and prevent other adverse health outcomes arising from the burden of everyday injuries." In addition, the document urges member states to assess comprehensively their prehospital and emergency care systems with regard to identifying unmet needs; ensuring involvement of ministries of health; establishing integrated emergency care systems; monitoring performance as a solid basis for ensuring minimum standards for training, equipment, infrastructure, and communication; ensuring that appropriate core competencies are part of relevant health curricula; and promoting continuing education.[39]

Improving Donations and Countering Disaster Myths

Appropriate handling of international donations remains an unresolved issue. At a conference in 1986, the main NGOs, government representatives, and UN agencies agreed on a set of recommendations for appropriate international humanitarian assistance.[15] Although these recommendations have been widely published and have been implemented by a small number of agencies, these guidelines are still not commonly practiced.[40] Presently, there are still large quantities of mostly useless supplies, sent at a high cost, that arrive too late to be beneficial following a disaster.

The types and quantities of humanitarian assistance donations are largely determined by the needs of the donors rather than by those requesting aid. Donations are still motivated by the horror of images on a television screen, rather than the sudden pressing needs of the affected population. To move toward resolving the problem, an international information campaign to educate the public and the media on ways to make appropriate donations is urgently needed. Improving the quality of donations will require further research investigating ways to change the public's behavior and perceptions and will need to align incentives with institutional donors.

Instruments exist that provide more transparency in the management of humanitarian supplies. In the early 1990s, the Humanitarian Supply Management System was developed as a joint effort of Latin American and Caribbean countries, with the technical cooperation of the PAHO. In 2004, the interagency Logistic Support System (LSS) was created to expand the experience of the Humanitarian Supply Management System in the Americas while building a global interface that serves agencies, NGOs, and donors, as well as countries. LSS was developed jointly with OCHA, the World Food Program, the United Nations Children's Fund, WHO, PAHO and the United Nations High Commissioner for Refugees, and is the most advanced example in the field.[41] This free instrument enables all users, both agencies and governments, to capture information on all humanitarian supplies received for the same disaster. This software enables the coordinating entity to collect and track the quantity of pledged and received donations. It complements existing tracking systems (systems designed to track supplies managed by one institution from the point of reception to the point of distribution). A large number of domestic disaster agencies have used the LSS software; however, this management tool and others similar to it are still rarely utilized by international relief agencies. This challenge of managing donations is likely to remain unresolved until public opinion demands that the international community be held as accountable as national governments.

The issue of appropriate donations is only one of the recurring concerns identified more than 20 years ago as disaster myths and realities.[16] Each of these seven notorious myths (see Table 4.3) requires further study to analyze why they persist and suggest new potential solutions to counter them.

Improving Knowledge Discovery

A systematic analysis of large disasters would be an effective technique to gain knowledge from previous experiences and many organizations have attempted to adopt this methodology. One problem is that only a few large-scale disasters (events that overwhelm national capacity) occur. Therefore, a systematic analysis at the institutional or even at the country level is problematic because the limited number of events makes it difficult to draw meaningful conclusions.

A second challenge is the difficulty in obtaining an impartial analysis. Many post-disaster analysis exercises are limited to providing success stories, and few address the issues that require change. No real progress can be expected without a scientific and objective evaluation of a disaster's management.

Finally, a method is needed to incorporate this information permanently into the growing body of knowledge in the science of disaster public health and medicine. Otherwise, this information will be lost as those who "learn" it retire or change jobs. The fact that the same issues are identified again and again demonstrates that these recommendations have not been incorporated by institutions and universities into the growing body of science. The commonly used term "lessons learned" is problematic as it implies that this information is gained on a personal level (as when a child discovers that touching a hot object hurts) and not incorporated into an expanding permanent record. More appropriate terms for the results of these exercises would be "issues for action," "outcomes identified" or "new knowledge discovered." Research centers have a responsibility to collect these identified outcomes, retain them, and make them accessible to professionals in the field and the public at large. Endeavors by universities such as those sponsoring the EMDM, or institutions offering postgraduate degrees in health disaster–related topics are changing this pattern but more work must be done. This methodology offers the only real long-term solution for disaster coordination entities and international humanitarian agencies to absorb this knowledge into their operations and policies.

Strengthening the All-Hazard Approach

Previously unrecognized hazards, events, and threats are becoming national or international concerns. For example, chemical intoxication from dumping sites in Cote D'Ivoire, hemorrhagic dengue in Paraguay or Africa, severe acute respiratory syndrome in Asia, and the threat of bioterrorism are among the types of challenges that have recently justified declaring a national emergency. This trend is likely to increase and become more complex in the future. Experts from various specialties would have responded to these same disasters 10 years ago, but such events would not have attracted a great deal of political attention. Now, even incidents with smaller numbers of deaths or with the mere potential to threaten neighboring countries have become events of international interest. The disclosure of threats is expected to further increase because countries must now report all public health events with international implications under the International Health Regulations procedures.[3]

With the recognition of each emerging threat, the tendency has been to create a new mechanism at the national or international level to address it. Bioterrorism and pandemic influenza are among the recent examples. Addressing each hazard with a separate and unique mechanism, project, or agency is not sustainable. Such an approach weakens the existing coordination mechanisms by establishing parallel systems. One solution is implementation of a comprehensive all-hazard approach to managing threats. This would stimulate countries to revisit and strengthen their existing national disaster coordination system each time a new threat is perceived, rather than creating another separate strategy. This strategy would initiate responses from both national and international systems during major crises, increasing interagency contact and enhancing mutual trust between all organizations. This all-hazard approach is logical but not yet widely recognized. The United States is one of the countries that has officially embraced an all-hazard strategy. To promote a better understanding of this methodology, further identification and refinement of the essential disaster components associated with these events is required.

Toward Stronger Interagency Cooperation

Due to the increasing number of specialized disaster-related topics and the diversification of players in the humanitarian assistance field, it will be increasingly difficult for one entity to address sufficiently the multifaceted needs of disaster response and risk reduction – even in a specific sector. To be relevant, institutions will need to further specialize while simultaneously striving for stronger interagency cooperation.

Entities representing regional organizations, such as the Asian Development Bank or African Union, and subregional intergovernmental agencies, such as the Andean Committee for Disaster Prevention and Assistance, will become increasingly relevant and dually supported by national governments and donor countries. These groups, however, should maintain a limited scope and address the challenges of interconnectedness with a mosaic of partners. To be efficient, each entity must identify its unique valued-added specialty within the global village environment. In contrast, entities involved in improving global response processes must better recognize regional or subregional processes, and most importantly, include national systems in all of their considerations.

Addressing Climate Change and Security

Significant progress has occurred in risk identification, stemming mostly from the analysis of previous disasters. Based on data from 1980 to 2000, the United Nations Development Programme produced the Disaster Risk Index and Analysis Tool (http://www.undp.org/cpr/disred/english/wedo/rrt/dri.htm) to enable "the calculation of the average risk of death per country in large- and medium-scale disasters associated with earthquakes, tropical cyclones and floods . . . It also enables the identification of a number of socio-economic and environmental variables that are correlated with risk to death and which may point to causal processes of disaster risk." In addition, a 2005 World Bank publication (http://www.worldbank.org/ieg/naturaldisasters/maps/) identifies "hot spots" or high-risk geographic regions in vulnerable countries where mitigation efforts can be directed.

New threats, such as the advent of climate change and its implications for disaster medicine, oblige relief organizations to revisit the concept of risk analysis. The 2003 heat wave, which is estimated to have killed approximately 15,000 persons in France, took Europe largely by surprise. In comparison, the threat of pandemic influenza has been much better anticipated. It is clear that efficient disaster management programs must guide their actions not only based on past experiences but also on future projections.

The concept of security is currently limited to discussions between northern hemisphere specialists. Developing countries remain more preoccupied by historically prevalent conditions rather than by lower probability "potential" threats. Bioterrorism and pandemic influenza are mostly overlooked in countries where they are not present today. This may likely change in the medium term.

Security threats and climate change are examples of recently emerging challenges. In the near future, disaster agencies will require tools that can assist them in recognizing and anticipating such potential risks. The methodology for identifying the risks a country is likely to face (mostly perceptions, based on probability analysis assessing rate of occurrence and magnitude of impact) is incomplete and must await future investigations. Once established, however, this methodology will allow disaster entities to switch from a reactive attitude (based on probability of past events) to a proactive stance (based on perceived risks in the future). This would be a much more scientifically valid method to focus disaster mitigation and preparedness efforts.

A Stronger Scientific and Professional Approach

Historically, disaster preparedness and risk reduction have been based on a nonscientific common sense analysis of past events. As new resources become available, a more scientific approach is required to address important issues such as a country's degree of preparedness. At present, there are no internationally recognized standards for estimating either a country's or an institution's level of readiness. Research focused on establishing benchmarks for the assessment of preparedness is necessary. The WHO Office for Southeast Asia has developed a framework of 12 national disaster preparedness benchmarks. These are associated with a corresponding set of standards and indicators that elaborate the best practices to facilitate political commitments through a uniform framework for planning and evaluating emergency preparedness actions for the countries of Southeast Asia.[43] Baseline surveys measuring progress in a region are necessary to provide a gauge for further growth and compliance with such benchmarks.[44] Other areas that would benefit from scientific inquiry include identification of where disaster preparedness and risk reduction programs are needed and the essential elements that comprise a national disaster management policy.

Scientific and professional organizations must be involved not only in the investigation of the aforementioned topics, but also in lending expertise in response to issues raised by disaster management personnel. Future progress requires that research centers and academic entities propose scientifically rigorous methods to study, analyze, and respond to present challenges. Therefore, universities and professional associations must be included as partners in the disaster preparedness field. Some of these professional societies exist; however, thus far most are in emergency medicine. These include the World Association for Disaster and Emergency Medicine, the European Society for Emergency Medicine, the American Public Health Association, the Australasian College of Emergency Medicine, and the American College of Emergency Physicians. Still, more professional associations should be encouraged to participate.

Determining precise definitions remains a problem due to the multiplicity of expertise involved in this field. More deliberation will be required to move beyond the current multitude of existing classifications and reach agreement on internationally accepted definitions. For example, the International Strategy for Disaster Reduction has proposed some excellent definitions of disaster risk reduction terminology;[45] however, too few entities regularly accept and utilize these definitions. Instead, they promulgate their own systems. Standardizing terminology would improve communication among sectors.

Research techniques will develop in new and innovative ways. The challenge imposed by difficulties in performing prospective investigations can be partially overcome through sophisticated simulation of disaster events. Simulation template models allowing experimental changes of environment, preparedness level, and response capabilities may serve as platforms for research and produce performance and outcome indicators. They may allow comparison of different scenarios and quantify the results of interventions in the environment, vulnerability, and preparedness without creating risk to populations and care providers.

In this field, the tradition of using simulation exercises has continued to evolve and now has the ability to address massive public health problems. One such example is the U.S. "Top Officials" simulation exercise, referred to as "Top Off." This full-scale simulation was the largest and most comprehensive terrorism-response exercise ever conducted in the U.S., involving multisectoral and multistate participants.[46] The ConvEx simulation exercises, coordinated by the Inter-Agency Committee for the Response to Nuclear Accidents, test and evaluate the international emergency management system. They identify best practices, deficiencies, and areas requiring improvement that could not be detected in national exercises.[47] Sometimes these simulations precede real events (mass gatherings where there is a risk of disaster), such as the simulations conducted for the Cricket World Cup in the Caribbean in 2007. These types of simulations are considered one-time events and frequently do not include evaluation or continuity parameters to build cumulatively on previous exercises.

Another example of using simulations to improve disaster preparedness is the I SEE (Inter-active Simulation Exercise for Emergencies) project, financed by the Leonardo da Vinci Agency of the European Union. The goal of this endeavor was to develop an electronic platform and a pilot exercise for the team training of all the participants involved in disaster response management. The project involved a collaborative effort of universities and educational institutions from five European countries (Belgium, Italy, Romania, Spain, and Sweden) and started with a survey on the educational needs of 206 teaching institutions, providing different levels of education, from these five countries.[48] Project design was based on the survey results and followed by system development, formative evaluations, refining and retuning of the product, and development of a policy for implementation.

The I SEE project ran from October 2004 through September 2007. It was developed primarily as a research project to evaluate training methodologies in disaster medicine.[49] In the future, however, it may evolve into a tool for studying decision making, preparedness, and logistics, as the template allows customization of the exercise environment and scenario.

Improvements in disaster management will continue at a greater rate and more publications on health disaster management will appear. Subsequently, this expansion of information will require more intense participation of information centers. In the near term, the gray literature will remain among the best sources of information. New initiatives must be encouraged, especially in lower-income countries, which do not have ready access to or appropriately consider peer review as part of their daily operations.

Reconstruction

Increasingly, reconstruction following disasters has been included as part of humanitarian assistance and mostly funded by emergency budget lines. The issues that arise during reconstruction, although similar to the acute aspects of risk reduction, are not lifesaving time-related decisions, but rather must be approached using a more deliberate and orderly process. Expertise is required of developers and planners that is unrelated to that for the decisions required for immediate disaster risk reduction. As such, it may not be optimal to have humanitarian assistance personnel involved in reconstruction.

Similar to the long-term aspects of risk reduction, humanitarian specialists should remain in the advocacy role and permit development specialists to supervise reconstruction. If the initial response and rehabilitation phase must be under the leadership of humanitarian specialists, the long-term reconstruction efforts should be the responsibility of development professionals.

CONCLUSIONS

Disaster management has been a thriving global field for the last 30 years and remains a very promising area of specialization. In a short period of time, the discipline has evolved from using an ad hoc emergency response approach to a more comprehensive preparedness, mitigation, and risk reduction approach. Presently, disaster management is at a critical point; it must move from utilizing a "common sense perspective" in analyzing disasters to one involving more systematic, scientific, and professional methodologies. Investment of additional resources is necessary to reach these objectives.

Disaster myths identified more then 20 years ago still persist, such as the ineffective manner in which donations are appropriated. These myths represent important areas for growth as they involve fundamental principals of disaster management. Although these issues have been identified and described over the years, they remain an ongoing concern.

The main risk for the future is that the importance of national preparedness will be minimized. Although there is still the need for a global response to disasters, it must be based on national coordination to be successful. Strong national coordination capacity is the best investment the international humanitarian community can make because it is the most effective way to ensure that international assistance is efficiently used. In addition, it preserves the function of local organizations and leaves behind a positive image among the assisted population.

Witnessing the significant negative impact of disasters on human life provokes a great deal of public sympathy. Often, the need to respond to such events seems overwhelmingly important. As such, the disaster response component of the overall disaster management strategy seems most significant. Hence investment in improving disaster response capabilities has seemed to be the appropriate answer. The last 30 years of disaster management indicate that preparedness and risk reduction play even more important roles than the response phase. A real improvement in response to disasters will only be possible when additional resources are invested prior to the event, rather than when it is already too late to make a real difference – when victims already exist.

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5

Ethical Issues in Disaster Medicine

Gregory Luke Larkin

OVERVIEW

Disaster situations present numerous moral and ethical challenges at the micro, meso, and macro levels. These dilemmas embroil not only patients and their providers, but they also involve a variety of stakeholders outside the doctor–patient dyad: peers, provider organizations, the press, the general public, payers, policymakers, politicians, public health leaders, and even corporate interests in the private sector. This group of moral agents may be considered the “Ten Ps” (Table 5.1).[1] The principles and concepts in this chapter are relevant to all candidate stakeholder and disaster organizations as well as individuals. This chapter first acknowledges the spectrum of medical–ethical and moral problems inherent in disaster preparedness and response, while focusing primarily on those that impact healthcare workers as individuals working in the trenches. After exploring some of the disaster-relevant bioethical principles and codes of conduct, it describes the fundamental virtues that inform ethical decision making in clinics, hospitals, and emergency departments and in the field in the immediate aftermath of a disaster.

CURRENT STATE OF THE ART

The Spectrum of Disaster Dilemmas

Although thoughts of disaster ethics generally conjure up visions of distributing life vests on a sinking Titanic, there are many other less dramatic examples of ethical challenges that confront the clinician working in the wake of a catastrophe. The broad array of potential ethical dilemmas in a disaster situation is vast and involves both individual and corporate actions. For example, providers may face ethical dilemmas when working as agents of individual patients, within hospitals, as members of medical response teams, as public health providers, in incident command centers, with nongovernmental organizations (NGOs), and as local or global volunteers with such entities as the U.S. Medical Reserve Corps or Médecins Sans Frontières (Table 5.2).

The ideal resolution to any given dilemma is also determined along a spectrum that is both time and situation dependent. An earthquake registering 7.0 on the Richter scale in Kabul, Afghanistan may create different challenges than an earthquake of similar magnitude in Los Angeles. In addition to differences of setting and culture, varying legal, political, and economic norms and values make any overarching description of disaster duties and rights challenging. Like etiquette itself, disaster ethics is sometimes subject to the particularities and practicalities of different baseline economies, governments, cultural norms, and religious contexts that impact how moral values and community goals are used to weigh alternative disaster responses or prioritize particular preparedness policies.

Although it would seem impossible to address every potential disaster conflict and ethicolegal situation herein, an overall approach incorporating key concepts can illuminate ethical conflicts regardless of the setting or disaster situation. The balance of this chapter provides an underlying moral framework for analyzing ethical challenges that can be applied in a given disaster context or circumstance. To provide such a framework, extant theories of ethics that are applicable to medicine more generally and disaster medicine, in particular, are first described. To be solvable, dilemmas require careful consideration and understanding of key ethical principles, codes of ethics, and virtues that together form a quantum of guidance, a common denominator across the moral quotient. Once these moral tools are understood, they can be applied and prioritized to minimize harm and maximize positive outcomes based on the particular values and exigencies of a given disaster context.

THEORIES OF MEDICAL ETHICS

Bioethics is the modern extension of philosophical ethics applied to the life sciences, rising to prominence in the decades after the World War (WW) II Nazi war crimes were exposed at Nuremberg.[2] Today, one of the most common and arguably the most popular bioethical theories in developed western democratic societies is the application of ethical principles or *Principlism*.[3] Under the influence of this theory, three bioethical principles have dominated clinical decision making within the confines of the doctor–patient relationship (Table 5.3).

Table 5.1: Stakeholders in Disaster Ethics: 10 Ps

1. (Individual) Patients
2. (Individual) Providers
3. Provider groups/peers/remote disaster response teams
4. Provider organizations/Local volunteer healthcare providers
5. Public health
6. Policymakers/Politicians
7. Payers/Insurers
8. Private sector/NGOs
9. Press/Mass media
10. Populace/General public

These principles, first articulated by Beauchamp and Childress in the United States, could ideally inform most individualized, everyday, micro-level doctor–patient interactions. Such principles are common tools of bioethics consultants who have time to deliberate on ethics consultation services for days and even weeks on individual cases of institutionalized patients, deciding for example, whether patients such as Karen Ann Quinlan (1954–1985) or Terri Schiavo (1963–2005) may be taken off ventilators while in persistent vegetative states.[4,5] Ranking the relative merits of the principles takes considerable time in a given clinical situation; however, opportunities for reflection on competing principles are rare in disaster contexts, making Principlism problematic.

The Disaster Context

In contrast to day-to-day bioethics practices, true disaster situations are frequently characterized by a relative lack of time as well as other resources; hence, one does not generally have the luxury of ethicolegal consultation or time-intensive deliberation. Although the trinity of aforementioned bioethical principles still applies in extreme situations of austerity, their relative weights and priorities change dynamically both within and between different types of disaster events. Disaster magnitude, and the aforementioned setting, resources, population, culture, and expertise also play roles in how the principles of bioethics apply. The southeast Asian Hmong population, for example, does not value the principle of respect for individual autonomy in the same sacrosanct sense as either the European or African American population.[6] The Hmong value community and traditions in ways unknown to most other cultures and yet, similar to many other immigrants, they have now settled in several large cities in the west. Beyond multicultural concerns domestically, disasters frequently occur in far-away places with diverse populations and societies with different priorities and worldviews than many of the would-be healthcare worker respondents from abroad.

Beyond multicultural concerns, it is vital to remember that mass casualty events easily threaten the ethical underpinnings of routine, individualized, and patient-centered healthcare. Workers, who only moments earlier may have been seeing three patients per hour, can instantly find themselves working in a sea of casualties where they must contend with basic lifeboat issues of triage, quarantine, system overload, and the thornier determinations of who will be given every chance to live and who will be allowed to die.

Distributing Scarce Resources: The Prominence of Justice

Disasters disrupt the normative functioning of civil society in general and impact the usual supply of healthcare goods and services in particular. Additionally, mass casualty events intrude on everyday principles of bioethics and their focus on individuals, thereby requiring the entry of a fourth, population-based principle into the bioethical calculus: *justice*. Justice has been famously described by the late Harvard Law professor John Rawls (1921–2002) as a relative fairness in the equitable (not equal) distribution of resources, according to relative need.[7] Disasters frequently redraw both the geographical and the bioethical landscape, lessening somewhat the importance of individual patient autonomy in deference to population health and the often-competing interests of multiple parties. The entry of justice into the conversation does not negate the relevance of beneficence and nonmaleficence; however, proportion and fairness matter a great deal when survival is threatened on a large scale. For instance, the ordering principle on the rubble of a Pakistani earthquake may be that of distributive justice whereas the first consideration in a modern intensive care unit 5 weeks after an earthquake may be nonmaleficence (avoiding harm).

Justice – Only a Partial Answer

Although an important guide in settings of resource scarcity, justice alone does not solve the problems of caring for whole populations in disaster situations. In fact, a misapplication of justice would demand that patients with the greatest need (expectant and moribund) are therefore deserving of the most resources just because they are so needy. Not so. Although platitudes of "everyone gets a fair share" or "treat all the same" sound reassuring, egalitarian arguments have a relatively small role in the ethics of disaster planning and response at the macro level. Severely ill and injured patients, such as those in cardiopulmonary arrest for example, should receive neither equal nor equitable treatment as doing so during a disaster can be expected to result in wasting needed resources for salvageable others. Heroic attempts to save lives in futile cases squander time, supplies, safety, and frequently entail huge opportunity costs; therefore, extraordinary attempts to save life must generally be discouraged. Disasters may leave many dying (expectant) patients in their wake who cannot be justly saved. Expectant status is itself a moving target, depending on shifts of contingent material, human, and intellectual resources over time. Hence, any Rawlsian notion of justice that gives the least advantaged top priority as a matter of routine is fraught with difficulty. An omnibus and functional ethical theory must be expandable to incorporate considerations of overall population needs within the disaster context; maximizing global goods and minimizing global harms is one consideration.

Triage and Rationing: Greatest Good for the Greatest Number

Disasters' greatest challenges revolve around the need for triaging and rationing to maximize population outcomes. Classically, the guiding ethic is one of *utilitarianism*. Famously described by the English philosopher Jeremy Bentham (1748–1832), utilitarianism underlines the notion of providing the greatest benefits to the greatest number to maximize human felicity or happiness.[8] Bentham's student and acolyte, John Stuart Mill (1806–1873),

Table 5.2: Ethical Challenges in Disaster Medicine

Provider–Patient (Micro) Level

1. Care of anxious, hypochondriacal, or "walking-wounded" patients who request extra care
2. Defining "expectant" and other triage categories within a dynamic situation
3. Balancing palliative care needs of expectant patients amid family requests to "do everything"
4. Care of noncitizens, foreigners, military, prisoners, or perpetrators of terror or other disasters
5. Prioritizing care of "VIPs," civil servants, leaders, military, blood relatives, friends, and healthcare personnel
6. Maintenance of privacy in the midst of crowding, surveillance, quarantine, and mass media "right to know" pressures
7. Reporting and surveillance requirements that impact individual patient liberty, confidentiality, and privacy rules
8. Conducting academic research and procuring informed consent from disaster-exposed patients under duress
9. Treating victims who are contaminated or contagious, or working in an environment with other potential safety threats to the individual provider's health
10. Triaging rapidly, objectively, accurately, and ethically given limited information and time
11. Standard of care issues at the limits of surge capacity or system saturation
12. Balancing primary provider roles with roles as agents of state or public health
13. Balancing duties to individual patients with duties to preservation of self and family amid infrastructure collapse, pandemic influenza, nuclear fallout, or other personally threatening disasters
14. Role stress and temptation to push scope of practice envelope and provide heroic intervention for patients in need
15. Balancing integrity with empathy/duty to individual disaster victims seeking compensation for damages and/or disability

Provider–Provider (Meso) Level

1. Assisting colleagues, public health officials, and hospital staff – even when doing so may endanger oneself
2. Role shifts, power struggles, turf battles, and misunderstanding of social, legal, hierarchical, and teamwork requirements in and out of hospital or under incident command system
3. Dealing with provider impairment, recklessness, unprofessionalism, and absenteeism of both leaders and subordinates
4. Trainee/employee safety and physical and mental health before, during, and after terrorist attacks
5. Occupational exposure, reporting requirements, and privacy concerns
6. Optimizing communication among first responders, consultants, organizations, and healthcare provider staff at all levels
7. Conflicts of interest within and between organizations competing for local, state, or federal funding
8. Magnanimity and goodwill toward colleagues and coworkers under stress
9. Correcting overzealous providers from mistriage, over- or undertreatment, and inappropriate resource allocation
10. Addressing mental hygiene, safety, and wellness needs for oneself and other providers
11. Policies for quarantine and reciprocity for disability, lost wages, family risk, and time off work
12. Balancing recruitment of skilled labor with the threat of oversubscription and convergent volunteerism
13. Determining how a disaster response is constitutive of altruism, professional duty, or both
14. Ensuring that disaster work is recognized and fairly compensated
15. Colleagues who cover shifts for peers deployed to distant disaster sites could share in the recognition usually given only to frontline responders
16. Determining how volunteers are certified as trained, up to date, culturally and technically competent, and how they should remain accountable
17. Establishing the circumstances under which hospital and other healthcare leaders can compel personnel to report to work
18. Acceptance of more humble job assignments and duties is challenging in the absence of clear compensation, insurance, authority, or control

Provider–Society (Macro) Level

1. Determining the duties and the limits of responding to disasters, be they local, domestic, foreign, or global in nature
2. Developing organizational codes of conduct vs. unfettered laissez-faire preparedness and response ethics
3. Organizational willingness/duty to respond altruistically to disasters on a corporate level vs. duties to dues-paying members' rights and individual interests (e.g., AMA/ACEP/IFEM/WMA, NGOs)
4. Maintaining integrity amid opportunities for self-enrichment and promotion by leveraging public ignorance, fear, and paranoia
5. Ensuring justice/fairness and minimizing conflicts of interest in setting priorities for allocating resources for disaster preparedness and response
6. Duty to support/subscribe to valid preparedness exercises, disaster drills, vaccination programs, and volunteer corps
7. Prudent stewardship, e.g., cost/benefit of stockpiling drugs, new vaccine development, and widespread purchasing of personal protective equipment amid other legitimate and competing needs for resources
8. Resisting unethical reporting polices, ethnic profiling, and vilification of specific religious groups or nationalities
9. Duty to honest/careful communication of risk to federal, state and local policymakers, the media, and the populace
10. Proactive vs. retroactive promotion of evaluation and waiver of consent policies for research on disaster populations
11. Appropriating prudent economic and political support of disaster exercises, evaluation, and research (e.g., funding to competent investigators vs. funding to politically powerful)
12. Establishing transparent protocols for ethical triage and activation/maintenance/termination of disaster plans
13. Scope of practice transgressions/expertise issues (e.g., healthcare provided by nonphysicians or untrained personnel)
14. Enduring economic, health, and legal risk in the absence of reciprocity, disability, or Good Samaritan protections
15. Working domestically or abroad with limited resources while being held to a nondisaster standard of care
16. Upholding quarantine, reporting, and other public health powers legislation
17. Accountability for preventable losses and preventable health consequences of disasters
18. Attempting needed assistance amid domestic or foreign government disinterest or hostility to outside help
19. Resisting corporate opportunities to exploit victims, provider groups, governments, NGOs, and philanthropists

Table 5.3: The Three Core Principles for the Doctor–Patient Relationship

1. Respect for patient autonomy
2. Nonmaleficence (avoiding harm)
3. Beneficence (doing good)

further developed the idea of maximizing social benefits in his book *On Liberty*.[9] The underlying essence of this utility principle is central to the lifeboat challenges of disaster planning and response. Under an ethic of utility, consequences weigh more heavily than Pollyanna-like pronouncements of treating "all patients equally." Resources are parsed to obtain maximal benefit for the most people.

Disaster triage (see Chapter 12) is grounded in principles of utility and equality, suggesting that one person's survival is no greater than another person's survival. This, however, is not always the case; to maximize societal outcome, one person may be more useful to save (e.g., the President) than another. The application of utility during disasters does not suggest that human rights can be violated or that rules of human decency are not important; for example, fresh organs cannot be harvested from one unwilling but healthy patient to save five others. Triage and rationing must proceed according to the goal of helping the most people when resources are severely limited. Hence, expectant patients are provided comfort care, but allowed to die; ambulatory wounded patients wait longer than nonambulatory patients; the sickest salvageable patients (given the resource-constrained environment) are top priority, all other things being equal. It may be difficult to determine reasonably which patients are salvageable in a specific dynamic disaster environment (i.e., more resources may or may not arrive, patient conditions may change, and more patients may or may not present). Priorities are established by need and by social utility. Prejudice based entirely on creed, color, age, and sex is unethical. However, it is not wrong that patients who contribute more transparently to the functioning of society may be prioritized. Within a given strata of priority, however, time elements also matter, and a "first-come, first-served" system may be the only reasonable option in the context of contingent resources and unpredictable demand.

Maximizing benefits for the larger population of victims is a primary concern. In pandemic situations, using nonpharmacological interventions such as quarantine prioritize population health over individual liberty. As a pediatric example, late second trimester newborns are resuscitatable under optimal circumstances; however, saving 23-week premature infants in the throes of a resource-poor disaster situation may result in a lack of supplies for many other infants, children, and adults. Trying to save all when all cannot be saved is neither good policy nor good practice. Furthermore, just because someone *can* be saved does not mean that person always *should* be saved. In a nonvitalistic sense, there are some outcomes worse than death. When electricity, clean water, beds, and medicine are in short supply, utilitarian ideals necessarily inform many of the rationing decisions that must be made on the spot. Even under nondisaster conditions, resources may be inadequate. In a multiple casualty disaster situation, the justification and need for utility-based rationing is even more transparent and the cost in human and emotional terms for providers and healers who may be put in a situation where patients cannot be saved is significant.

Limits of Utilitarianism

Utilitarianism has limitations. For example, although maximizing benefits for the majority may appeal to a sense of democracy and fairness, legitimate minority concerns are easily marginalized in a utilitarian schema. In addition, some goods are more worthy of pursuing than others and some goods require a more long-term calculation of consequences. In WW II London, for example, water was a scarce resource; however, when civil servants asked Winston Churchill (1874–1965) whether a fire at St. Paul's Cathedral should be extinguished or allowed to burn in deference to needy Londoners, Mr. Churchill was clear: He opined that England could afford to lose a few of its citizenry, but if they lost St. Paul's, they would lose the will to win, and hence the war itself.[10]

Another challenge with utilitarianism is the need to weigh biases, minority interests, and competing definitions of the good to be maximized. In wartime, heads of state are responsible for millions of lives; they may need special "very important person" [VIP] treatment, despite their minority status. Similarly, healthcare workers in the frontline of a pandemic may need added protection as an especially valuable and scarce resource warranting preferential vaccination, prophylaxis, and even compensation to ensure their optimal function in guarding the health of others. A person's VIP status and social worth become material to the utilitarian sum of goods in a disaster, whereas such preferential treatment would be unethical in normal circumstances. Sometimes a rule-utilitarian would subordinate VIP interests to the short-term interests of the majority. Whether to allow a mayor to receive treatment ahead of people who have been waiting for a longer time is one such example. Utilitarianism is sometimes applied as a rule and sometimes applied according to anticipated consequences; in either case it does not always provide clear and consistent guidance. The interests of rank and file individuals may give way to the functioning of society and the overall interests of the greater population.

Another problem with unbridled utilitarianism is its application to the disabled and chronically ill. When two or more persons may be saved for the same resources needed to save a severely disabled person who will continue to consume a disproportionate share of scarce goods and services, principles of utility may lead to a total disregard of the disabled, seemingly making difficult decisions easier. Such harsh biases are inconsistent with notions of fairness and a healthcare provider's natural desire to protect first the vulnerable and those with the greatest medical needs. Utilitarian extremism can be a slippery slope and may hearken back to the horrors of Nazi Germany or ancient Sparta, in which disabled adults and infants were systematically discarded. Hence, utilitarianism can favor some groups while penalizing others. Although utility is useful for guiding disaster triage, resource rationing, quarantine, and distribution dilemmas, it has many shortcomings. Like justice, it does not provide a comprehensive solution to all ethical dilemmas before, during, or after disasters. At an operational level, advance preparation, policy, character, and Codes of Ethics can provide more guidance than theories of ethics.

Code of Ethics and Disaster Response

Optimal moral action in a disaster requires more than an understanding of utility, rationing, and triage. Beyond standard bioethical principles, codes of ethics and/or codes of conduct can help

Table 5.4: ICRC 10 Principles of Conduct

1. The humanitarian imperative comes first
2. Aid is given regardless of the race, creed, or nationality of the recipients and without adverse distinction of any kind; aid priorities are calculated on the basis of need alone
3. Aid will not be used to further a particular political or religious standpoint
4. We shall endeavor not to act as instruments of government foreign policy
5. We shall respect culture and custom
6. We shall attempt to build disaster response on local capacities
7. Ways shall be found to involve program beneficiaries in the management of relief aid
8. Relief aid must strive to reduce future vulnerabilities to disaster as well as meeting basic needs
9. We hold ourselves accountable to both those we seek to assist and those from whom we accept resources
10. In our information, publicity, and advertising activities, we shall recognize disaster victims as dignified humans, not hopeless objects

provide a moral framework that addresses at least some of the many micro-, meso-, and macro-level disaster challenges. Organizational codes of conduct are useful for disaster preparedness and planning at the meso level. Many national and local disaster response organizations, such as Disaster Medical Assistance Teams, Medical Reserve Corps, the Centers for Disease Control and Prevention, and other governmental organizations and NGOs within the U.S., lack Codes of Ethics or Conduct that guide their organizational response to disasters. Conversely, some international organizations, notably the International Committee of the Red Cross (ICRC), do promulgate ethical guidelines (Table 5.4).[11]

The ICRC Code of Conduct includes the following "Principles of Conduct for the International Red Cross and Red Crescent Movement and NGOs in Disaster Response Programmes."[11]

1) **The Humanitarian imperative comes first.**

The right to receive humanitarian assistance, and to offer it, is a fundamental humanitarian principle which should be enjoyed by all citizens of all countries. As members of the international community, we recognize our obligation to provide humanitarian assistance wherever it is needed. Hence the need for unimpeded access to affected populations, is of fundamental importance in exercising that responsibility. The prime motivation of our response to disasters is to alleviate human suffering amongst those least able to withstand the stress caused by disaster. When we give humanitarian aid it is not a partisan or political act and should not be viewed as such.

2) **Aid is given regardless of the race, creed or nationality of the recipients and without adverse distinction of any kind. Aid priorities are calculated on the basis of need alone.**

Wherever possible, we will base the provision of relief aid upon a thorough assessment of the needs of the disaster victims and the local capacities already in place to meet those needs. Within the entirety of our programmes, we will reflect considerations of proportionality. Human suffering must be alleviated whenever it is found; life is as precious in one part of a country as another. Thus, our provision of aid will reflect the degree of suffering it seeks to alleviate. In implementing this approach, we recognize the crucial role played by women in disaster-prone communities and will ensure that this role is supported, not diminished, by our aid programmes. The implementation of such a universal, impartial and independent policy, can only be effective if we and our partners have access to the necessary resources to provide for such equitable relief, and have equal access to all disaster victims.

3) **Aid will not be used to further a particular political or religious standpoint.**

Humanitarian aid will be given according to the need of individuals, families and communities. Not withstanding the right of Non Governmental Humanitarian Agencies (NGHAs) to espouse particular political or religious opinions, we affirm that assistance will not be dependent on the adherence of the recipients to those opinions. We will not tie the promise, delivery or distribution of assistance to the embracing or acceptance of a particular political or religious creed.

4) **We shall endeavour not to act as instruments of government foreign policy.**

NGHAs are agencies which act independently from governments. We therefore formulate our own policies and implementation strategies and do not seek to implement the policy of any government, except in so far as it coincides with our own independent policy. We will never knowingly – or through negligence – allow ourselves, or our employees, to be used to gather information of a political, military or economically sensitive nature for governments or other bodies that may serve purposes other than those which are strictly humanitarian, nor will we act as instruments of foreign policy of donor governments. We will use the assistance we receive to respond to needs and this assistance should not be driven by the need to dispose of donor commodity surpluses, nor by the political interest of any particular donor. We value and promote the voluntary giving of labour and finances by concerned individuals to support our work and recognize the independence of action promoted by such voluntary motivation. In order to protect our independence we will seek to avoid dependence upon a single funding source.

5) **We shall respect culture and custom.**

We will endeavour to respect the culture, structures and customs of the communities and countries we are working in.

6) **We shall attempt to build disaster response on local capacities**

All people and communities – even in disaster – possess capacities as well as vulnerabilities. Where possible, we will strengthen these capacities by employing local staff, purchasing local materials and trading with local companies. Where possible, we will work through local NGHAs as partners in planning and implementation, and co-operate with local government structures where appropriate. We will place a high priority on the proper co-ordination of our emergency responses. This is best done within the countries concerned by those most directly involved in the relief operations, and should include representatives of the relevant United Nations (UN) bodies.

7) **Ways shall be found to involve programme beneficiaries in the management of relief aid.**

Disaster response assistance should never be imposed upon the beneficiaries. Effective relief and lasting rehabilitation can best be achieved where the intended beneficiaries are involved in the design, management and implementation of the assistance programme. We will strive to achieve full community participation in our relief and rehabilitation programmes.

8) **Relief aid must strive to reduce future vulnerabilities to disaster as well as meeting basic needs.**

All relief actions affect the prospects for long term development, either in a positive or a negative fashion. Recognizing this, we will strive to implement relief programmes which actively reduce the beneficiaries' vulnerability to future disasters and help create sustainable lifestyles. We will pay particular attention to environmental concerns in the design and management of relief programmes. We will also endeavour to minimize the negative impact of humanitarian assistance, seeking to avoid long-term beneficiary dependence upon external aid.

9) **We hold ourselves accountable to both those we seek to assist and those from whom we accept resources.**

We often act as an institutional link in the partnership between those who wish to assist and those who need assistance during disasters. We therefore hold ourselves accountable to both constituencies. All our dealings with donors and beneficiaries shall reflect an attitude of openness and transparency. We recognize the need to report on our activities, both from a financial perspective and the perspective of effectiveness. We recognize the obligation to ensure appropriate monitoring of aid distributions and to carry out regular assessments of the impact of disaster assistance. We will also seek to report, in an open fashion, upon the impact of our work, and the factors limiting or enhancing that impact. Our programmes will be based upon high standards of professionalism and expertise in order to minimize the wasting of valuable resources.

10) **In our information, publicity and advertising activities, we shall recognize disaster victims as dignified humans, not hopeless objects.**

Respect for the disaster victim as an equal partner in action should never be lost. In our public information we shall portray an objective image of the disaster situation where the capacities and aspirations of disaster victims are highlighted, and not just their vulnerabilities and fears. While we will cooperate with the media in order to enhance public response, we will not allow external or internal demands for publicity to take precedence over the principle of maximizing overall relief assistance. We will avoid competing with other disaster response agencies for media coverage in situations where such coverage may be to the detriment of the service provided to the beneficiaries or to the security of our staff or the beneficiaries.[11]

The organizational model provided by the 10 Principles in the ICRC Code of Conduct addresses the critical need for objective, apolitical, culturally competent, dignified, humane, and sustainable disaster responses at both the macro and meso levels. Although the ICRC suggests an important corporate ethical posture, it does not address basic micro-level issues around disaster response, per se. For example, individual providers are often confronted with the fundamental questions: "Should I respond to this disaster by going to the scene, near or far?" "Should I stay home with my family where I am also needed?" Alternatively, the dilemma may be one in which providers' hospitals are in the eye of the storm itself, and they must decide whether to stay and work or evacuate to a safer location. For an answer to this basic "stay or go?" question, more specific ethical guidance is required.

Codes of Medical Ethics

Although the ICRC Code of Conduct may apply to NGOs and the ICRC itself, other guidance is needed for individuals serving as healthcare workers in unaffiliated organizations or working as individuals. Organized medicine has provided general ethical guidance to physicians that may be extrapolated to disaster situations. Although each disaster has its own set of moral challenges, physicians, like other professionals, operate under extant codes of conduct, both within medicine as a whole and within emergency and disaster medicine, in particular. These more general ethical principles and professional duties may provide specific guidance for disaster planning and response.

American Medical Association Code of Ethics

Inspired by John Gregory (1724–1773) in 18th-century Scotland,[12] Thomas Percival (1740–1804) penned the first modern Code of Western Medical Ethics in 19th-century England.[13] Across the Atlantic, the American Medical Association (AMA) followed suit with a similar Code of Medical Ethics, first published in 1847.[14] These codes were visionary in addressing issues of personal risk in rendering service during epidemics. In fact, the AMA Code was the first to suggest that

> When pestilence prevails, it is [physicians'] duty to face the danger, and continue their labors for the alleviation of suffering, even at the jeopardy of their own lives.

Such strong statements as this were largely unprecedented and, according to Zuger and Miles, helped formalize a sense of duty that was sustained though the following century.[15] As the threats of smallpox, polio, and related epidemics were dissolving in the 1950s and 60s, so too were heroic statements vanishing from the AMA Code.[16]

Decades later, the human immunodeficiency virus threat motivated changes in the Code that were less inspired, suggesting in 1986 that treating patients with human immunodeficiency virus was only required if the physician was "emotionally able to do so."[17] This self-serving stance was ridiculed and short-lived; within 6 months a revised statement was issued.

> A physician may not ethically refuse to treat a patient whose condition is within the physicians' current realm of competence solely because the patient is seropositive.[16]

More recently, the events of September 11, 2001 and the ensuing anthrax attacks in the United States ushered in a new "Social Contract with Humanity" adopted by the AMA House of Delegates in December 2001.[18] Within the Social Contract is a Declaration of Professional Responsibility which, like an oath, begins with a general promise followed by nine duties; the fourth obligation is reminiscent of the personal risk declaration in the 1847 AMA Code of Medical Ethics.

> We, the members of the world community of physicians, solemnly commit ourselves to:
>
> 4. Apply our knowledge and skills when needed, though doing so may put us at risk.[19]

This promise or oath is not forsworn by all physicians and many may rely instead on the AMA's enforcement of professional autonomy, found in Principle VI of the AMA Code.

> VI. A physician shall, in the provision of appropriate patient care, except in emergencies, be free to choose whom to serve, with whom to associate, and the environment in which to provide medical care.[20]

This emphasis on professional autonomy led the American College of Emergency Physicians to develop a separate Code of Ethics in 1996; this code is especially important because emergency physicians in particular do not choose "whom to serve" and are committed to open access to all who seek their services in both disaster and nondisaster situations.

The first two, and arguably, the most important Principles of Ethics for Emergency Physicians within the Code, are the most instructive.

"Emergency Physicians Shall:

1) Embrace patient welfare as their primary professional responsibility.
2) Respond promptly and expertly, without prejudice or partiality, to the need for emergency medical care."[21,22]

These guideposts underscore the need to put patients first, and to treat all patients promptly, regardless of their particular problems, contagions, viruses, or other illnesses.

Such principles from organized Emergency Medicine have, in turn, inspired more recent versions of the AMA Code to consider more seriously the notion of patient centeredness; the 2001 Preamble to the AMA Code states

> A physician must recognize responsibility to patients first and foremost, as well as to society, to other health professionals, and to self.[23]

Responding physicians understand the need to be there when others are unwilling or unable to care for victims of a disaster. Some healthcare workers, such as emergency personnel, have special training and skills that may buttress their obligations to treat those disaster victims who are acutely ill, vulnerable, and lack other sources of medical care. Although some patients may have severe acute respiratory syndrome (SARS), influenza during a pandemic, or Ebola virus, a certain level of risk taking has always been constitutive of emergency medical practice, and part of the idealized expectation of emergency medicine is to be ready, willing, and able to treat anyone and everyone who enters as a patient into the hospital emergency department.[24]

Duty to Respond: Social Contract

Public expectations of emergency- and disaster-trained professionals transcend extant Codes of Conduct, Principles of Ethics, and professional oaths, into the realm of social contracts, professional responsibility, and reciprocity. Under the social contract arrangement, physicians enjoy the status, respect, honor, and income of an autonomous profession. As a profession, physicians are accorded the rights to self-police and set the standards and rules that govern emergency and disaster medical practice. As quid pro quo, physicians are then expected by society to fulfill a certain duty or role to help those in need of their services. Emergency physicians in particular have special abilities to provide initial care to the acutely ill and injured. In some cases, public funding sources supported the development of these skills. Duties of reciprocity and solidarity suggest that physicians should give back to society by fulfilling their expected roles to treat the sick and injured, regardless of the disaster or their personal risks.

As a professional, there is a duty to report to work, including during times of disaster, unless other arrangements have been made with the employer. Despite modern trends toward unionization within nursing and medicine, physicians constitute a trusted profession that enjoys economic and status advantages that compel service in disasters; this is especially true when they comprise an explicit part of a disaster plan wherein there is a fiduciary duty to show up for work as part of an agreed institutional arrangement. Need, proximity, capability, and the lack of other responders create an obligation and duty of care that cannot be ignored; yet this obligation must be counterbalanced with the duty to future patients, coworkers, and to family and self when faced with a particularly dangerous exposure or situation. There is no duty to disaster martyrdom, or even to being a Good Samaritan, but personnel who deploy as part of organized disaster response teams have a clear duty to disaster patients, irrespective of their race, sex, religion, or underlying medical conditions. Physicians themselves benefit from this kantian duty and the reciprocal social contract as both providers and potential patients who may themselves need to depend on the willingness of other doctors to assume personal risk should they become ill or injured in the next disaster.

Although considerations of duty, principles, utility, and codes of ethics are illuminating, a more overarching ethical theory is needed that is immune to many of the variables and contingencies inherent in principlism, utilitarianism, contracts, and codes of ethics. Each specific context may defy an overly simplistic algorithm that can be applied like a cookie cutter to the meltdown of every Three Mile Island or Chernobyl. Something more than knowledge of principles, contracts, or codes is required to determine moral valence and ethical action in real-time disaster practice. That something more goes beyond ethical ideology and considers the characteristics of the doctors and other healthcare workers that make transparent, real-time, disaster decisions. That something more is *virtue.*

VIRTUE: A Transcendent and Timeless Ethic

Ethike, Greek for character, is the etymological basis on which much of classic western ethics is built. The earliest recorded depictions of character (*ethike*) or virtue (*ârete*) are found in Homer's Iliad;[25] here the heroes of the Trojan War, Hector and Achilles, are animated with an overarching quest for virtue. Homer used the Greek word *ârete* to describe not only virtue, but excellence of every kind.

> A son excels his father in every kind of ârete – as athlete, as soldier and in mind. (Iliad 20.411)

Arete has been described as those excellences or virtues that enable individuals to do properly what their roles require. Hence, the extension of *ârete* from soldiers on the ancient battlefield of Troy to an embattled disaster relief team working amid the rubble of a modern earthquake is a fitting extrapolation.

This notion of moral excellence, or virtue, was central to the ancient conception of ethics developed by Aristotle approximately 330 BCE. Under his genius, virtues became the basis of ethics for the next 2,000 years. In his famous *Nicomachean Ethics*, Aristotle asserts that the exercise of virtues is necessary to live a good and happy life.[26] Virtues are dispositions to be good, and include not only good actions, but good thoughts and feelings as well. Aristotle further described virtue or character as the golden mean between deficiency and excess; courage, for example, was described as the mean between foolhardiness and cowardice. Like Socrates and Plato before him, Aristotle also recognized that virtue must be practiced and cultivated to become a regular habit of moral behavior.

Virtue is the most ancient branch of ethics, reaching its apex 1,500 years after Aristotle's death under the teaching of St. Thomas Aquinas (1225–1274). Aquinas taught the importance of the four primary virtues (prudence, temperance, courage, and justice); he also added the theological virtues of faith, hope, and charity. To this revised list of seven cardinal virtues, St. Thomas contrasted the seven deadly sins or vices (gluttony, envy, wrath, sloth, greed, lust, and pride).[27]

Since Aquinas and the advent of modern science, medieval virtue was successively challenged in the west by Machiavelli, Hobbes, Nietzsche, Ayn Rand, and others.[28–31] Only recently, since the publication of Alasdair MacIntyre's (1929–) *After Virtue* in 1981, has there been any consideration given to reversing this trend.[32] The medical ethicists Edmund Pellegrino and David Thomasma, apostles of MacIntyre, have argued that healthcare has become too steeped in the tradition of following rules, laws, Hippocratic codes, and utilitarian practice guidelines.[32,33] Although following rules and guidelines can be useful, the classic notions of character and virtue, while often neglected, are of central importance in ensuring that healthcare professionals can fulfill their roles in promoting the interests of patients and the greater community of which they are a part.[24]

VIRTUE AND DISASTER

Asserting virtue as an essential element to the practice of disaster medicine requires accepting as a starting premise that there is an ideal toward which emergency and disaster healthcare professionals should strive. Aristotle discussed this ideal way of being as *telos*, or natural end; this *telos* is integral to the social fabric and not only individual morality.[26] Some experts assert that the *telos* or goal of the disaster professional is not merely to support legal dicta, Hippocratic principles, and disaster plans; it is also to become a good, moral, and honorable professional who genuinely cares for and about disaster victims and the societies in which disasters occur.[24]

Virtue provides an ideal model of behavior in the quest for professional excellence. Virtue is also its own intrinsic good and promises a stronger possibility for fulfillment, thereby enriching the satisfaction that healthcare providers as both professionals and members of a community, obtain from the practice of medicine. Strictly following rules, algorithms, and the status quo, by contrast, threatens to diminish autonomy and create adversarial relationships with patients, legalistic restrictions, and a morally impotent and inflexible disaster response system. Virtue can provide a dynamic solution that supports provider strengths in ways that are good for patients, professionals, and society, regardless of context.

Having trustworthy and available healthcare workers with a basic integrity and goodness of character is a moral prerequisite and central to any preparedness plan or disaster response that is both reliable and responsive to changing circumstances. Proactively selecting for "the right stuff" is an important consideration as time exigencies in the wake of mass casualty events do not allow for protracted moral reflection and ethical deliberation; thus preventive measures and a priori policies that amplify virtue and clarify expectations for ethical practice are warranted. Disaster preparedness training and related exercises must include opportunities for character and team building as well as provide guidance on optimal and ethical distribution of scarce medical resources. Fostering virtue proactively may be thought of as a kind of moral vaccination against the ethical pitfalls inherent in emergency medical services provision. Manifest virtue gives frightened, anonymous, and vulnerable victims and the sometimes mentally exhausted disaster team members something in which to believe when they need it the most.

CARDINAL VIRTUES FOR DISASTER PREPAREDNESS AND RESPONSE

Eight virtues that express the qualities, dispositions, and uniqueness of the ideal disaster response team volunteer are: prudence, courage, justice, vigilance, stewardship, resilience, communication, and self-effacing charity (Table 5.5).

These virtues, detailed later, are not intended to be all-inclusive. Equally important virtues such as humility are beyond the scope of this chapter. As both Plato and Aristotle noticed, there is considerable overlap between many of the virtues, reflecting both the compatibility and interdependence of virtues on each other.[26,34] It would be difficult to have only one virtue and

Table 5.5: The Cardinal Virtues of Disaster Response

1. Prudence
2. Courage
3. Justice
4. Stewardship
5. Vigilance
6. Resilience
7. Self-effacing Charity
8. Communication

not possess at least some of the others. Timeless insight can be gleaned from the classic virtues of antiquity, and three such virtues are examined first: prudence, courage, and justice.

PRUDENCE

Prudence was first defined by the Greeks as *phronesis*, or practical wisdom. This virtue connotes discernment, perspicacity, judiciousness, and proper discrimination. *Phronesis* was considered by Aristotle to be the prerequisite basis of all other virtues because it was needed to properly weigh between justice, temperance, and all the other virtues and vices. Prudence, or practical judgment, was necessary to "do the right thing in the right place at the right time in the right way and the right amount."[26] Unlike rigid Hippocratic rule-following, prudence or sound judgment is central to the dynamic functioning of the healthcare team in a disaster situation. Prudence connotes practical wisdom or a basic common sense, which is indispensable to the proper application of technical and moral facts in any particular crisis. In disaster medicine there are no quick formulas for the determination of right action and right emotion because each patient and each situation is unique. Balancing burdens and benefits, determining a triage category, choosing when to refer, knowing when to withhold advance life support interventions, when to vaccinate for smallpox, and what to tell the mass media and when to tell them – cannot be found in textbooks, but are all manifestations of prudence. All clinical judgment involves some measure of prudence. This is particularly critical in disaster medicine when uncertainty and urgency are rampant. The exercise of prudence reflects professional competency and is, therefore, essential to the development of leadership, trust, and respect within the disaster response team. Because prudence promotes safety, its opposite is recklessness. Persons lacking prudence are vectors of danger and collateral damage and must be removed from leadership when disaster strikes.

COURAGE

> Virtue is bold, and goodness never fearful.[35]
>
> Tisn't life that matters! Tis the courage we bring to it.[36]

Moral courage is a type of *fortitude* that is especially important when preparing for and responding to disasters or multiple casualty events. Courage is often exemplified by being steadfast, for example, advocating for public health needs when nonmedical influences convince policymakers to support directing resources to smallpox preparedness in the absence of a highly credible threat. Courage may also be shown at the micro level by advocating for patients when utilization review nurses and managed-care gatekeepers deny medical services or when consultants, families, or employers fail to act in patients' best interests. It is also manifest in the determination required to put aside fear when treating the violent, psychologically agitated, or criminal (even terrorist) patients. Unlike machismo, courage sometimes means accommodation or "turning the other cheek" when, for example, an angry patient makes threatening statements, delivers insults, or spits. The words of Austrian poet Rainier Maria Rilke (1875–1926) offer insight into this higher form of courage.

> Perhaps all the dragons in our lives are princesses who are only waiting to see us act, just once, with beauty and courage. Perhaps everything that frightens us is, in its deepest essence, something helpless that wants our love.[37]

Courage is manifest in other ways, for example, by acting decisively when information is lacking. Fortitude is also needed to abide by reporting statutes or to enforce quarantine provisions during a bioterrorism event or other public health emergency like SARS. As mentioned previously, courage can be seen as an Aristotelian mean between cowardice and foolhardiness. Although refusing to treat a monkeypox patient can be considered cowardice, expressing pus from an anthrax-laden abscess with bare hands simply shows poor judgement. Courage is entirely different. Courage is embracing the duty to care for victims of disaster without undue concern for malpractice exposure, infectious disease risk, or economic reimbursement.

A measure of bravery is also required to report incompetence, impairment, or academic fraud, at the times when it occurs in the disaster preparedness industry. It takes courage to say "no" to the temptations of wealth and notoriety when it is being distributed widely to any who would hold themselves out to be an expert in the area of disaster preparedness. Healthcare providers must have the courage and integrity to take responsibility for any shortcomings of the medical profession. Self-discipline and monitoring are important rather than blaming others, e.g., society, attorneys, bureaucrats, and insurers, when moral problems arise. In summary, courage is having the moral resolve to do the right thing even when it is difficult, inconvenient, risky, or unpopular to do so.

JUSTICE

As mentioned previously, justice is one of the four core principles of western medical ethics (along with beneficence, nonmaleficence, and respect for autonomy). It is also a key virtue in disaster circumstances. Justice is a quality that helps disaster workers and planners shepherd resources, employ therapeutic parsimony, and administrate well. Justice requires that practitioners be fair and resist selfish passions. Justice was the principle theme of Plato's *Republic*;[34] today, in some countries it is the ordering principle of healthcare reform and discussions of rationing, access, and runaway costs. Although establishing distributive and social justice policy seem like a more appropriate task for the electorate, disaster workers must assume this duty as well. Specifically, they must steward resources by prioritizing disaster needs fairly in relation to other programs. At the micro level, a just provider defers or denies marginally beneficial care to some victims and patients (e.g., expectant or non-critical ambulatory wounded) whereas guaranteeing a basic level of care for others. Disaster physicians and other medical volunteers and disaster practitioners must resist public, legislative, or institutional policies that are unfair or unjust. The ethical and virtuous disaster professional must also act to ensure that disaster aid is accessible and available to all who need it, especially the most vulnerable. Justice would enjoin practitioners to adhere to the World Medical Association's Declaration of Geneva's entreaty to treat all patients regardless of "age, disease or disability, creed, ethnic origin, gender, nationality, political affiliation, race, sexual orientation or social standing."[38] Such justice is a lofty goal and may contradict the political will of government, for example, to care for soldiers ahead of civilians or for politicians ahead of members of the lay public. Providers may also be challenged by the demands of VIPs, families, and friends that do not support the greater good of humanity. Justice, as with prudence, is essential to the development of mutual trust, especially between team members in administrative roles.

Having discussed three of the cardinal virtues of antiquity and their role in the modern practice of disaster medicine, additional virtues that help disaster workers realize their true ideal will now be explored. The following virtues express some of the community of values unique to the practice of emergency and disaster medicine, which disaster responders need but Aristotle could not have foreseen. Specifically, these are: stewardship, vigilance, resilience, self-effacement/charity, and communication.

STEWARDSHIP

The *American Heritage Dictionary* defines a steward as "one who manages another's property, finances, or other affairs."[39] Stewardship, like justice, is a quality that helps disaster workers shepherd resources, use therapeutic parsimony, and administrate with temperance and self-control. Preparing for disasters requires objectivity and a steadfast refusal to be swayed by marketing, vendors, or even government when money and resources are being dissipated or squandered. Corporate and individual greed are antithetical to the good of society. Rationing at the micro, meso, and macro levels is required in times of austerity. Emergency providers are often trained to guard resources by encouraging them to withhold marginally beneficial care to some victims and patients, while guaranteeing a basic level of care for others. The duty of stewardship has been previously recognized in the "Principles of Ethics for Emergency Physicians" adopted by the Board of Directors of the American College of Emergency Physicians in 1997 and reaffirmed in 2001.[21] Principle 9 of this document states, "Emergency physicians shall act as responsible stewards of the health care resources entrusted to them."[21] The duty of stewardship thus enjoins emergency physicians to make effective use of the healthcare resources at their disposal.[22] In times of plenty, this is less challenging, but in times of disaster, austerity may require limiting the provision of beneficial care, or outright rationing. Rationing may raise the ire of clinicians and the distrust of patients, but it is sometimes a necessary component of stewardship in the wake of a mass casualty incident. Although it would be challenging to provide comprehensive protocols that address all of the allocation and triage decisions that providers must make in austere situations, the ethical and prudent steward will maximize outcomes and minimize harm in the overall population being served. This utilitarian approach to stewardship demands a careful consideration of the likelihood, magnitude, and duration of benefits to patients and populations, the urgency of the situation, and the cost of burdens of allocation and triage strategies to patients, payers, government, and society.

VIGILANCE

Vigilance is both a defining and essential virtue to the enterprise of disaster preparedness and response. Vigilance is nearly synonymous with preparedness. In few venues other than disasters are physicians or other disaster responders called on to be ready, willing, and able to assist patients, paramedics, and colleagues, immediately, competently, and compassionately, 24 hours a day. This around-the-clock and watchful guardianship does not weaken during weekends, holidays, or nights; in fact, disaster care is often provided during nontraditional work hours. In the wake of a tsunami, earthquake, terrorist or other type of disaster, demands are often unpredictable and uncontrollable, evolving over time, and rarely defined by an individual patient's needs. Yet utmost alertness, stamina, and preparedness are required, despite the circadian disharmony that threatens personal wellness. Expectations of excellence demand participation in preparedness exercises so that no matter what the illness or injury, no matter what the crisis, some emergency or disaster responder is available to provide assistance. This is what it is to be vigilant in times of trauma, disaster, terrorism, or life-threatening illness.

RESILIENCE

In a disaster setting, amid human suffering, flooding, and destruction, an overstressed staff requires a certain elasticity and optimism to stave off physical and emotional fatigue, cynicism, resignation, disillusionment, and professional burnout. This type of diverting optimism that allows one to sustain competence under the stress of disaster is called *resilience.* Resilience enables disaster workers to recharge emotional stores so that, for example, when a frightened and lost child comes to the command center after the parent is pronounced dead, they are able to provide compassion and comfort the child.

Resilience greatly facilitates the ability to recover undaunted from trauma, change, or misfortune. This self-preserving virtue does not, however, imply that compassion, empathic listening, and sensitivity are to be abandoned. To the contrary, a resilient disaster worker is "all things to all people," giving both victims and coworkers exactly what they need without becoming distracted from the overarching job at hand. A resilient responder is sensitive and compassionate, but keeps the balance between apathetic indifference and over-identification with the victims, thereby avoiding the paralysis of either extreme.

True excellence in emergency and disaster medicine requires transcendent flexibility, adaptability, and a cooperative nature, thereby allowing a responder to work well with patients and team members of all types. It is also manifest in an ability to resist taking criticism too seriously from angry patients, families, and coworkers. Resilient persons are hardy, curious, purposeful, expectant and acceptant of change, and trust in their own power to influence the course of events. Maintaining flexibility and coping with the typical circadian rhythm disruptions of the disaster recovery worker is difficult, but aikido-like resilience is facilitated through the psychosocial support of the healthcare team. An appropriate sense of humor and wittiness coupled with an optimistic outlook can keep the team spirit afloat even in the harshest environment. Resilience is thus another essential virtue needed for disaster workers to remain functional amid the turmoil of catastrophe.

SELF-EFFACING CHARITY

Effacement of self-interest, temperance, humility, altruism, and charity are perhaps the highest levels of human virtue. Charity goes beyond ethical principles of nonmaleficence and mere beneficence. Charity denotes the volunteer who willingly stays late to help cover for a colleague in quarantine. An altruist is willing to attend to a coworker's concerns beyond the work relationship despite real or imagined interprofessional boundaries. Examples of benevolent charity would include: canceling a vacation to volunteer to help hurricane victims in Haiti; taking care of SARS patients without concern for combat pay; and working for a pregnant colleague during a nuclear disaster.

A fictitious example of charity in times of plague is provided by Mark Twain in his work, *A Connecticut Yankee in King Arthur's Court*. Here, King Arthur risks death to assist a woman dying of plague.[40]

Aquinas first introduced charity as one of the cardinal virtues in the Middle Ages, but the reason that it has never fallen out of fashion and remains noble in secular society today is its rarity and beauty.[27] Like diamonds or gold, charity's supererogation, self-sacrifice and generosity is precious, and transcends the white coat duties that are merely expected by the social contract of a medical professional with society. Charitable providers take literally the opening eloquence from the World Medical Association's Declaration of Geneva.

> I solemnly pledge to consecrate myself to the service of humanity.[38]

To be truly charitable, a responder must be humble and allow other members of the team to receive praise. Also, true charity is nonjudgmental and understanding when coping with self-involved or narcissistic coworkers. Charity is critical to the team effort in delivering disaster care as Aristotle's golden mean between the extremes of obsequiousness and self-centeredness. Charity helps disaster practitioners cope with uncooperative coworkers or clientele. Generosity to patients and colleagues may be manifest in many ways. Beyond simple diplomacy, being charitable to others includes being a willing team player who is both forgiving and magnanimous. Even with a trend in some locales for diminishing professional autonomy and heightened entrepreneurism, charity remains the pinnacle of all virtue because, at bottom, it is about core values, destiny, and the calling to genuine caring and selfless giving. The poet Rilke describes charity as the ultimate task.[37]

> For one human being to love another human being: that is perhaps the most difficult task that has been entrusted to us, the ultimate task, the final test and proof, the work for which all other work is merely preparation.
>
> (Rainier Maria Rilke 1875–1926)[37]

COMMUNICATION

Communication skills are key elements necessary for crowd control, media interactions, debriefings, and incident command center functions. Of all the virtues of emergency and disaster teamwork, communication is most essential. Almost every obstacle to successful disaster team interaction may be overcome through good communication. "Good communication" within the incident command structure consists of four integral characteristics: empathy, shared power and control, self-disclosure/ventilation, and confirmation.[41,42]

Empathy

Empathy refers to observing the world from another person's point of view. To communicate empathetically healthcare providers must be consciously aware of the behavior, moods, and feelings of others, the influence of their own communicative style and the responses, both spoken and unspoken. Entering another person's world enables the empathetic listener to interpret more accurately the intended message. Thus empathy helps professionals build interpersonal relationships with one another and with patients – an almost universally desired goal of the successful disaster management team. Such relationships may ease tensions among team members and thwart occasions for conflict.

Shared Power and Control

Sharing control is a sensitive issue especially in "life and death" or disaster situations. Under these conditions, healthcare professionals may believe they require total control so that the environment in which they attempt to save lives becomes maximally efficient and predictable. Although there is often a named "incident commander" during disaster operations, healthcare professionals must depend on one another if they are to function with optimal effectiveness. Through sharing control, interdependence can be achieved without any individual losing control. In addition to these factors, the obstacle of professional hubris, provoked by interprofessional ignorance, must be mitigated through education and the virtues of self-effacement and trustworthiness. Colleagues and other professionals are coequal as far as morals are concerned, and they are due respect accordingly.

Self-Disclosure

Self-disclosure may appear at first to be of primary concern to the physician–patient relationship but it is just as important to the intimate and interpersonal relationships among members of a disaster response team. A close relationship with teammates affords the opportunity to share feelings, concerns, and frustrations, fostering the mutual comfort and trust necessary to cope with difficult situations. This *sharing*, then, reciprocates in the self-disclosure of other team members. Emotions are communicated across professional boundaries, yielding greater interprofessional understanding and empathy, cultivating more intimate interpersonal relationships, and nurturing unity of team spirit.

Confirmation

Confirmation is a method to communicate interpersonal acknowledgment and acceptance of others. Praising a team member's accomplishments, acknowledging another's frustrations, and simply listening openly to patients' worries exemplifies confirming communication. Confirmation and the virtues of empathy and compassion require one to recognize the need of health professionals to feel accepted and worthwhile. Although rarely spoken, most healthcare workers have compelling needs to be viewed as important to the functioning of the team. Feeling included provides a sense of purpose transcending simple team membership.

Confirming communication can be difficult especially when angry patients and teammates generate negative responses to attempts at compassionate and empathic speech. Despite this, confirmation is reciprocal in nature and, if practiced, influences others to communicate similarly over time. Communicating in a confirming manner is essential in showing respect for peoples' hopes, abilities, and concerns. Disaster team members should enhance their teamwork and communication skills by engaging in team building activities before they are required to work together during a critical incident.

Team Leaders: Models and Mentors of Virtue

U.S. President Abraham Lincoln once said, "It has been my experience that folks who have no vices have very few virtues."[43] Sometimes in disaster situations, a vice can become a virtue. Physicians who are hypomanic may be able to work long hours without sleeping. Narcissistic responders may be better able to interact with the media and function as leaders. Self-confidence is often better than extreme humility in effecting optimal disaster teamwork. Highly sensitive individuals may not perform well when confronted with body parts or human debris.

Given the many ethical pitfalls in disaster settings, persons with strong moral character must be actively recruited as leaders to help teach, model, and grow virtue in other team members. Excellent communicators, for example, foster team-based virtues and individual traits of prudence, justice, self-effacement, charity, compassion, and resilience in others. Strong leaders and loyal staff learn from each other because they are neither dependent nor independent of each other; rather they are interdependent.[44] Effective and ethical disaster managers, chairpersons, chief executive officers, policymakers, and other leaders understand this interdependence and empower their coworkers first and foremost with strong moral support and a virtuous example. In the aftermath of September 11, 2001, New York City Mayor Rudy Giuliani understood the importance of both support and example, visibly working hard in and around New York City's five boroughs to keep morale at a high level. His leadership secret? "Attend every funeral."[45] Giuliani attended many New York police and firefighter personnel's funerals, wakes, memorial services, and other functions. At a critical time in history, his behavior was virtuous and his physical presence was deeply appreciated. Strong leaders inspire others. Similarly, both responders and adult learners in preparedness exercises learn better to adopt optimal virtues when real-life models are visibly present. Although intrinsic character cannot be easily measured, virtuous behaviors can be evaluated objectively. For example, role-play can be used during disaster preparedness exercises with video review and feedback to formatively teach optimal crisis and emergency risk communication skills to peers, patients, and the media. The more closely teachers and leaders exemplify a virtuous ideal, the more successful they will be in developing useful, skilled, and truly excellent disaster medicine teams that measurably improve the quality of care for patients, enrich the environment and relationships in which disaster response teams operate, and bring honor and integrity to the forefront of disaster service.[46]

RECOMMENDATIONS FOR FURTHER RESEARCH

This chapter presents important ethical principles, codes of conduct, and cardinal virtues gleaned from history that may assist emergency managers and disaster response personnel who are confronted by ethical dilemmas encountered in disaster preparedness and response. Future work should focus on more explicit and transparent policies that can be developed both locally and globally, incorporating the principles of utility and justice into more concrete operational guidelines. Traditional individualistic principles of bioethics are insufficient when the functioning and viability of civil society is at stake. Realistic disaster triage protocols must be refined and tested to show that they improve outcomes. Furthermore, studies are urgently needed to determine fair and equitable allocation of scarce resources during a catastrophic disaster.[47,48] Leaders must inform the public of the need to embrace the difficult issues of social worth and prioritization within disease and illness strata; a policy of "first come, first served" without consideration of the overall circumstances is insufficient as a moral rule.

Beyond the application of public health ethics, disaster situations create a parallel need for a host of virtues not commonly required in daily medical practice, including vigilance, courage, stewardship, prudence, resilience, justice, and self-effacing charity. Ongoing research suggests that such traits form a cadre of core competencies, "the right stuff," from which the ideal disaster worker is made. Future work should evaluate the ability of such virtues to act as a polyvalent counterpoint to the vices of apathy, cowardice, profligacy, recklessness, inflexibility, and narcissism. Outcome data may validate virtues that empower providers at all levels to integrate vertically principles of safety, public health, utility, and medical ethics at the micro, meso, and macro levels. Longitudinal and prospective studies should explore if, over time, virtuous behavior can be modeled, mentored, practiced, and institutionalized to become a useful vaccine against the vast array of moral threats inherent in disaster preparedness and response.

Future empiric research in the field should help discern the feasibility of screening for, selecting, teaching, and modeling the cardinal virtues among provider candidates in advance of a disaster or multiple casualty incident. Multisite studies must also be conducted that validate the ability to measure and imbue core values of fairness, utility, and virtue in a multicultural context. Future codes of conduct must also incorporate practical aspects of provider discretion, the importance of good intent, and the challenge of dynamic decision making amid changing disaster circumstances. Mass media must help engage the populace and leaders alike into dialogue to discern in advance how best to help the disabled, the incarcerated, noncitizens, and the poor and disenfranchised. Future work must determine how best to prioritize and weigh the long-term goals of civil society and public health over the short-term liberty and health interests of individual citizens during a catastrophic event.

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6

Emerging Infectious Diseases: Concepts in Preparing for and Responding to the Next Microbial Threat

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INTRODUCTION

Former U.S. Surgeon General William H. Stewart has been attributed with stating in the late 1960s that the time had come to "close the book" on infectious diseases as major threats to public health. Even though the statement's authenticity has been called into question, it is often used to convey the optimism widely expressed at the time by health experts and world leaders. Indeed, it did appear that the age of infectious diseases that had plagued humans for millennia was coming to an end. Vaccines and antibiotics had substantially reduced the incidence and mortality of many diseases. The smallpox eradication campaign was on its way and it was thought that eradication of other diseases (for example tuberculosis and polio) would not be too far behind. Improved food and water safety resulted in less exposure to disease-causing microbes, and the use of pesticides to control arthropod populations had reduced vector-borne diseases. It seemed the battle with the microbial world had been won and it was time to focus efforts and funding on the looming threat of chronic diseases.

Of course, this confidence largely ignored the burden of infectious diseases in the developing world. Four decades later, although great strides have been made to control infectious diseases, microbial pathogens are still major threats to public health throughout the world. The last few decades have ushered in new challenges: "old" pathogens once thought to be controlled by antibiotics have developed multidrug resistance, new pathogens have emerged, and traditional pathogens have appeared in new places. Furthermore, factors such as increased global commerce and travel, and the threat of the intentional release of pathogens have set the stage for infectious disease disasters with large numbers of casualties. In this chapter, "casualties" includes all persons with symptoms of the infectious disease, not just fatalities.

There is a wide body of knowledge on the emergence and reemergence of pathogens of public health importance. It is now clear that humans are in a delicate balance with microbial cohabitants of the earth; circumstances can tip that balance in favor of microbes with new or renewed pathogenic vigor. There will always be emerging pathogens, and consequently there is always the chance that a virulent microbe will cause extensive human disease and death. Exactly what the causative agent of the next big infectious disease disaster will be and when it will happen is not known. Using examples from past events, this chapter addresses the concepts and tools necessary to prepare better for and respond to infectious diseases disasters in general.

OVERVIEW

The Threat of Emerging Infectious Diseases

Infectious diseases are caused by microorganisms such as bacteria, viruses, fungi, and protozoa, and by proteinaceous particles called prions. The majority of microbes on earth are benign to humans; many are necessary for ecological stability, and even human and animal health. Microbes that do cause disease are collectively referred to as pathogens. There are more than 1,400 pathogens known to cause disease in humans.[1]

Some pathogens are prevalent at a constant and stable rate in a given population and are considered "endemic" (see Table 6.1 for a list of definitions). Other infectious diseases are not common to a given population but, at times, a number of cases occur that is higher than expected. This situation is considered an "outbreak" (for a more localized increase in disease incidence) or an "epidemic" (for a larger regional increase in disease incidence). The concept of the epidemiological triangle (Figure 6.1) is used to understand the factors involved in promoting such an outbreak or epidemic. This model highlights the interactions among an agent (e.g., *Salmonella*), a host (e.g., elderly patients at a nursing home), and an environment (e.g., undercooked chicken left at room temperature) that cause disease (e.g., acute gastroenteritis).

Many pathogenic microbes have been associated with human disease for hundreds or thousands of years. Examples of infectious diseases with long human histories include smallpox, plague, cholera, malaria, tuberculosis, and syphilis. These diseases, and others, resulted in millions of deaths over the centuries and were the focus of targeted efforts to reduce the burden of infectious diseases on human populations. Improvements to public health systems, such as sanitation and education,

Table 6.1: Definition of terms[a]

	Description	*Example*
Airborne transmission	The process whereby agents are spread by small-particle ($\leq$5 μm) droplet nuclei that can suspend in the air and travel by air currents or through ventilation systems; respiratory PPE (N95 respirator) is often required to prevent infection in responders.	*Mycobacterium tuberculosis*
Biological Incident	The presence of a pathogen in a population from a natural, accidental, or intentional exposure that has the potential to cause extensive public harm and/or fear.	2003 SARS epidemic in Toronto (natural); 1979 atmospheric release of anthrax spores in Sverdlovsk, USSR (accidental); 2001 dissemination of anthrax spores in U.S. mail (intentional)
Communicable	The ability of an infectious agent to be transmitted from one host to another; contagious.	Influenza, smallpox
Contact transmission	The process whereby agents are spread by direct contact with a person or indirect contact with contaminated objects.	Direct contact: skin (MRSA); mucous membrane (HIV) Indirect contact: fecal-oral (norovirus)
Droplet transmission	The process whereby agents are spread by large-particle ($>$ 5μm) droplet nuclei produced by, for example, coughing and sneezing; agent does not remain suspended in the air for a long time and infection usually occurs when susceptible person is within 1 m of infected person. A surgical mask may offer protection.	Influenza virus
Endemic	A disease that is consistently present in a population at a certain level or rate without requiring introduction from another area.	Malaria in India and Africa
Epidemic	A level of disease that is higher than the expected level at a time or location. Similar to an "outbreak" but usually refers to disease incidence that spans a large region, country, or multiple countries for a prolonged period of time.	Diphtheria in Russia
Host – Resistant	The state in which a person is immune to infection by a specific pathogen.	In general, a person who has had chickenpox is resistant to subsequent infection with the chickenpox virus
Host – Susceptible	The state in which a person can be infected by a specific pathogen. May be due to lack of immunity and/or to host factors that promote infection (e.g., a specific receptor).	A person who has not had the Measles/Mumps/Rubella (MMR) vaccine is susceptible to the agents that cause these diseases
Isolation	The separation of *infectious disease cases* from the general population to prevent transmission of the agent to susceptible people; instead of physical separation, may use barriers such as masks on cases to "isolate" the infection and prevent transmission (this may be necessary in disasters with many casualties).	SARS cases were sequestered on specific hospital wards
Mode of Transmission	The mechanism a pathogen uses to spread from one host to another.	Airborne transmission by small particles in the air
Outbreak	An increased incidence of a disease in a region. Usually on a smaller scale (regionally and temporally) than an epidemic. A food-borne outbreak typically refers to disease caused by food(s) contaminated with a specific pathogenic microorganism.	*Neisseria meningitidis* outbreak on a college campus
Pandemic	The global spread of an epidemic.	1918 Influenza pandemic
Quarantine	The restriction of movements of *healthy people who were exposed* to a contagious agent to prevent contact with the general public. The duration of the quarantine period is usually the longest time for symptoms to appear after exposure (incubation time). Work quarantine refers to permitting exposed healthcare workers and emergency responders to go to work using appropriate PPE so that disaster operations can remain intact; this modification does not apply to workers in the general public.	In Ontario, Canada in 2003, people who were exposed to SARS were quarantined for 10 days. At times during the epidemic, over half of the paramedics in the Toronto area were operating under work quarantine conditions

	Description	Example
Reservoir	The environmental niche of a pathogenic organism, usually another organism unaffected by the infectious agent	Specific rodent species are the reservoirs for particular hantavirus strains
Transmission rate (R_0)	For an infectious agent, the number of people to whom an infected person spreads the disease in the absence of control measures (such as vaccination, isolation of cases).	According to historical data, a person with pandemic influenza will transmit the disease to 3 other people
Vector	An organism (e.g., insects or other arthropods) that harbors and transfers agents that are pathogenic to another organism (e.g., humans).	*Ixodes* ticks transfer *Borrelia burgdorferi*, the causative agent of Lyme disease, to humans; *Anopheles* mosquitoes transfer *Plasmodium* sp, the causative agents of malaria, to humans
Zoonoses	Infectious diseases in which the pathogenic agent is transmitted to humans from animals.	West Nile virus encephalitis is transmitted to humans from birds (via the mosquito vector)

[a] Terms are defined as they pertain to infectious diseases biology.

reduced human contact with pathogens. Scientific advances, such as antibiotics and vaccines to treat and prevent infectious diseases, revolutionized the medical arsenal against microbes. As a result, by the middle of the twentieth century, the incidence of many infectious diseases plummeted, particularly in the developed world. It was widely thought that science had conquered the threat that infectious diseases posed to human health.

What is appreciated now is that microbes are constantly interacting with their environment and evolving. As they do, circumstances may allow for the emergence of new infectious agents/diseases, or the reemergence of previously controlled contagions. These emergences fall into many categories:[2]

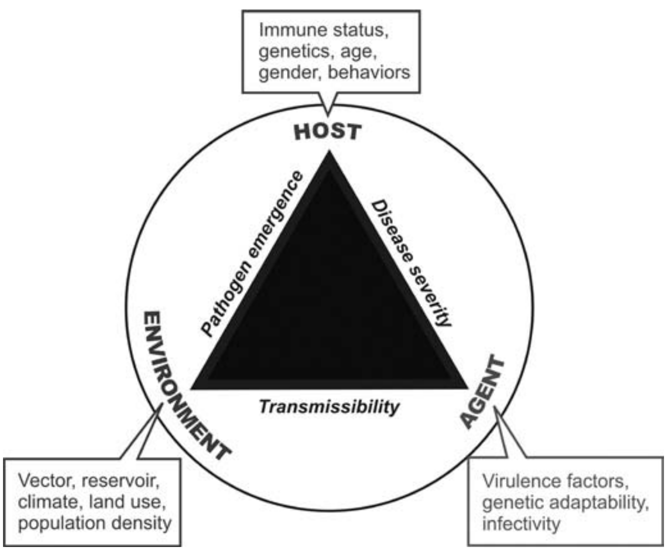

Figure 6.1. The epidemiological triangle. This type of diagram is widely used to represent the interconnectedness of the three major components involved in the emergence of infectious diseases. The "Host" is the organism that is affected by the pathogen or toxin and can develop disease. The "Agent" is the infectious microorganism (pathogen) or toxin. The "Environment" refers to the circumstances that influence the interaction between the Host and the Agent. Examples of influencing factors are given for each component.

- Microorganisms that have not been known previously and that cause new diseases (e.g., severe acute respiratory syndrome coronavirus [SARS-Cov]; human immunodeficiency virus [HIV] that causes acquired immunodeficiency syndrome [AIDS]);
- Agents that have been known previously and that cause new diseases (hantavirus in the U.S. in 1993 that caused respiratory distress instead of kidney disease);
- Microbes that have been known previously to cause disease, but the incidence of disease is noticeably increasing in a region (e.g., whooping cough caused by *Bordetella pertussis* in the U.S.; diphtheria caused by *Corynebacterium diphtheriae* in Russia);
- New, and often more virulent, strains of a known pathogen that cause disease (e.g., *Vibrio cholerae* O139 and epidemic diarrheal disease; highly virulent *Clostridium difficile* NAP1/027 and increased incidence of *C. difficile*-associated disease in North America and Europe). Increased virulence often occurs when a pathogen acquires a genetic element that allows for the production of a new virulence factor such as a toxin (e.g., *Staphylococcus aureus* that produces TSST-1 and causes toxic shock syndrome);
- Microbial pathogens that cause disease in a new geographical location (e.g., West Nile virus encephalitis in North America);
- Microbes of animal origin that infect humans (zoonoses). This includes animal-associated microorganisms to which humans are newly exposed (e.g., hantavirus pulmonary syndrome due to Sin Nombre virus from the rodent population in the U.S.), or animal-associated microbes that are newly able to infect humans (e.g., influenza virus from birds or swine);
- Microbial pathogens that have acquired the ability to resist the antimicrobial effects of antibiotics (e.g., multidrug resistant tuberculosis [MDR-TB]; methicillin-resistant *S. aureus*).

The occurrence of emerging infectious diseases (EIDs) or reemerging infectious diseases in human history is not new. The great plague and influenza pandemics are well-known historical examples. The last few decades have witnessed a recrudescence of EIDs. Furthermore, as global surveillance of diseases has

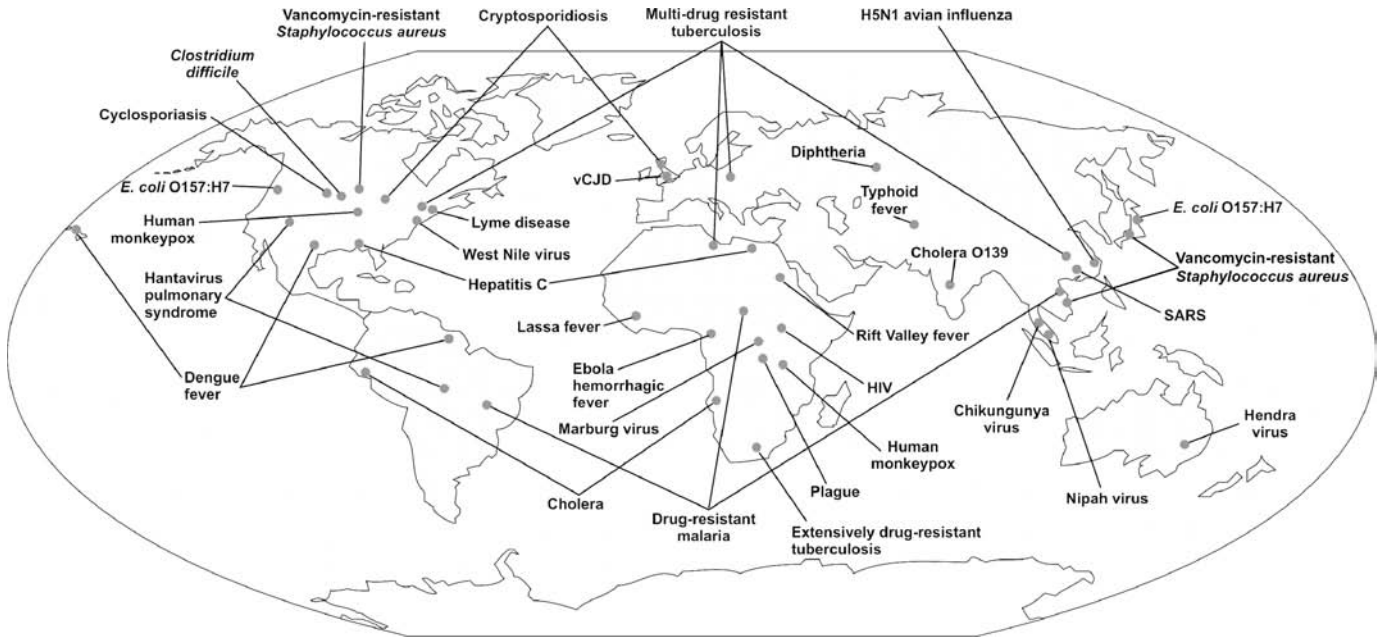

Figure 6.2. Emerging and reemerging infectious diseases/agents, 1990–2006. *E. coli, Escherichia coli*; vCJD, variant Creutzfeldt–Jakob disease; HIV, human immunodeficiency virus; SARS, severe acute respiratory syndrome. Adapted from the National Institutes of Health website (www3.niaid.nih.gov/about/overview/planningpriorities/strategicplan/emerge.htm).

developed, the awareness that new EIDs are occurring has increased. Although exact numbers of EIDs are debatable due to differences in criteria used, Taylor and colleagues suggest that 175 of the 1,400 plus known human pathogens are EIDs (approximately 12%).[1] Figure 6.2 shows recent EIDs and reemerging infectious diseases in both the developed and developing world.

The question then is: Why are EIDs occurring so frequently despite the optimism of past generations? In 2003, the Institute of Medicine (IOM) published *Microbial Threats to Health: Emergence, Detection and Response*,[3] which outlined 13 factors that contribute to the emergence or reemergence of new pathogens (Table 6.2). The factors reflect a very different world from previous decades – "globalization," often characterized by changes in global movement, economic development, and environmental and agricultural practices – has unwittingly exposed the world's populations to microbial threats. Not all of the categories are necessary for every emerging pathogen; however, neither are they mutually exclusive. The emergence or reemergence of a pathogen is usually a function of many factors. An understanding of all the factors is necessary to prevent future EIDs and to determine how to effectively mitigate an EID disaster. Table 6.3 uses pandemic influenza, dengue hemorrhagic fever, multidrug resistant tuberculosis, and AIDS to demonstrate how these factors interplay in the emergence or reemergence of diseases.

Many of the 13 factors outlined by the IOM drive disease emergence by influencing the interaction of humans with animal reservoirs of potential pathogens. In fact, approximately 75% of recently emerged pathogens are zoonotic, or transmitted from animals to humans. The abundance, location, and behaviors of putative animal reservoirs, and human influences on them, are important factors in disease emergence. Microbes often live in harmony with certain animal hosts and the pathogenic infection of humans is inadvertent.

Infectious Diseases and Disaster Medicine

History has shown that infectious disease outbreaks, epidemics, and pandemics have the potential to afflict large numbers of people. Estimates for the next severe influenza pandemic suggest millions of cases in the U.S. alone with hundreds of thousands of flu-related fatalities. The 2001 deliberate release of anthrax spores in the U.S. through the postal system and the 2003 SARS pandemic are reminders that the scope of the disaster is not just a function of actual case numbers, but of the ability to respond to the outbreak and to the public reaction during the event. Both situations taxed the available resources of some of the most sophisticated public health systems in the world despite relatively low numbers of cases.[4,5]

Disasters are commonly considered to be acute, often regional, events. Even in the realm of infectious diseases, the anthrax letters incident in the U.S. is often cited as an example of the type of response required for an infectious disease disaster. More likely, however, biological situations (of either intentional or unintentional origin) that strain response efforts will unfold in a more gradual manner. Furthermore, if disasters are defined as situations that require external resource assistance, then the global AIDS pandemic (now decades long) can be considered a disaster. Disasters due to EIDs are of particular concern given the paucity of information on the biology of the agent, the course of disease, and mechanisms of treatment. Even a local outbreak of a known infectious agent can strain a response effort.

Management of infectious disease disasters shares many general aspects of the management of other disasters. The basic principles of leadership and collaboration, resource management, surge capacity, triage and public relations are all important; however, the specifics of response activities can have special considerations when an infectious agent is the cause of the disaster.

Table 6.2: Factors that Drive the Emergence or Reemergence of Infectious Diseases

Factor in Emergence	*Description*	*Example*
Microbial Adaptation	Microbes are under constant selective pressure from the environment to adapt genetically for survival. Evidence of adaptation includes: the evolution or acquisition of antibiotic resistance genes that allow bacteria to survive exposure to antibiotics, the mutation of genetic material, and the horizontal transfer of virulence genes from one microbe to another.	The emergence of multidrug-resistant tuberculosis, which is resistant to at least two of the primary antibiotics used to treat disease. Even more alarming is the appearance of extensively drug-resistant tuberculosis (XDR-TB), resistant to many first-line *and* second-line antibiotics.
Human Susceptibility	The ability to stave off a pathogenic infection is predominantly due to host immunity, a multiorgan system involving physical barriers, complex cell–cell signaling, recognition, and memory to fight invading pathogens. A healthy immune system is a function of many factors. The extremes of age, poor nutrition, and presence of chronic and/or infectious diseases could result in an immunocompromised state.	The increased incidence of *Pneumocystis carinii* pneumonia in the U.S. as the HIV/AIDS population increased.
Climate and Weather	Changes in climate and weather affect every organism in a region. As plant and animal life is affected, so too is the interaction between humans and these organisms, and the microorganisms they may harbor. Climatic changes can also affect human activities. For example, a negative effect on crop production can increase malnutrition and render a population more susceptible to disease. Furthermore, agricultural practices may be altered, exposing populations to different vectors and microbial agents.	Certain species of zooplankton are associated with the presence of pathogenic *Vibrio cholerae*.[a] In South America, the El Niño southern oscillation of 1991–1992 increased coastal water temperatures, zooplankton density and, consequently, exposure of people to *V. cholerae*. The ensuing cholera epidemic was the first in the region in a century.
Changing Ecosystem	The environment can have a profound impact on the emergence of pathogens, predominantly through wildlife ecology and the interaction of humans with the vectors and animals that carry potential pathogens. Environmental changes in forestation, humidity, and predator density due to natural or anthropogenic causes can all affect vector and pathogen biology.	Dam building in Ethiopia to improve agricultural productivity had the undesired side effect of increasing mosquito breeding grounds, an outcome implicated in increases in malaria cases in children.[b]
Human Demographics and Behavior	At over 6 billion people, the world population is four times as large as it was at the beginning of the 20th century when advances in science, medicine, and public health first allowed for the widespread control of infectious diseases. The increasing population has resulted in crowded living conditions and habitation of previously undeveloped areas, exposing more individuals to new diseases. Human behaviors, often for economic gain, can also influence disease emergence.	Live-animal markets that put humans and pathogens in close contact (e.g., SARS-CoV and influenza viruses). Commercial sex workers who engage in unprotected sexual intercourse (e.g., HIV emergence in Asia).
Economic Development and Land Use	Globalization of national economies has resulted in an unprecedented interdependence in trade and commerce, and an increase in the volume of goods produced. Land use for industry and agriculture, and for population expansion, can influence emerging diseases.	Widespread deforestation in Malaysia for the expansion of plantations encroached on the natural habitat of fruit bats, the reservoir for the previously unknown Nipah virus. The fruit bats found food in the orchards that were adjacent to swine farms and infected the swine with Nipah virus. In 1988, human disease emerged.
Technology and Industry	Medical technology has improved lives, but also has led to an increase in immunocompromised persons (e.g., transplant recipients). Technology has allowed for mass production in the food industry. Larger animal feedlots and processing plants facilitate the transmission of infectious agents from one animal to another. Refrigeration, packaging, and transportation networks allow foods from different regions and countries to be distributed throughout a nation. Advanced water distribution systems for consumption, hygiene, recreation, and indoor temperature regulation are comforts particularly associated with and expected in the developed world. With this technology comes the risk of mass distribution of pathogens.	Hemophiliacs who were infected with HIV from infected blood products. Spinach contaminated with *E. coli* O157:H7 affected people in over 25 states in the U.S. in 2006.
International Travel and Commerce	The movement of people across regions means the movement of microbes and vectors as well. In addition to traveling for pleasure or for business, people move across borders for temporary employment, as military personnel, as immigrants, as refugees, as undocumented persons, or in situations of forced labor. Commerce is highly dependent on international production and trade of goods. For example, foods once considered exotic or seasonal are available in the U.S. year round due to importation from other countries.	One infected person spread the SARS-CoV from Guangdong Province, China to 12 guests at a Hong Kong hotel. The 12 people spread the virus to 5 other countries. In 6 months, the SARS-CoV spread from China to over 30 countries on 6 continents.

(*continued*)

Table 6.2 (*continued*)

Factor in Emergence	*Description*	*Example*
Breakdown of Public Health Infrastructure	Public health measures, such as sanitation, health education, vaccinations, and access to care, are critical for preventing infectious diseases. These measures must be consistently upheld, or microbial pathogens will return to the niche they once inhabited. Reasons for public health inadequacies or collapse include economic hardship, political instability, war, complacency, disasters, and lack of priority standing.	In the early 1990s, diphtheria reemerged in the former Soviet Union amidst a turbulent political, economic, and social environment. In 2000, approximately 2,300 people in Walkerton, Ontario, Canada became ill after consuming inadequately treated and monitored drinking water contaminated with *E. coli* O157:H7 and *Campylobacter jejuni.*
Poverty and Social Inequality	Increased populations, political unrest, and/or inadequate food production in some areas have resulted in increased numbers of persons who are malnourished and without access to medical care. Infectious disease outbreaks in these areas tax already overburdened healthcare systems. Inadequate resources spread disease by failing to reach the sick, transmitting the pathogen in the healthcare setting due to crowding and reusing supplies, and neglecting to educate the population on safe practices. In addition, the lack of adequate courses of medication leads to incomplete treatment of disease and the emergence of antibiotic-resistant pathogens.	The incidence of AIDS, malaria, and tuberculosis has reached alarming rates in developing countries where resources are scarce.
War and Famine	War often unsettles populations and increases the reliance on public health infrastructures to provide medicines, food, and emotional support to affected persons. As noted above, these health systems are often inadequate during peacetime and cannot undertake additional responsibilities during unrest. Furthermore, poor health status in a population may result from 1) substandard housing in refugee camps, 2) guerilla-controlled access to food and medicines, 3) elevated pollution, and 4) interrupted power and water distribution. Infectious diseases can spread from contaminated food or water, from persons with contagious respiratory diseases, or from sexual assaults.[c] Famine, like poverty, deteriorates the health of populations and renders them more susceptible to old and new infectious diseases.	Cholera outbreaks in the 1990s among Rwandan refugees in the Democratic Republic of Congo resulted in thousands of deaths in weeks.[d]
Lack of Will	Four segments of the global society that must commit to combating emerging infectious diseases are monetary donors, health professionals, governments, and patients and civil society. Donors, both private and public, are necessary to provide funding for research and for health programs; health professionals must be available to design and implement intervention and prevention programs; governments must prioritize infectious disease science, surveillance and reporting, build public health infrastructures, and collaborate with other nations and global partners; and the community needs to motivate the other segments to act by voicing concerns and participate in intervention and prevention programs.	In the West, early efforts to understand HIV and determine intervention strategies were stalled by political and societal discomfort that the disease was spreading in the homosexual male population. Inadequate education on the myths and facts of sexually transmitted disease prevention led to widespread transmission of HIV through Africa and Asia.
Intent to Harm	There is heightened awareness to the threat of an intentional attack with a bioweapon. In addition to the unpredictability of when and where such an attack will occur, the type of microbe that will be used is largely unknown. There is concern that an agent used will be one not regularly encountered in the afflicted area. In effect, a bioterrorist attack could result in the emergence or reemergence of infectious diseases in an area, with the potential to cause many casualties. In addition, the social, political, and economic disruption could be far-reaching.	2001 release of anthrax spores via the U.S. postal system.[e]

Source: Institute of Medicine.

[a] Lobitz B, Beck L, Huq A, et al. Climate and infectious disease: use of remote sensing for detection of *Vibrio cholerae* by indirect measurement. *Proc Natl Acad Sci.* 2000;97(4):1438–1443.

[b] Ghebreyesus TA, Haile M, Witten KH, et al. Incidence of malaria among children living near dams in northern Ethiopia: community based incidence survey. *BMJ.* 1999; 319(7211):663–666.

[c] Tam CC, Lopman BA, Bornemisza O, Sondorp E. Epidemiology in conflict – a call to arms. *Emerg Themes Epidemiol.* 2004;1(1):5.

[d] Connolly MA, Heymann DL. Deadly comrades: war and infectious diseases. *Lancet.* 2002;360(Suppl):s23–s24.

[e] Institute of Medicine. *Microbial Threats to Health: Emergence, Detection and Response.* Washington, DC: National Academies Press; 2003.

Table 6.3: Examples of How Multiple Factors Influence the Emergence or Reemergence of Infectious Diseases

Infectious Disease (Agent)	*Pandemic Influenza* (Highly pathogenic avian influenza [HPAI] virus)*	*Dengue Hemorrhagic Fever (Dengue virus; transmitted to humans by mosquito vector)*	*Multidrug-resistant Tuberculosis (Mycobacterium tuberculosis)*	*AIDS (HIV)*
Emergence Factor				
Microbial Adaptation	Reassortment of or mutations in influenza virus genes that allow for human–human transmission of HPAI virus	Adaptation of viral strains to urban mosquitoes facilitated emergence	Improper usage of antibiotics allowed *M. tuberculosis* to develop resistances	Mutation of simian immunodeficiency virus to infect humans; emergence of drug-resistant HIV; high mutation rate complicates vaccine development
Human Susceptibility	Extensive viral adaptations means no inherent immunity in humans; no vaccine-enhanced immunity in the initial months of the pandemic	No cross-immunity to the 4 different viral strains; heterologous infection increases chance of severe disease	Increased tuberculosis in HIV-endemic areas	Lack of host immunity when virus emerged; no vaccine-enhanced immunity
Climate and Weather	Cold weather in some countries during flu season encourages social clustering and, consequently, viral transmission	Rainy seasons increase mosquito population		
Changing Ecosystems	Changing marshland habitats and waterfowl distribution	Repopulation of New World by mosquito species after mid-20th century mosquito eradication programs ended[a]		
Human Demographics and Behavior	Increased worldwide poultry production to feed increased human population; cohabitation with potential zoonotic sources	Disease centers in overpopulated urban areas with poor housing and utilities management that promote mosquito breeding grounds	Failure to adhere to medication regimens; people in remote areas hard to treat consistently; immigration of infected persons	Unprotected sexual activity; illicit intravenous drug use; prostitution
Economic Development and Land Use	Live markets put humans and infected birds in close contact	Dam building promotes mosquito breeding grounds		
Technology and Industry	Crowded poultry feedlots favor viral transmission between birds	Possible disease transmission through blood products		Disease transmission through blood products
International Travel and Commerce	Global travel can rapidly spread disease; illegal exotic bird trade can transfer infectious birds unchecked	Travelers can spread strains between endemic areas; outbreaks in nonendemic areas with appropriate mosquito species (e.g., southern U.S.)	Dissemination of *M. tuberculosis* on airplanes via recirculation of air	Global travel spreads disease
Breakdown of Public Health Infrastructure	Prolonged nature of the pandemic will strain resources	Lack of effective mosquito control, poor water and sewage systems in developing areas	Inability to monitor tuberculosis population; high treatment interruption rates in developing countries; HIV epidemic areas overwhelmed	Lack of educational and intervention programs, overwhelmed workforce in developing countries
Poverty and Social Inequality	Rapid spread of the virus in the developing world	Developing countries that lack vector control programs risk high incidence	Expense of directly observed therapy inhibits consistent use in poorer nations	Expense of antiretroviral therapy; stigmatization of men who have sex with men, especially in early days of the emergence; marginalized women's rights in some societies

(*continued*)

Table 6.3 (*continued*)

War and Famine	Increased global travel during World War I facilitated propagation of 1918 influenza pandemic		Tuberculosis spreads quickly through refugee camps (e.g., Somalia)	Treatment programs are difficult to administer in areas of conflict
Lack of Will	Pharmaceutical industry and vaccine/therapeutic development	Poor surveillance in endemic countries	Inadequate infection control policies or practices	Low research and intervention priority initially for an agent primarily spreading in men who have sex with men; refusal of officials in some developing countries to acknowledge HIV in the population
Intent to Harm	Theoretical potential of genetically reconstructed 1918 pandemic influenza virus to be used in an attack			

* At the time of this writing, pandemic HPAI has not reemerged. Based on knowledge from prior influenza pandemics and extensive studies on influenza virus epidemiology and genetics, experts have uncharacteristically broad insight into factors that affect how these zoonotic pathogens emerge.

[a] Moncayo AC, Fernandez Z, Ortiz, D, et al. Dengue emergence and adaptation to peridomestic mosquitoes. *Emerg Infect Dis.* 2004;10(10):1790–1796.

Table 6.4 provides a description of unique features of infectious disease disasters that are not usually encountered in many other disaster response efforts.

The Infectious Agent

Infectious disease disasters, unlike other physical and chemical incidents, are caused by biological entities that are diverse and under constant selective pressures to change. So, it may be clear that an outbreak has occurred due to the contagiousness and nature of the illness that characterize cases presenting to healthcare facilities; however, the identity of the agent that is making patients sick may be elusive, and any effort to mitigate the disease and spread of the agent will be compromised. Cases of severe atypical pneumonia perplexed physicians in Guangdong province, China in 2002. Chinese officials maintained the causative agent to be a bacterium called *Chlamydia*.[6] It was not until months later, after global spread occurred requiring an unprecedented international response effort, that a new coronavirus was publicly identified as the cause of a heretofore-uncharacterized disease, SARS.

For a number of infectious agents, previously known or unknown, there is no specific treatment or cure. Medical management is limited to supportive care, which may require long hospital stays. Depending on the number of afflicted persons, this could affect resource availability (discussed later). The unknown nature of some pathogens also limits detection and diagnostic capabilities.

Infectious agents are often zoonoses. Human infection from the animal reservoir occurs when environmental and behavioral factors coincide to allow for transmission of the agent. In the case of EIDs, the identity of the animal reservoir may be unknown. Successful mitigation of disease spread is contingent on discovering the reservoir. The 1993 emergence of hantavirus pulmonary disease in different locations in the U.S. occurred due to increased contact between rodent and human populations; disease eradication followed reduction of human contact with rodent excreta.

The Disease

In some situations, the medical literature may not have previously described the disease (e.g., the various viral hemorrhagic fevers that have emerged over the years), or a particular disease was not previously associated with a type of infectious agent (e.g., acute respiratory disease and hantaviruses). In either case, understanding the mechanism of disease is important to provide effective care and prevent future cases. Incomplete or incorrect disease classification will hamper an effective response effort. Alternatively, a disease may be classically associated with an infectious agent; however, outbreaks are rare and the medical community lacks experience in identifying and treating the disease (e.g., smallpox). This scenario also can affect the timeliness with which a disaster is controlled.

In many instances, an EID has similar symptoms to other diseases that are endemic to a region. SARS patients had general symptoms of fever, headache, and malaise that typically progressed to pneumonia. Healthcare workers had the daunting task of differentiating patients with respiratory ailments to properly isolate and treat the SARS cases.[7] Likewise, a 1995 *Neisseria meningitidis* outbreak in Minnesota occurred during flu season, overwhelming a hospital emergency department and complicating triage.[8]

Particularly during epidemics with common symptoms such as headache and fever, healthcare facilities may be inundated with the so-called "worried well." Although psychology experts have advocated for abandoning this phrase and replacing it with more appropriate terminology such as "medically unexplained symptoms," it is still often used to refer to persons who think they may have symptoms although they do not actually have the

Table 6.4: Challenges of Infectious Disease Disasters that May Differentiate Them from Other Types of Disasters

Category[a]	*Challenge*
Infectious Agent	Novel agent or one not previously associated with disease
	No known treatment or cure
	Unknown reservoir
	May not initially be recognized as the causative agent of the disaster
Disease	Not characterized previously
	Medical community lacks experience treating
	Symptoms are similar to other infectious diseases
	People who are concerned about exposure but not truly exposed
Transmission	Contagious agent – large numbers infected over time
	Global response may be necessary to contain agent
	Multiple cities affected
	Disaster could last weeks, months, or years
	How to decide when the disaster is over
Personnel	Exposure of healthcare workers to agent
	Healthcare workers absenteeism due to fear of contracting agent
Resources	Isolation of cases in the healthcare facility
	Decontamination of hospital equipment
	Capacity of laboratory to process samples
	Distribution of limited supplies (drugs, equipment)
	May be other infectious disease outbreaks going on
The Public	Quarantine
	Screening for symptoms (at hospitals, airports)
	Controlling movement (closed borders)
	Closing services (schools, churches, public transportation)
	Psychological fears
	Media relations
Ethics and Law	Mass vaccinations
	Quarantine/restriction of movement
	Allocation of resources
	Demands on healthcare workers, first responders
Terrorism	Balancing epidemiological and criminal investigations

[a] The first three categories (agent, disease, transmission) are unique to infectious disease disasters. The remaining categories (personnel, resources, the public, ethics and law, and terrorism) may apply to other types of disasters, but the challenges listed are unique or particularly applicable to infectious diseases disasters.

disease or well persons who may present to healthcare facilities in the hopes of receiving prophylaxis "just in case" (see Chapter 7). These situations are understandable given the fear of contracting the infectious disease and the desire to protect oneself and one's family. Communication with the public is an important component of the response effort to provide information on the disease and actions to take if people think they have been exposed. Ultimately, effective crowd control, screening, and triage may be necessary to separate infected and uninfected persons.

Transmission of the Infectious Agent

An infectious disease may be contagious. This occurs when the transmission rate (R_0), the average number of secondary cases to which an infected person spreads the disease when no control measures are used, is greater than 1. Some agents, such as *Bacillus anthracis* (the causative agent of anthrax) are not contagious ($R_0 < 1$) and containment of the disaster is dependent on prevention of human contact with *B. anthracis* spores in the environment. Many other infectious agents are contagious ($R_0 > 1$). Pandemic influenza R_0 estimations vary, but most are approximately 2–3.[9] This means that one person with influenza will likely infect two other people. Interestingly, in the case of SARS-CoV, the R_0 was usually approximately 2–4, yet some people appeared to be superspreaders, passing the virus to at least 10 people.[10] This variance in R_0 among different hosts complicates predictions of the magnitude of the epidemic.

The implications of a communicable disease agent for disaster relief are many. Large numbers of afflicted persons could result from a single "emergence" of an agent or from one bioterrorist attack because more and more people are exposed to the agent. Due to travel of infected persons (e.g., SARS in 2003), or environmental factors that influence animal ecology (e.g., hantavirus pulmonary syndrome in 1995), the infectious disease may affect many cities, straining the ability of federal and state agencies to assist in local response efforts. Furthermore, as multiple neighboring public health jurisdictions are affected, communication and collaboration becomes important. If the infectious agent crosses international borders, a global effort may be required to end the spread of disease. This could include travel restrictions, surveillance, and the sharing of resources (e.g., vaccines and antibiotics) and technology (e.g., diagnostics).

The communicability of an infectious agent can also affect the duration of the disaster. Rather than resulting in an acute incident, an infectious disease disaster could last weeks, months, or even years as waves of people are affected in a region or across the globe. Pandemic influenza is predicted to last 18–24 months. The AIDS disaster has lasted for decades. Sustaining disaster relief for years will be challenging – resource utilization, a fatigued healthcare workforce, even changing political administrations, can all affect the response and recovery efforts. As mentioned previously, other infectious disease outbreaks will surely occur, requiring an even greater effort from an already overwhelmed system.

Implementation of the incident command system for disaster relief of an acute event such as a fire delineates when the disaster is controlled and afflicted persons are receiving care. When is an infectious disease disaster over? All too often, a period of days occurs when no new cases are diagnosed, the outbreak is determined to be over, and healthcare procedures return to normal; then, the community is hit with a second wave of cases and healthcare facilities must work quickly to reinstate outbreak procedures. The 2003 SARS epidemic curve for Ontario, Canada

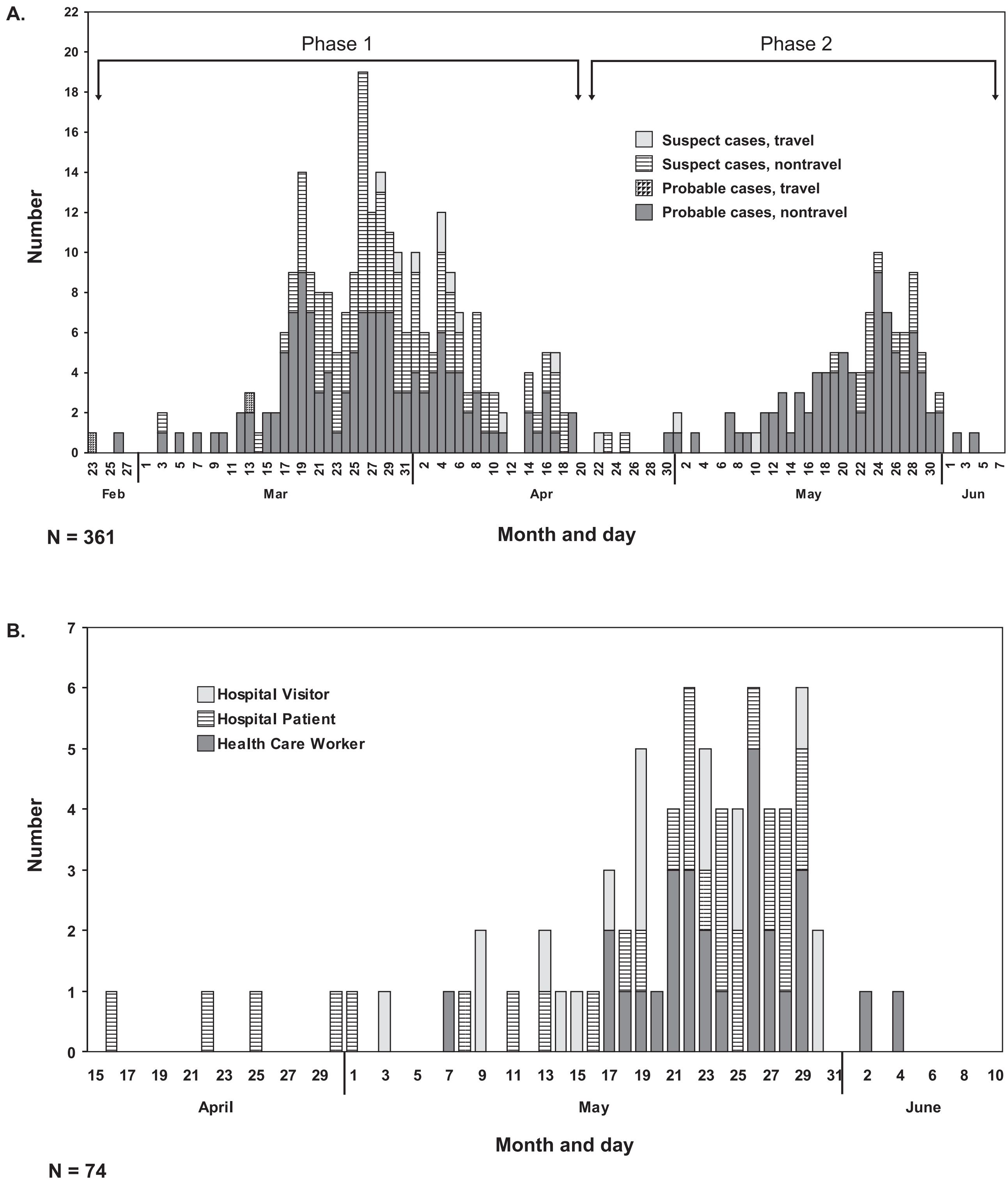

Figure 6.3. Reported SARS cases in Ontario, Canada in 2003 demonstrating the two phases of the epidemic. **A**) Number of reported cases of SARS by classification and date of illness onset – Ontario, Canada, February 23 – June 7, 2003. **B**) Number of reported cases of SARS in the second phase of the epidemic by source of infection and date of illness onset – Toronto, Canada, April 15 – June 9, 2003. Adapted from U.S. CDC.* See color plates.

demonstrates two phases of increased disease incidence (Figure 6.3A). Provincial public health officials had assumed that the outbreak in Ontario was contained at the end of April 2003 because no new cases of SARS were diagnosed after April 20. The World Health Organization (WHO) officials concurred; the travel advisory to Toronto was lifted on April 30 and Toronto was removed from the WHO list of locations with disseminating

* CDC (U.S. Centers for Disease Control and Prevention. 2003. Update: Severe acute respiratory syndrome – Toronto, Canada. MMWR 52(23):547–550.

SARS on May 14, 2003. Ontario health officials relaxed the strict hospital infection control directives for SARS. Days later, the second phase of the epidemic in Ontario began. Apparently, patient-to-patient and patient-to-visitor spread of the virus was still occurring unnoticed at one hospital. When SARS control measures were lifted, viral exposure of hospital workers led to a resurgence of cases (Figure 6.3B). Once again, infection control directives were issued, the hospital ceased admitting new patients, and hospital workers faced restrictions and quarantine. This example stresses a number of points: 1) Surveillance is critical to limiting the spread of an infectious agent in the healthcare setting. All patients and healthcare workers should be monitored for development of symptoms; 2) Decision makers must be wary of relaxing strict infection control measures too soon. Although officials in Ontario and at WHO waited at least 20 days (two incubation periods) before lifting the SARS directives, this action was complicated by the difficulty in differentiating SARS patients from patients with other respiratory ailments; and 3) The psychological toll on affected citizens, and especially healthcare workers, was immense. This certainly was not the first time an epidemic was prematurely declared resolved, and public health officials were trying earnestly to prevent illness and death. The very nature of infectious agents is often unpredictable, especially when the agent is newly emerging. This reality needs to be balanced with the desire to return an overwhelmed staff and system to normal operations.

Food-borne transmission of the infectious agent injects additional facets to the epidemiological investigation. Identification of the contaminated product(s) can involve: obtaining food histories from cases and controls, sometimes weeks after the initial cases surface; extensive laboratory analysis of food and environmental samples; consideration of food distribution networks and trace-backs to food sources; implications on the food industry and consumer perceptions; differences in local, state and national food outbreak surveillance protocols; and ramifications of/to international trade. The 2008 *Salmonella* serotype Saint Paul outbreak, associated with over 1,400 cases in the U.S. and Canada, was first attributed to tomatoes and then to Mexican hot peppers – and has been the subject of numerous hearings and analyses to elucidate the shortcomings in food safety and outbreak response.[11]

Response Personnel

The communicability of infectious diseases poses a unique threat to first responders and primary care providers. Although a radiological attack can result in exposure of healthcare workers, the mechanism and nature of the injuries is well defined and the threat, once identified, can be relatively easily contained and avoided. In contrast, containing an infectious agent in the healthcare setting can be far more insidious – some people may be asymptomatic carriers of the agent, hospital surfaces may be contaminated, and appropriate personal protective equipment may not be in use. The infectious nature itself of a newly emerging pathogen may not even be recognized. All of these factors can result in exposure of healthcare workers to the agent. SARS in Toronto primarily spread in the healthcare setting (72% of cases were healthcare related), and 44% of cases were healthcare workers.[12] In the 1957 influenza pandemic, healthcare workers constituted a large proportion of the infected. The emergence of Ebola-Zaire virus in 1976 devastated the region, including the clinic run by Belgian missionary Sisters. Almost 20 years later, 30% of physicians and 10% of nurses were infected with Ebola-Zaire during an outbreak in the Democratic Republic of the Congo (formerly known as Zaire).[13]

It may be necessary to restrict the movement of individuals in a community to prevent spread of the infectious agent. This is particularly true in the healthcare setting where infectious people will congregate and where immunocompromised patients can be exposed. During the SARS pandemic, many healthcare workers were directed to function under work quarantine. These workers were instructed to go to work or stay home, with minimal contact outside these areas. Many healthcare workers are stationed at different facilities or have more than one healthcare-related job. The movement of workers between facilities could expose many more patients to the infectious agent, yet prohibiting this movement would leave facilities understaffed.

Health professionals are a dedicated group of individuals who adhere to a code of ethics to provide care for the ill and injured (often referred to as "duty to care"); however, the management of infectious disease outbreaks is stressful. The long hours often due to understaffing, high volume of patients, duration of the outbreak, and publicity can have adverse psychological impacts on responders and primary care providers. If the infectious agent is emerging and unknown, highly communicable and/or highly lethal, it is possible that healthcare workers will refuse to perform their duties. In a survey of more than 6,000 healthcare workers, a considerable proportion of respondents said they would be unwilling (or not sure) to report to work during a smallpox (38%) or SARS (51%) event.[14] In contrast, only approximately 15% of respondents said they were not willing (or were not sure) to report to work after explosive or environmental disasters.

The personnel "on call" during an infectious disease disaster are not just the direct patient care staff. Public health staff (nurses, epidemiologists, sanitarians, and laboratory technologists) will be involved from the beginning to determine the extent of the disaster, how to stop the spread of the infectious agent (e.g., mass vaccinations), and to identify the infectious agent source (e.g., a rodent reservoir). These efforts necessitate long work hours for days or often weeks. A second unrelated infectious disease outbreak or disaster could occur during or shortly after the first disaster, requiring the same personnel to act without respite. This protracted demand on the workforce may require recruitment of additional personnel not specifically trained for a particular task to maintain the increased level of service (surge capacity). For example, in the 1995 *N. meningitidis* outbreak in Minnesota, extra people were needed to dispense antibiotics, a job that legally could only be performed by a registered pharmacist until the licensing board provided emergency authorization. Understanding surge capacity is critical to timely, consistent, and effective remediation of the event.

Resources

The availability of resources in public health can be a concern even in the absence of a disaster situation. Recall the long lines, distribution issues, and public attention caused by the 2004 shortage of the seasonal influenza vaccine in the U.S. – the shortage itself became a disaster of sorts. This scenario would be heightened in the event of an influenza pandemic in which disease severity is high and vaccine, if available, will be limited. During an outbreak or epidemic, mobilization of potentially large volumes of preventive and/or prophylactic medicines to the affected area(s) is necessary in a short period of time. Approximately 10,000 courses of ciprofloxacin were required to treat the people *possibly exposed* to anthrax spores in the U.S. in October 2001.[15] The 1995 *N. meningitidis* outbreak in Minnesota resulted in the vaccination of 30,000 people, more than half the population of the town. The vaccine stock was not available locally and it took 2 days to deliver the medication to the impacted area.

If the infectious agent is contagious, healthcare workers and other response personnel at risk of exposure will be required to use appropriate personal protective equipment (PPE). U.S. hospitals use national guidelines for the types of PPE required based on the mode of pathogen transmission (e.g., contact, droplet, or airborne). Details on the types of PPE required for the different modes of transmission can be found at the Centers for Disease Control and Prevention (CDC) website (http://www.cdc.gov/ncidod/dhqp/gl_isolation.html; Guideline for Isolation Precautions in Hospitals from the Hospital Infection Control Practices Advisory Committee). Extra precautions may be recommended when the agent initially emerges and complete information on the mode(s) of transmission is not available. For example, evidence suggested that SARS-CoV was not spread by airborne transmission (characterized by dissemination through the air on small particles); however, healthcare workers were often directed to wear airborne PPE (N95 respirators). Consideration should be given to ensuring that PPE can be used properly in an emergency situation (e.g., some masks need to be fit tested for optimal functioning) and to contingency plans if not enough PPE will be available.

The healthcare workforce is a resource itself. As workers become ill, stressed, or quarantined, fewer people will be available to care for patients (in fact, the number of patients may increase as workers are admitted as patients). Some of the most qualified people to treat disease will be on the front lines at the beginning of the disaster and at increased risk of contracting disease. This may require less experienced individuals from other departments to fill the void. Many healthcare workers died from SARS in 2002 and 2003, including Dr. Carlo Urbani, the WHO infectious diseases specialist in Viet Nam who is credited with discovering the outbreak in that country and taking steps to prevent its spread.

Even with the proper use of PPE by healthcare staff, a contagious microbe can spread in the healthcare setting. Examples of such include from patient-to-patient or patient-to-visitor transmission. Therefore, the isolation of infectious patients to one area of the facility is recommended. This may necessitate extra equipment and supplies dedicated for use in the isolation area. Patients infectious with pathogens spread by airborne transmission (or with emerging pathogens for which airborne transmission is suspected) should be sequestered in negative pressure rooms from which air is filtered before recirculation throughout the facility. There are, however, limited numbers of these units and a large infectious disease disaster may require keeping multiple patients in the same room or even the establishment of facilities committed to treating only infectious patients. During other types of large disasters, patients are often transferred to various hospitals in the region. Although this has been successfully accomplished in some infectious disease disasters (e.g., in Singapore during the SARS epidemic), any patient transfer risks further spreading of the disease and should be undertaken within the context of overall containment strategies. Furthermore, in systems that allow it, neighboring hospitals may refuse to accept patients from hospitals with confirmed cases due to fear of the disease spreading to their own patients and staff. If the original hospital is designated as an infectious disease facility, these other hospitals may be willing to accept nonexposed patients in transfer thereby increasing capacity for contagious patients within the original facility.

Equipment that is used to treat multiple patients, ranging from stethoscopes to ventilators, must be properly decontaminated between patients. This may be particularly difficult for new infectious agents for which effective decontamination protocols are not known. Furthermore, taking equipment out of circulation, even temporarily, may delay treatment of patients.

There are usually two general aspects to mitigating an infectious disease outbreak: the care of patients (to alleviate disease and suffering) and the epidemiological investigation (to prevent further transmission). In both cases, laboratory testing of human and/or environmental samples for evidence of the pathogen is important to ensure the correct intervention strategies are directed to the correct people and areas. Although the increase in the number of patient samples during an outbreak is often expected, the number of environmental samples can be quite large. At times, the magnitude of the testing required is overwhelming to even the larger regional, state, national and international laboratories, whose services are required for large incidents and/or for the testing of certain pathogens. For example, tens of thousands of analytical assays were done on environmental samples in the 1993 hantavirus pulmonary disease epidemic, in the 1999 West Nile virus emergence in the U.S., and in the 2001 anthrax attacks. The response to an EID outbreak may be largely dependent on the local public health workforce but this response may be directly reliant on the capacity of other health departments and agencies.

Finally, it is important to remember that other infectious diseases, either endemic or disease outbreaks, will be occurring while the infectious disease disaster is occurring. These situations may also require the resources needed for the disaster response.

The Public

The 2003 SARS epidemic in Toronto provides numerous examples of the unique considerations for interacting with the public during an infectious disease disaster. The etiology of SARS was unknown initially, but it was apparent that person-to-person transmission was occurring. Therefore, voluntary quarantine measures were implemented, representing the first time in 50 years that such measures were used in North America to control disease transmission in a community. Approximately 23,000 people were asked to adhere to home quarantine (remain at home, wear a mask, have limited contact with family members, and measure their temperatures twice a day) and/or work quarantine. Studies after the epidemic ended suggest that complete compliance to home quarantine requirements was low.[16] Respondents to a web-based survey indicated confusion over the quarantine instructions and inability to contact public health officials for clarification. Furthermore, the quarantine period was necessarily 10 days, a relatively long time for most people to be away from work and community activities.

For this pandemic, it was not necessary to close borders (within and/or between nations) to general travel. Diseases with higher transmission rates, say smallpox from a bioterrorist attack (estimated $R_0 = 10$),[17] may require such stringent measures. Issues to consider are enforcement, the effect on businesses, and the effect on the supply chain for disaster management.

Table 6.5: U.S. Health and Human Services[a] Select Agents and Toxins

Bacteria
Bacillus anthracis (anthrax)
Brucella abortus, *B. melitensis*, *B. suis* (brucellosis)
Burkholderia mallei (glanders)
Burkholderia pseudomallei (melioidosis)
Clostridium species that produce botulinum neurotoxins
Coxiella burnetii (Q fever)
Francisella tularensis (tularemia)
Rickettsia prowazekii (typhus fever)
Rickettsia rickettsii (Rocky Mountain spotted fever)
Yersinia pestis (plague)
Viruses
Cercopithecine herpesvirus 1 (Herpes B virus)
Crimean-Congo hemorrhagic fever virus
Eastern equine encephalitis virus
Ebola virus (viral hemorrhagic fever)
Hendra virus
Lassa fever virus (viral hemorrhagic fever)
Marburg virus (viral hemorrhagic fever)
Monkeypox virus
Nipah virus
Reconstructed 1918 influenza virus
Rift Valley fever virus
South American hemorrhagic fever viruses
Tick-borne encephalitis complex (flavi) viruses
Variola major virus (smallpox) and Variola minor virus (alastrim)
Venezuelan equine encephalitis virus
Fungi
Coccidioides immitis (coccidioidomycosis)
Coccidioides posadasii (coccidioidomycosis)
Toxins
Abrin
Botulinum neurotoxins
Clostridium perfringens toxin
Conotoxins
Diacetoxyscirpenol
Ricin
Saxitoxin
Shiga-like ribosome–inactivating proteins
Shigatoxin
Staphylococcal enterotoxins
T-2 toxin
Tetrodotoxin

[a] All agents are on the U.S. Health and Human Services list. Some agents overlap with the USDA list, which is not completely represented here.

Source: CDC (http://www.cdc.gov/od/sap/docs/salist.pdf).

Institutions within a community where people congregate may require closure, including schools and places of worship.

Whether or not movement or quarantine measures are implemented, public fear and psychological trauma will likely be high for both contagious and noncontagious diseases. This fear will be a function of exposure risk to the agent and subsequent infection, the severity of illness, and the availability of treatment for themselves and their dependents. Media coverage during the disaster can do much either to allay or stoke public fear, depending on perceptions of the mitigation effort and accuracy of the messages.

Ethics and Law

There are many ethical and legal considerations in an infectious disease disaster response. The following issues are given as examples.[18]

- The process of making population-based decisions for infection control during a disaster (e.g., mass vaccinations, quarantine, and movement restrictions) will raise concerns about the legality and necessity of individual rights infringements.
- A scarcity of resources such as vaccines, therapeutics, or hospital equipment will require difficult decisions about who receives the resources and who does not.
- In the event of a disaster caused by, for example, a highly contagious, highly virulent, uncharacterized, and/or genetically engineered agent, to what extent should first responders and healthcare workers be expected to comply with duty to care orders for the public good?

Terrorism

This chapter will not elaborate on preparedness specifically for bioterrorism events because disease, as well as transmission management, will essentially present itself similarly to other microbial threats. Bioterrorism is addressed in Chapter 29. The criteria to be considered will include most of those already described, albeit some will be particularly relevant (e.g., public fear, the number of affected areas, and laboratory capacity). The U.S. Department of Health and Human Services (HHS), specifically the CDC, maintains a list of select agents and toxins that are likely candidates for use as bioweapons against human beings (Table 6.5). Many of the agents on this list, including the anthrax spores released in the U.S. postal system in 2001, smallpox, and the hemorrhagic fever viruses, are not commonly seen by the medical community in the Western hemisphere. A bioterrorist may use an agent that has been genetically engineered to be highly virulent, resistant to therapeutics, and/or to cause a novel disease. In these cases, health professionals will be at a further disadvantage to prevent disease and death.

> As with every terrorist attack, a criminal investigation should ensue after a bioweapon is used. In other types of attacks, this investigation begins immediately after the actual incident has occurred (e.g., an explosion) during the aftermath and rescue efforts. When a bioweapon is used, it may be days or longer before exposed people develop symptoms. Depending on the agent used, it may be an even longer time before a crime is suspected. The site or mechanism of the actual agent release may never be known. If the agent used in the attack occurs naturally in the region, foul play may not even be suspected. Table 6.6 lists some clues that suggest an outbreak could be due to criminal activity. Although the criminal investigation will focus on finding the perpetrators of the attack, a second investigation – an epidemiological investigation – will be progressing as well to determine the cause and spread of disease. Both investigations will require sample analysis and interviews with the public and must progress without hindering each other.

Table 6.6: Indications that an Infectious Disease Outbreak in the U.S. May Be due to a Bioterrorist Attack

Category	*Indication of Bioterror Attack*[a]
Agent	The disease or agent is not usually seen in the region (e.g., smallpox anywhere in the world; plague caused by *Yersinia pestis* on the East Coast of the U.S.).
	Multiple geographically distant areas have disease outbreaks occurring at the same time due to a genetically identical strain of an agent. (e.g., identical *Francisella tularensis* strain causes outbreaks in Washington, DC, St. Louis, MO, and Las Vegas, NV) Note: unintentional food-borne outbreaks may display this incidence pattern if the contaminated product is widely distributed.
	Genetically engineered to be resistant to multiple antibiotics, particularly those commonly used to treat disease (e.g., ciprofloxacin-resistant *B. anthracis*).
	Genetically engineered to cause a novel disease for that agent (e.g., incorporation of genes that cause symptoms of a chronic disease).
	Genetically engineered to be more virulent than usual (e.g., incorporation of genes for toxin production; reconstructed 1918 influenza virus).
Host/Environment	Larger number of casualties in a region in a short period of time compared to expected incidence.
	Cases do not have risk factors for exposure (e.g., brucellosis cases without known exposure to contaminated foods or infected animals). This may indicate an unconventional infection route, such as aerosolization of the *Brucella* pathogen.
	Cases may have risk factors for exposure, but no common exposures (e.g., all salmonellosis cases ate from restaurant salad bars, but they ate different foods at different restaurants).
Environment	Case distribution and/or environmental distribution of the agent follow wind trajectories (e.g., accidental release of anthrax spores in Sverdlovsk, USSR in 1979).
	Other types of attacks (e.g., chemical, radiological) occur at the same time.
	More than one outbreak (with potentially larger numbers than usual) in a region caused by different agents, especially if one or more agents is uncommon.
	An outbreak of disease in an unexpected season, or that does not follow usual global incidence trends (e.g., SARS in August in the U.S. without cases in other countries).

[a] More than one indication may be present after an attack.

The amount of microbiological sampling after an act of bioterrorism will likely be extensive. Contaminated areas could have very high concentrations of the bioweapon, risking cross-contamination of personal protective equipment and transfer of the agent to other surfaces in the area or other regions. The criminal investigators must take precautions to avoid contracting disease. In the 2001 U.S. anthrax attacks, investigators had to develop microbiological methods specifically for dried spores. Still, handling the most contaminated samples, including both the attack letters and cross-contaminated letters, created aerosolized spores and a very hazardous situation.[19]

STATE OF THE ART

As with other types of events, the response to an infectious disease incident of any origin is only as effective as the monitoring and relief infrastructure in place. After the 2001 anthrax attacks, the U.S. entered a period of heightened awareness of infectious disease threats. An era of preparedness ensued, with the U.S. Congress allocating unprecedented sums of money to enhance the response to bioterrorism. The immediacy for response action plans was amplified by the 2003 emergence of SARS* and the threat of pandemic influenza. These events have highlighted the possibility of a large infectious disease disaster and broadened the scope of many preparedness plans.

Preparedness is the state of being ready to act. In the infectious disease disaster context, it broadly refers to the ability to detect a pathogen, act to prevent its spread, and mitigate disease in humans (or animals or plants). Accomplishing this is no small task, given the large number and variability of pathogenic microbes, the potentially rapid global spread of disease, and the extent of communication required between individuals, agencies, governments, and nations. Furthermore, the working definition of "infectious diseases disaster preparedness" and the mechanisms and priorities to achieve it can vary widely between jurisdictions and nations. Because the exact nature of the infectious disease in a disaster situation cannot be known in advance, current planning procedures are largely dependent on assessment and subsequent remediation of response vulnerabilities (often identified from previous events and practice exercises).

Figure 6.4 shows a general schematic of selected response stakeholders and the activities that occur before, during, and after a biological incident. While not all inclusive, the diagram serves to illustrate 1) the ongoing nature of EID preparedness, surveillance and response, 2) the complexity of the response, 3) the overlapping responsibilities of stakeholders, and 4) the current "feedback" approach to EID preparedness. The light grey circle just outside the heavy black line (designated "Biological Incident Occurs") diagrams the "incident threshold." This circle

* LeDuc JW, Barry MA. SARS, the first pandemic of the 21st century. *Emerg Infect Dis*. 2004 Nov. Available at http://www.cdc.gov/ncidod/EID/vol10no11/04-0797_02.htm. Accessed January 13, 2009.

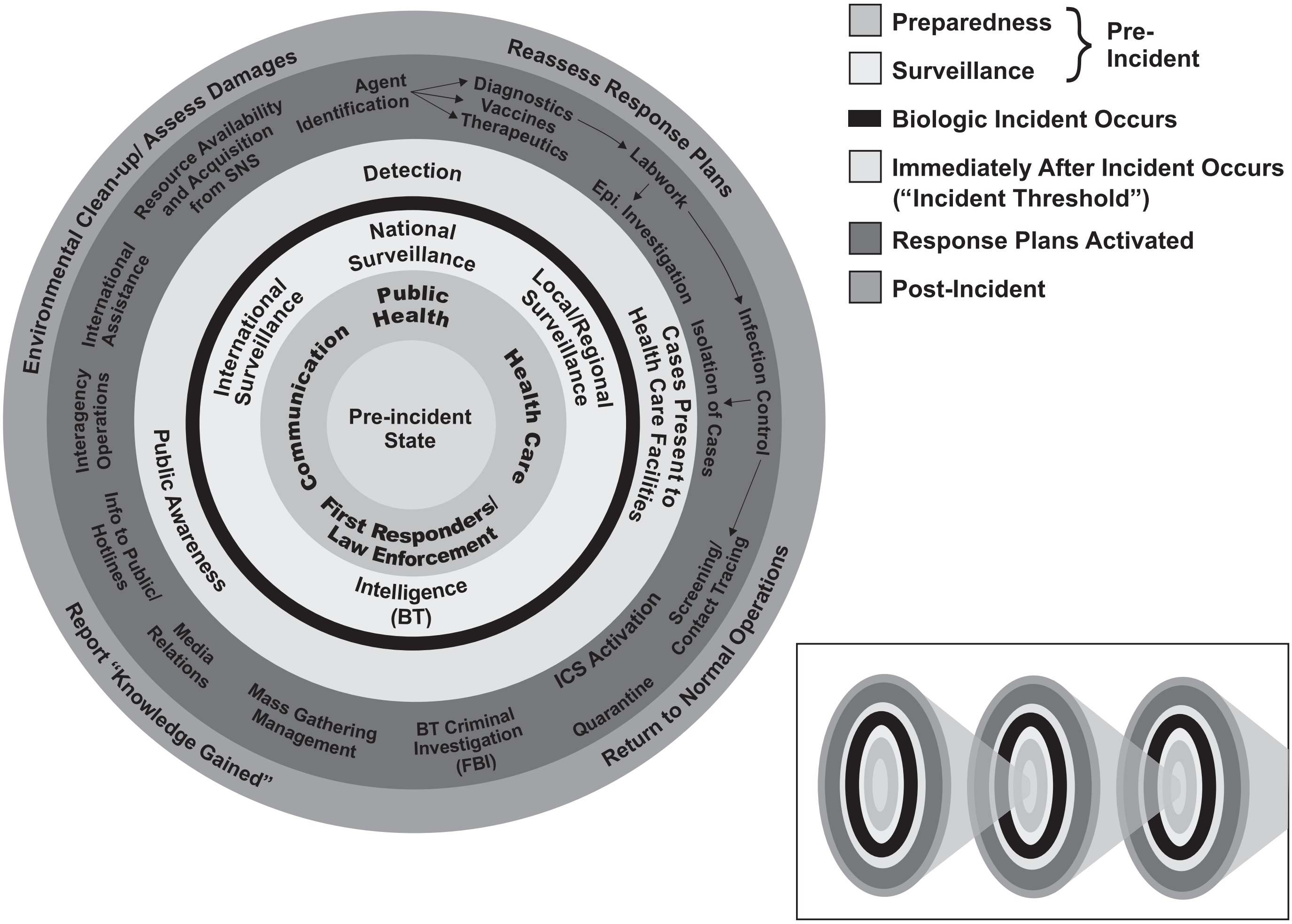

Figure 6.4. Schematic of events before and after a biological incident. “Incident” refers to the exposure of a population to a newly emerging disease (e.g., SARS), to an infectious disease with the potential for extensive casualties and/or public fear (e.g., *Neisseria meningitidis*), or to an act of bioterrorism. Represented are examples of the factors that need to be considered before, during, and after an incident. Increased size of the concentric circles generally corresponds with the progression of time; however, events in larger circles may “feed back” on smaller circles. The use of circles symbolizes the interconnectedness of entities and events within each ring.

The center of the diagram (“Preincident State”) represents the situation prior to a biological incident; during this phase, the various response stakeholders (e.g., Public Health, Healthcare, First Responders/Law Enforcement and Communications) enhance preparedness by, for example, improving response plans and participating in practice exercises. This aims to fortify comprehensive preparedness plans (second ring labeled “Preparedness”) and surveillance activities (third ring labeled “Surveillance”). The heavy black line represents the occurrence of an actual biological incident. After this happens, a period of time ensues when response stakeholders should become aware of the incident (fourth ring labeled “Incident Threshold”), either by active detection through surveillance efforts or passively by presentation of cases to healthcare personnel. Depending on the agent, the incident may not be initially apparent. This time between the occurrence and detection of an incident is the “incident threshold.” Response plans are activated (fifth ring labeled “Response Plans Activated”) when the incident is recognized. Some elements of the response are shown to illustrate the types of actions the preparedness stakeholders may need to take. This includes agent identification and development of diagnostics/vaccines/therapeutics, activities that will not be timely for an EID unless solid scientific programs are in place in the Pre-incident State. The events in the final circle (sixth ring labeled “Post-Incident”) largely occur in the post-incident phase when disease transmission has been controlled and no new cases are detected. Some actions such as the clean up of environmental contamination may initiate sooner to prevent disease transmission. Disaster mitigation efforts are analyzed in the post-incident phase. “Knowledge Gained” is used to optimize preparedness plans for the next potential biological incident (this flow of information is symbolized in the inset). Effective planning and surveillance in the circles before an incident occurs can reduce the incident threshold time and make the events of the subsequent circles easier to manage. See color plates.

represents the time it takes for detection of the biological incident (during which time agent transmission progresses essentially unchecked), and can determine the extent of response measures necessary. This section of the chapter discusses the components of infectious disease preparedness that aim to facilitate response activities and minimize the duration, disruptiveness, and impact of the incident. The text uses the U.S. perspective to illustrate one approach to EID preparedness. Other countries may address these issues differently. Nonetheless, the section highlights some of the considerations for infectious disease disaster preparedness.

Disaster Response Plans

As the aftermath of hurricane Katrina in the U.S. has demonstrated, a large event can overwhelm a response system. The predicted characteristics of infectious disease disasters outlined in the previous section, coupled with evidence from past incidents, serve as tools for understanding the challenges of the next EID disaster. Questions such as "who is in charge?" and "how well do different jurisdictions interact?" have been the subject of many workshops, symposia, and planning meetings that have occurred at local, regional, national, and international levels.

Local, State, and National Systems

The response effort to an infectious disease outbreak usually begins with local authorities as the first cases of disease are reported. Therefore, local preparedness plans can do much to prevent dissemination of the infectious agents to other regions. This is particularly important in the event of a bioterrorist attack when more than one locality may be affected at the same time, straining national and international assistance mechanisms. In response to the terrorist events of 2001, the U.S. government appropriated over a billion dollars to the states to augment disaster preparedness. The CDC Public Health Emergency Response Guide suggests that each local jurisdiction and state should have a general incident response plan in place that establishes the following: working relationships between local public health partners (e.g., health departments, emergency management agencies and services, fire and law enforcement, hospitals and their emergency departments, volunteer/aid organizations, emergency planning committees and response coordinators, academic institutions, private businesses, and neighboring health jurisdictions), risk and hazard assessments for the area, a risk communication plan, resource and surge capacity, operational objectives, procedures and guidelines for action during a disaster that are in line with the Department of Homeland Security (DHS) National Response Framework (NRF) and the National Incident Management System (NIMS), surveillance systems to monitor public health, a trained public health workforce (e.g., on proper use of personal protective equipment, emergency operations procedures, incident command system), and exercises to evaluate and review response plans. Specific plans for biological incidents should address operations in the event that the agent spreads to or from neighboring jurisdictions.

At the time of this writing, within the U.S. system, Federal aid for Incidents of National Significance is meant to supplement the local and state response and is considered for distribution upon request by the state using the NRF. The NRF is structured in the framework of the NIMS, a unified command approach to disaster response that directs different organizational branches as required. Federal funding to support state, local, and tribal preparedness plans is dependent on NIMS compliance. The "all-hazard" approach of the NRF necessarily gives broad guidelines for the organization of the response so that procedures apply to many situations. The NRF also outlines more specific considerations for certain types of incidents; for example, depending on the nature of the incident, certain Emergency Support Functions can be implemented. The Biologic Incident Annex "describes incident management activities related to a biological terrorism event, pandemic, emerging infectious disease, or novel pathogen outbreak."[20] This Annex, coordinated by HHS, evokes primarily the Public Health and Medical Services Emergency Support Functions. This entity defines the core functions for supplemental federal aid to be the assessment of public health and medical needs, public health surveillance, medical care personnel, and medical equipment and supplies. The Biologic Incident Annex also delineates special considerations (e.g., surreptitious nature of a bioterrorist attack, the importance of surveillance systems), policies (e.g., collaboration with the Environmental Protection Agency in the case of environmental contamination, involvement of the Federal Bureau of Investigation [FBI] during a bioterrorist attack), concepts of operations (e.g., effective response elements such as detection and containment), and planning assumptions (e.g., multiple jurisdictions may be affected, disease transmission mode is important) that are unique and/or fundamental to a biological incident response.

An important distinction between typical infectious disease disasters and many other disasters is the lack of a specific and immediately recognized incident initiation point (rather, there is an "incident threshold" period). With the notable exception of the anthrax letter terrorist attacks in the Fall of 2001 (which behaved more like discrete chemical incidents), by the time a biological agent is detected in the U.S., many people in diverse areas may be affected. The response plan initiates well after media involvement, public awareness, and possible maladaptive behavior have occurred. Biological incidents also have the potential to spread to the international community. In this case, the U.S. Department of State becomes involved in conjunction with HHS to alert international health agencies such as the WHO of the outbreak. This action should occur early in the disaster response effort to help prevent global spread of disease.

Within the U.S., many local jurisdictions have improved neglected infectious disease surveillance and response networks since receiving the federally allocated funds. There is a tendency to formulate broad goals and intentions for preparedness however; distinct plans at the local level are often not formed due to lack of information, lack of consensus, and/or lack of priority standing. Practice exercises still uncover lapses in communication and resource allocation. Furthermore, the specifics on when to enact the NRF for federal aid have proven to be confusing. Hurricane Katrina in 2005 occurred shortly after the NRF was established (then known as the National Response Plan), but controversy on when to "federalize" the response was rampant and public. Criticisms of the response have focused on inadequate communications, including the failure of federal officials to declare the hurricane a "Catastrophic Incident" that supersedes a state request.[21] In any case, data from the Hurricane Katrina response can be analyzed to better enact the NRF in the event of a biological incident. For example, the U.S. CDC is using the Hurricane Katrina response to plan better for the response to pandemic influenza (CDC website).

Hospital Emergency Management Systems

Hospitals should be aware of the unique aspects of large infectious disease outbreaks that could compromise the usual functioning of a disaster management system. These include the transmissibility of the infectious agent to persons not involved in the initial outbreak, the protracted nature of the incident as the agent spreads through the community, and the possibility of infection and absenteeism in hospital staff. Contagious agents necessarily confer an environment of population-based decisions to prevent widespread transmission to the community, which differs from the individual-based care customary of critical care and emergency medicine.

Hospitals should be prepared to operate using an Incident Command System (ICS) during an infectious disease disaster situation. Functioning within an ICS has the advantages of a pre-event determined assignment of roles, ease of coordination of multiple facility responses, and scalability of the response as the disaster progresses or is resolved. Within the U.S., facilities that receive medical and trauma patients on a daily basis are required to be NIMS compliant, which allows for the coordination of response efforts on a national level. Compliance includes the implementation of a number of elements in the areas of command and management systems, preparedness planning, workforce training, preparedness exercises, resource management, and communication and information management.[22] Within these areas, hospitals and healthcare facilities must plan for possible bioterrorism or large-scale infectious disease events. For these types of disasters, infectious disease specialists and infection control experts should be included in the incident command organizational chart to provide guidance on the management of potentially infectious patients with respect to triage, care, further assessment, and the handling of infectious decedents.[23]

An important component of the hospital response to a communicable disease is infection control policies to prevent the spread of the agent to healthcare workers. Hospital ICS plans for communicable disease disasters must assume that a proportion of the people in the command structure will be unavailable for duty due to illness or the need to care for ill family members. Preparedness includes a mechanism for real-time alternative assignments for each role in the command structure. Hospital infection control may also result in the temporary discontinuation of elective procedures. With adequate prior training, personnel from these areas can be diverted to critical response areas that are overwhelmed.

In an infectious disease disaster situation, potentially exposed persons will present to many hospitals in a region. A coordinated incident command Emergency Operations Center for all hospitals in a region is a particularly relevant system given the issue of resource availability; however, cooperation between facilities may be limited. Hospitals not yet affected by the disaster must balance the responsibility to assist in the emergency and accept patients with the need to prevent spread of a contagious agent. Transfer of resources such as ventilators and prophylactic medications to overwhelmed facilities may also be hindered because hospitals not yet involved anticipate future casualties. Therefore, hospital preparedness plans for mass casualty bioevents should also include response actions in the situation of limited outside assistance. Additional recommendations have been published on infection control, the types of interventions to use, deciding who should be treated, and who should administer care.[24] These recommendations, although developed for an intentional attack, can guide planning for all types of infectious disease disasters.

Admittedly, the need for extensive infectious disease disaster management plans has been publicly debated. Arguments have been made that the threat of an infectious disease disaster with a high human toll, such as pandemic influenza, is greatly exaggerated. Modern day medicines and technologies have provided an arsenal against microbes not available during historical epidemics. Yet this is hard to gauge for novel pathogens, including new pandemic influenza strains. Nonetheless, some assert that the constant barrage of reports on the lack of preparedness only serves to either reduce public confidence in the event that any infectious disease outbreak occurs or fosters an atmosphere of complacency.[25] SARS is often used as an example: public concern and economic loss were extensive, but there were only approximately 8,000 cases and 750 deaths worldwide. It would seem that the world overreacted. Recall, however, that the causative agent, transmission rate, treatment, and mortality of this new respiratory infection were not known at the beginning of the pandemic. During this time of uncertainty, global spread occurred only weeks after international awareness of a new disease. Fortuitously, the SARS-CoV was not as infectious as initially thought. This pandemic serves as a warning that preparedness plans are necessary, especially in the event of an EID with high transmissibility.

Mechanisms to Prevent Disease Transmission in the Community

Specific actions taken by responders during an infectious disease disaster will depend on the nature of the agent. In general, the transmission rate will determine the extent of the measures necessary for containment. Of course, this may not be known at the beginning of an EID outbreak and will have to be predicted from epidemiological data on the initial cases. In the event that the agent is transmissible from person to person, mechanisms of varying degrees of restriction can be implemented. The concepts of isolation, quarantine, evacuation, shelter-in-place, and social distancing are important containment strategies. Whether these measures are implemented in a voluntary or mandatory fashion will depend on the agent and on legal and ethical considerations. Control of a contagious disease may also require contact tracing, which involves identifying and locating the people with whom an infectious person has come in contact, and the mass distribution of prophylactic medication or vaccination if available. Implementing controls at national borders to prevent inbound travelers from importing the infectious agent are an option but may be very difficult in some countries and may not be highly effective. Models of pandemic influenza in the U.S., for example, suggest that even if incoming infections were reduced by as much as 99%, this would only delay peak disease incidence by approximately 3 weeks.

Some infectious disease outbreaks may require rodent or arthropod control programs to eliminate reservoirs or vectors that carry the agent. This can be challenging for EIDs of unknown (or mistaken) etiology. An outbreak of suspected St. Louis virus encephalitis in New York in 1999 prompted mosquito control and public education activities. Experts soon realized that the encephalitis cases were actually caused by West Nile virus, a closely related virus that is transmitted by a broader range of mosquitoes. The initial intervention strategies were expansive enough to be constructive but were optimized with the new diagnosis to the different habitat and activity patterns of West Nile virus–carrying mosquitoes.[26]

Control of zoonotic diseases may require extensive elimination of animals of agricultural importance. The emergence of Nipah virus in Malaysia and avian influenza in Asia in the early 2000's resulted in the slaughter of millions of pigs and fowl, respectively.[27,28] Although arguably necessary to prevent disease transmission to humans, this type of activity can have many negative consequences. Economically, segments of the agricultural industry may be devastated due to decreased production, costs of disease containment and clean-up, trade embargoes, and reduced consumer confidence. Associated industries such as transportation, suppliers, and food service would be affected. Public reaction to an extensive or prolonged slaughter may put political pressure on decision makers to develop other methods for disease control.

Science and Technology

Scientific advances in molecular biology over the last half century, and particularly in the last 20 years, have greatly benefited infectious disease public health. The successes of the core goals of public health in any infectious disease disaster, namely detection of an outbreak, prevention of its transmission, and mitigation of disease, are all functions of the body of scientific knowledge on the pathogen and the technological capabilities to translate that knowledge into action. In the case of an EID, this specific kind of knowledge may initially be sparse. This highlights the need for solid work in basic infectious disease biology, because EIDs will likely (but not always) be novel strains or species of known infectious agents.

Basic scientific research on the bioterrorism potential of select agents has increased dramatically in the last few years, providing insight into their pathogenic mechanisms. These advances can lead to the discovery of targets for novel countermeasures and/or to new diagnostic tools. Some critics have suggested that extensive funding for specific select agents is detrimental to preparedness goals. Biodefense research needs to be translatable to infectious diseases in general, and to public health policy.

Identification and Characterization of the Agent

Standardized techniques, such as microscopy and cultivation, are very useful in determining the nature of the agent (e.g., the type of bacteria) and whether any known therapeutics are active against it. Further genetic and molecular analyses, including polymerase chain reaction and immunofluorescence techniques, can differentiate the agent from other similar microorganisms. Along with these types of assays, genome sequencing (the identification of the nucleic acid composition of the organism's entire DNA) can determine if the etiological agent is a previously identified pathogen or if it is a novel pathogen and newly emerged. For example, the SARS coronavirus was only distantly related to other known human coronaviruses (an etiological agent of the common cold) and produced a very different disease, so it is considered to be a newly emerged variety of this type of virus.[29]

Obstacles to rapid and definitive identification and characterization of a novel agent are many. Known animal models may not exist, precluding the ability to show that the isolated agent does indeed cause disease. Culturing techniques to grow microbes in the laboratory are very specific for different types of agents, even within the same genus. Due to the unknown nature of transmission and disease severity, specialized containment labs with specifically trained staff may be required. Many regional testing laboratories do not have the equipment or experience to conduct molecular testing.

Diagnostic Assays

Diagnostic assays are important to quickly identify new cases of disease, to differentiate between cases and noncases with similar symptoms, and to determine environmental sources of the pathogen. Genetic tests are often developed due to the rapidity and relatively high analytic sensitivity (ability to detect small amounts of the agent) and analytic specificity (ability to differentiate the agent from other organisms) of the results compared with conventional laboratory techniques. Time is often required to create these assays. During an EID situation, significant pressure exists for rapid development of diagnostics so that clinicians and epidemiologists have a tool to identify new cases. These first-line diagnostics are useful, but they may have a higher risk of producing false-negative and false-positive results.

Therapeutics

Antimicrobial drug discovery waned in the 1960s when pharmaceutical companies turned their attention from the supposedly declining threat of infectious diseases to the more pressing and lucrative concerns of chronic illnesses. Now, in the face of increasing antimicrobial resistance and emerging agents, new therapies are needed. Scientists are using molecular and structural biology techniques to understand microbial pathogenesis. This information can enhance approaches to discovering novel classes of drugs that block pathogenic processes. The drive for the discovery of new drugs effective against bacteria and viruses has not been an industry priority, however. From 1998 to 2003, only nine new antibacterial drugs were approved, the same number as those approved for just one virus alone, HIV, in the same period. More important, only two of the nine antibacterial drugs had novel mechanisms of action.[30]

Emerging agents provide a unique challenge for therapeutic design. As noted previously, treatment options for EIDs may be limited, with even broad-spectrum antimicrobial drugs having little or no effect. Information is learned about the causative agent and the disease as the outbreak or epidemic progresses but using conventional therapies (such as specific immunomodulating factors) that work for similar diseases is risky without efficacy studies. In a systematic review of more than 50 published studies that assessed treatment efficacy during the 2003 SARS pandemic, no therapy (including antivirals, corticosteroids, intravenous immunoglobulin, convalescent sera, and type I interferon) conclusively improved patient outcomes. In fact, some studies reported possible harmful effects of treatment with ribavirin or corticosteroids.[31] The development of novel drugs for an EID is challenging. Even if a molecular target is discovered, the design, development, and approval of a therapeutic agent would not be rapid. For example, in the U.S. it takes approximately 8 years for a new drug to complete clinical trial phases, gain approval, and be marketed. Furthermore, factoring in the relatively low numbers of cases of an EID initially, the chance that the epidemic will end with no further cases, and the high cost of drug development, pharmaceutical companies would be unlikely to even initiate the discovery process without government intervention and/or incentives.

Vaccines

Vaccines are one of the most successful public health tools to improve the health of populations. By preventing infectious diseases, vaccines limit human suffering and the spread of contagious agents. There are many infectious diseases that are endemic in parts of the world for which no vaccines are available. Finding mechanisms to produce effective vaccines is the subject of extensive basic research. Molecular and genetic advances have vastly improved the understanding of immune system regulation and of vaccine delivery methods. Translating this knowledge into approved vaccine products has been slow for numerous reasons. In some cases, the knowledge base on the infectious agent simply is not advanced enough to make a vaccine. For example, some viruses have high mutation rates; consistent vaccine efficacy is difficult because mutated forms of the viruses arise that are not affected by vaccine-enhanced immune functions. As with therapeutic development, pharmaceutical companies are hesitant to engage in vaccine design. The return on investment is relatively low, demand for vaccines that target sporadically occurring agents is unpredictable, some vaccines for endemic diseases are not extensively used (e.g., yellow fever in Africa and South America) and safety and liability issues abound.

Government Incentives

After the terrorist attacks of 2001, the U.S. federal government implemented Project BioShield to "accelerate the research, development, purchase, and availability of effective medical countermeasures against biological, chemical, radiological, and nuclear agents" (HHS website). The three main goals of Project BioShield are to 1) provide funding for the procurement of critical medical countermeasures, 2) give authority to the National Institutes of Health of HHS to prioritize the granting procedure for research and development of medical countermeasures, and 3) assist in the use of medical countermeasures during an emergency. BioShield lays the groundwork for increased vaccine and drug development for bioterrorist agents. Major pharmaceutical companies have not utilized this funding system due primarily to concerns about liability protection for expedited countermeasures that cause human harm. Funding smaller biotechnology companies can help fuel an industry, but the risks for both parties involved are greater. Some companies may not be able to produce the contracted pharmaceutical after receiving federal funding or the government may opt to purchase less of the product than expected.

The U.S. pharmaceutical industry needs motivation beyond Project BioShield to expand antimicrobial therapeutic and vaccine development. In this regard, the Pandemic and All-Hazards Preparedness Act was approved in December 2006. This Act directs the formulation of the Biomedical Advanced Research and Development Authority (BARDA) within the Department of Health and Human Services. BARDA is charged with promoting the translation of scientific research into antimicrobial products, including provisions to induce participation by the pharmaceutical industry. The creation of BARDA is not without controversy. Consumer advocacy groups question the safety of using expedited drugs even in emergency situations. Scientific associations are concerned about the lack of transparency of BARDA activities and decisions, the potential for gaps in or duplication of research efforts, and funding sources and amounts.[32]

Dual-use Risk

The 2001 anthrax attacks in the U.S. made the fear of a bioterrorist attack a reality. To increase preparedness against future attacks, the American government has allocated billions of dollars for biodefense research and development on certain pathogens (Table 6.5). Policymakers realized, however, that increased research on select agents could increase the risk that the agents, or scientific information learned about them, would fall into the hands of terrorists. As a result, measures have been taken through the Biopreparedness Act to limit access to the select agents, regulate genetic manipulations of these agents, and restrict publication of information that could lead to enhanced virulence of the select agents. The Biopreparedness Act also mandates FBI clearance rules for scientists working with select agents. The National Science Advisory Board for Biosecurity was formed to oversee the balance between increasing scientific research to prepare better for a bioterrorist attack and preventing potential adversaries from accessing scientific reagents and information.

Surveillance

Surveillance systems function in an ongoing capacity to "collect and monitor data for disease trends and/or outbreaks so that public health personnel can protect the nation's health" (CDC website). There are four basic components to surveillance: monitoring for disease, detection of disease, analysis of data, and dissemination of findings. The sooner the detection of an infectious disease outbreak or emergence occurs, the faster the response can be to prevent spread of the agent and human disease. In addition, early detection can prevent the dissemination of the pathogen to other regions or countries and potentially prevent an epidemic or pandemic situation.

Surveillance is also an assessment tool for the general functioning of a public health system. Monitoring disease incidence, morbidity, and mortality can indicate regions that must boost existing public health infrastructure. These regions would be more likely to suffer greater casualties during an infectious disease disaster.

National Surveillance Efforts

Healthcare practitioners play a central role in the surveillance process by notifying public health authorities regarding patients with reportable diseases or atypical symptomatology. For example, U.S. physicians in the early 1980s noticed that young men were contracting *Pneumocystis carinii* pneumonia and/or certain malignancies not normally associated with that demographic group. This was one of the first indications that a new immunocompromising infectious disease (now known as AIDS) was circulating in the population.

This classic method of outbreak identification is a key component of disease control in a population, but relying on it solely is problematic. Recognition of cases that should be reported and subsequent data submission are not always timely. There is heavy reliance on subjective determination of what should be communicated to public health and not all infectious diseases are reportable. Furthermore, early surveillance opportunities that could potentially prevent human disease and death may be missed. In the first North American outbreak of West Nile virus in 1999, unexplained bird deaths had been noticed 2 months prior to the human outbreak investigation, but no extrapolation was made to possible human consequences.

Recognizing the value of time, many health departments, health agencies and governments have developed a number of surveillance systems and networks to more rapidly and consistently detect disease events. Examples of the types of systems include 1) those that monitor the environment for the presence of bioterrorism agents (e.g., BioWatch in the U.S.), 2) those that collect data from different regions to monitor and provide assistance for infectious disease cases (e.g., the U.S. CDC's Early Warning Infectious Disease Surveillance program for northern and southern border states), and 3) syndromic surveillance. Typical syndromic surveillance systems analyze health data prior to disease diagnosis, such as diagnostic coding or over-the-counter drug sales, to give early indication of a possible infectious disease outbreak (e.g., BioSense, ESSENCE). Major challenges to effective national surveillance systems are interagency operations, data integration, and validity testing. These types of problems can be overcome if prioritized, as exemplified by the highly developed U.S. national response network for food-borne outbreak surveillance (FoodNet) and agent characterization (PulseNet).

International Surveillance Efforts

Globalization has conversely made international infectious disease surveillance both increasingly necessary and possible. Emerging infectious agents can arise in any country and potentially spread globally due to travel and commerce. Clearly, quick identification of when an outbreak emerges will give public health officials, clinicians, and researchers throughout the world an opportunity to prevent dissemination and to develop diagnostics and therapeutics. Increased global interactions, which can promote spread of a disease agent, can also encourage cooperation in surveillance efforts.

Disparities exist in the capabilities of different countries with respect to workforce, tools, and effort. Many developing countries have a strained public health infrastructure that cannot extend to support intensive surveillance efforts. Therefore, global partnerships that link networks from many regions and countries, such as those supported by the WHO Member States, can serve to share expertise and information.

Reporting compliance is a necessary component of global surveillance. Some countries may delay reporting a disease outbreak to avoid stigmatization and negative impacts on travel and trade. Others may believe that an outbreak is under control and of little threat for further spread. Although cases of SARS first appeared in Guangdong Province in November 2002, Chinese officials only confirmed the outbreak to the WHO in February 2003 after international surveillance networks were alerted through media and Internet reports.[33] Chinese public health officials worked with the WHO to control the outbreak, but international dissemination had already occurred. In response to the SARS pandemic, the Chinese government has overhauled its infectious disease surveillance and reporting systems. Of course, the public health infrastructure problems that delayed the Chinese response are not unique to that country, substantiating the need for international collaborations to detect EIDs and support mitigation efforts. In May 2005, the World Health Assembly adopted the International Health Regulations (2005)[*] – international law that provides a framework for enhancing the surveillance, assessment, notification, and control of public health emergencies of international concern, while limiting unnecessary interruption of global traffic and trade. In general, State Parties to the IHR (2005) became bound by the agreement on June 15, 2007.

Workforce Preparedness

Workforce preparedness is the state of readiness of public health, public safety, and healthcare employees to act in an infectious disease emergency. Workforce readiness is primarily related to workforce capacity and education/training. The concept is often used to describe readiness at the community and state level, but EID or large biological incidents will likely require participation on a national level as well. The jobs performed by these employees are critical to the proper and sustainable functioning of the other preparedness requirements such as surveillance and resource management. Furthermore, practice exercises and past disasters have demonstrated that the response and mitigation effort is improved by good working relationships between public health, public safety, and healthcare workers.

Public Health Workforce

Inadequate public health workforce numbers and expertise are not limited to developing nations. For example, it is well established that decades of budget cuts and neglect have resulted in an understaffed public health infrastructure in the U.S. This has compromised the ability to respond effectively during an infectious disease disaster. In some jurisdictions and facilities, especially smaller ones, the roles of public health nurses, laboratory technologists, epidemiologists, and infection control practitioners are accomplished by staff with multiple duties. Furthermore, these positions are often characterized by staff who are reassigned when needed, by employees working overtime, and/or by the use of temporary workers. These options will be limited during an infectious disease disaster as demand for these employees will increase and movement between facilities will be restricted.

Formal education of public health workers in the U.S. for epidemic situations largely rests on the CDC. The Epidemic Intelligence Service (EIS) is probably the most well-known program. For more than 50 years, the EIS has trained public health professionals with hands-on field experiences in epidemiology. CDC Public Health Leadership Institutes, provided in partnership with academic institutions, groom public health workers for leadership positions at the state and local level and promote networking between jurisdictions. In 2000, the Association of Schools of Public Health and the CDC established a network of 38 Centers for Public Health Preparedness in academic institutions to train the public health workforce in such fields as disaster epidemiology, emerging biological threats, and volunteer training. Collaborations between the Centers for Public Health Preparedness, CDC, and the National Association of County and City Health Officials are encouraging preparedness learning for public health workers in local governments.

Laboratory technologists are a fundamental part of the infectious disease disaster response team. Timely surveillance, detection, and diagnosis are all dependent on laboratory services and can reduce transmission and disease severity during an infectious disease disaster. Chronic underfunding has left many public health laboratories understaffed. As demonstrated by the 1999 West Nile virus emergence, 2001 anthrax attacks, and 2003 SARS pandemic, the laboratory workforce can quickly become overwhelmed with samples. The Association of Public Health Laboratories Emergency Preparedness and Response Program is charged with preparing laboratories for the increased demand of services in the event of a major disaster. The U.S. CDC implemented the Laboratory Response Network in 1999 to act as a networking platform for laboratories (local, state, federal, international, military, veterinary, and agricultural) in response to terrorism. This role has since been expanded to include EIDs and other public health emergencies.

The public health workforce is expected to provide accurate information to the general public. Such timely and reliable data are a vital resource for control of an epidemic. Public health telephone hotlines are a common mechanism to disseminate information and to answer specific questions. Disaster plans do not, however, always consider the volume of calls that an information hotline receives. Over 316,000 calls were placed to the Toronto SARS hotline, which was established the day after the first Toronto SARS case was announced at a press conference. Almost 60% of the callers selected the "listen to recorded information" option. Of the calls in which the "speak to a staff person" option was selected, almost 80% (104,852 calls) were *not*

* World Health Organization Website. Available at: http://www.who.int/csr/ihr/en/. Accessed January 12, 2009.

answered by a staff member.[34] This number illustrates the overwhelming burden of responsibilities that can be associated with infectious disease disasters. Case numbers alone do not always correlate with workload.

Public Safety Workforce

First responders such as law enforcement, firefighters, and emergency medical services are important segments of the public workforce for management of an infectious disease disaster. These workers will be involved in the distribution of resources, crowd control at mass gatherings, the transfer of patients, and any criminal investigation resulting from a bioterrorist attack. In some countries, first responders have the advantage of extensive ICS training and experience; however, as outlined previously, biological incidents are unique in many facets. As one of the primary interfaces with the general public, first responders are at risk for exposure to infectious agents. Jurisdictions must determine in advance how best to protect first responders in the event of a contagious infectious disease disaster. The U.S. CDC website provides information for state, local, and tribal public health directors, and for first responders with respect to emergency response after a biological incident. These recommendations include use of PPE by first responders and suggestions for the handling of contaminated mail or containers. Preparedness also includes an understanding of public health law with respect to quarantine orders and other public movement restrictions, and plans for enforcing these orders.

Healthcare Facility Workforce

A component of NIMS hospital compliance in the U.S. is workforce training in core competencies so that hospital personnel will be able to function in a coordinated fashion during a disaster. The U.S. CDC found that the ICS format for disaster response was critical for providing stable and continuous action after Hurricane Katrina. As a result, the CDC pandemic preparedness plan uses the ICS to structure stable functioning during a prolonged disaster scenario with high staff turnover. Hospital ICS plans for an infectious disease disaster should account for reduced workforce capacity as the disaster progresses due to illness, absence to care for ill family members, refusal to work, and psychological stress. In that regard, healthcare workers should be trained in advance to understand possible implications of a contagious infectious disease disaster and methods to contain the disease. This training should include proper use of PPE, duty-to-care expectations, and infection control practices. Workforce preparedness must also address psychological consequences of a prolonged disaster. Recent disasters have demonstrated that the toll on those expected to respond is significant and this stress has usually not received adequate attention. This is especially important when the workforce is already understaffed.

International Workforce

Infectious diseases affect more people in developing nations than in other areas of the world. An underdeveloped and understaffed public health workforce partly contributes to this poor outcome. Augmenting fields such as epidemiology and infection control in these nations can reduce human suffering and increase detection of emerging pathogens and impending pandemics. International partnerships among aid organizations, government agencies, and industries have resulted in programs to develop global information networks and workforce alliances to train public health workers in developing countries. The WHO's Knowledge Management for Public Health and Global Health Workforce Alliance programs are two examples of international efforts to improve workforce capacity and training in developing nations.

Response Communications

Many aspects of successful management of an infectious disease disaster are dependent on timely and accurate communications between different stakeholders. Examples of such aspects include surveillance, implementation of scientific advances, resource allocations, and delivery of assistance.

International Communication

As previously outlined, infectious disease disasters and emerging new pathogens can rapidly become global in nature. Communication among governments and agencies is fundamental to limiting the extent of an infectious disease disaster. The initial delay in disclosure of a new severe respiratory disease to the world was a likely factor in the global spread of SARS. Once it was clear a new disease had emerged, the international response demonstrated unprecedented cooperation and communication. The WHO, facilitated by the Global Outbreak Alert and Response Network, established secure communication networks and websites for the daily exchange of information on surveillance, epidemiology, and disease characteristics. The utility of this networking system was nowhere more evident than in the discovery of the etiological agent. The Laboratory Network, which consisted of 11 laboratories in nine countries, shared data and information. Together, they identified the causative agent of SARS, sequenced its genome, and developed diagnostic tests, all in a matter of weeks. These laboratories were already in communication prior to the SARS pandemic via the well-established WHO Influenza Surveillance Network, substantiating the value of ongoing partnerships.

National Response Communication

Communication between jurisdictions and between levels of government is vital during an infectious disease disaster due to the transmissibility of the agent. It can be the difference between a contained localized outbreak and a national epidemic. As an example, the U.S. federal communication response during a national incident is coordinated by the National Communications System through NRF Emergency Support Functions. Unlike many other disasters, communications interoperability will likely remain intact during an infectious disease disaster. This is in contrast to the situation during Hurricane Katrina, where widespread physical disruption of communication systems made information exchange between response teams difficult. Without a distinct starting point for the biological incident, however, extensive and formal interagency and intergovernmental communication through the NRF may be delayed. This could undermine unified command and result in multiple and disparate efforts toward similar goals. Even in nondisaster situations, past experiences suggest that poor communication results in conflicting actions. For example, during the 2004 U.S. influenza vaccine shortage, agencies at different governmental levels recommended vaccination of different age groups.[35]

Communication with the Public

Communication of disease and containment information to the community by the public health system can determine, to a large degree, the extent of an epidemic. In fact, the WHO held the first Expert Consultation on Outbreak Communication symposium in Singapore in 2004 to discuss risk communication to the public. It is widely agreed that providing the public with accurate and timely information is necessary to prevent spread of the infectious agent. Yet, these tasks are usually very difficult because the information may change as the epidemic unfolds. Inconsistent messages may be viewed as untrustworthy.

The media is a very powerful tool for disseminating information. In a survey of people quarantined in Toronto during the SARS epidemic, more people claimed that they got helpful information on the quarantine orders from the media than from public health officials or from their healthcare providers. Good working relationships between health department public relations liaisons and local news stations before an incident occurs can encourage cooperation during an outbreak. In a large disaster, it may be necessary to establish an information center to coordinate messages for the public. In addition to the disaster itself, the media will also be reporting on the management of the emergency.[36] Some decisions will need to be explained or justified. In any case, as defined by the ICS structure, a credible spokesperson should be selected as the point of contact with the media to ensure delivery of consistent and accurate messages to the public.

Resource Management

In a biological incident, critical resources are needed for detection of the pathogen in the community and for appropriate patient care. Yet, real outbreaks from the past and mock tabletop preparedness exercises have ascertained that resources in these areas will be limited.

National Resources

Within the U.S., HHS and the CDC maintain the Strategic National Stockpile ([SNS] formerly known as the National Pharmaceutical Stockpile). The SNS is a supply of critical resources that includes antibiotics, antitoxins, ventilators, N95 respirators, and medical equipment for use in the event of a public health emergency. The CDC distributes SNS resources to supplement local capabilities on request from the governors of affected states and on assessment of need. Aid is in the form of 12-hour Push Packages and Vendor Managed Inventory. The 12-hour Push Packages are designed for distribution of nonspecific critical resources from regional warehouses within 12 hours of federal approval of allocation. The Vendor Managed Inventory supplies additional and more specific resources within 24–36 hours directly from pharmaceutical companies; the CDC may choose to supply Vendor Managed Inventory instead of a Push Package. The CDC will send a Technical Advisory Response Unit to assist in receiving, organizing, and distributing the supplies.

The SNS is an extensive cache, but insufficient for a catastrophic disaster effecting multiple jurisdictions. A large infectious disease disaster, such as a bioterrorist attack, is an example of an event that will affect many areas at one time. The CDC may have to prioritize which states receive aid from the SNS based on severity of the outbreak. Some SNS resources may even be reserved in the event of a second attack. Furthermore, the 12-hour response time refers to distribution from federal stocks to state authorities; it is up to the states to then determine which localities will receive supplemental aid. Given all of these circumstances, hospitals should stockpile *at least* a 48-hour supply of PPE and drugs likely to be used during a mass casualty infectious disease event. A 3–7-day supply may be necessary in the event of a large or widespread disaster.

Hospital Resources

A large biological attack or epidemic could result in hundreds of people a day presenting to hospital emergency departments during peak disease incidence. As the number of ill patients increases, hospital critical care providers will have to assess resource capacity and determine allocation procedures to save the most numbers of lives instead of focusing the majority of resources on a few critically ill patients. This is a difficult task because intensive critical care for the very ill in nondisaster situations often results in improved outcomes.

As discussed previously, hospital plans must include provisions for isolating infectious patients. These should include requirements for beds, equipment, and staff dedicated for that purpose. The availability of mechanical ventilators is a particular concern during an infectious disease emergency. Many microbial pathogens cause respiratory complications that require mechanical ventilation. Yet preparedness assessments have demonstrated that hospitals cannot accommodate ventilation for all patients, even operating under surge capacity guidelines. For example, during a Minnesota drill, regional vendors could only provide 16 extra ventilators.[37] Proper allocation of resources is also a function of knowing what resources are available. An up-to-date list of available staffed beds, ventilators, and other limited resources can help with the triage process.

The hospital infectious disease triage system is an important process in quickly determining patient health and susceptibility status. People efficiently and accurately categorized as "susceptible," "exposed and/or infectious," or "immune" (due to vaccination or prior recovery from the disease) can receive the appropriate management with minimal suboptimal use of resources.[38] In the midst of a disaster, the tendency is to either overclassify people as "exposed" or to protect individuals who are at minimal risk. Both of these situations can result in increased numbers of people unnecessarily using limited hospital resources.

Allocation of Resources

Preparedness plans need to include guidelines for resource allocation in the event that supplies are limited. In other words, algorithms are needed to help identify which patients may not qualify for treatment. Making these decisions at the time of an infectious disease disaster without prior consideration can lead to heightened confusion among providers, contention among policymakers, and anger among the public. Legal, social, and political factors will be as much a part of the decision-making process as patient care.

Most agree that to save the most lives, the patients most likely to survive (that is, the least critically ill) should be treated with limited resources first. Whatever system is adopted, administration must be equitable and transparent to all patients and to the public. One mechanism to promote the just allocation of limited resources is to numerically code the survivability of patients based on clinical assessment. Resource distribution is then based on patient scores.

A Specific Case: 2009 H1N1 Pandemic Influenza and Resource Availability

For many years prior to the emergence of the novel influenza A (H1N1) virus in April 2009, the threat of pandemic influenza was often used to examine resource availability in public health. The 2009 novel H1N1 event (declared a pandemic by the WHO on June 11) highlighted that disease emergence characteristics can be unpredictable despite well-informed "best guesses:" viral emergence and disease were first detected in North America, not Asia; the pandemic virus was a novel H1N1 quadruple reassortant of swine, human and avian genes, not (yet) a highly pathogenic H5N1 avian virus with increased transmissibility in humans; transmission and disease continued during the summer months in the United States; and world-wide disease severity during the initial wave (at the time of this writing) was mild or moderate with low mortality rates. Unlike disease transmission and global spread, in June 2009 disease severity was not officially factored into the decision to elevate the pandemic alert phase, but this pandemic demonstrated that concern for public overreaction and for response activities tied to elevation of alerts necessitated a carefully worded declaration statement addressing that disease was moderate at that time. In addition, it caused the WHO to rethink the definitions of the alert phases.

In the United States, the initial wave of the 2009 H1N1 pandemic illustrated some of the suspected resource challenges of a novel disease outbreak, including increased volumes of patients in emergency departments, management of changing recommendations and information overload, scarcity of PPE (e.g., requirements for and availability of surgical masks and N95 respirators), viral resistance to existing therapeutics, hospital employee issues (e.g., absence due to influenza-like illness, wage compensation for absence after exposure, fatigue), availability of diagnostics, and lack of a vaccine. Mass vaccination may be the best strategy for protecting a susceptible population from a second (and perhaps more severe) wave of H1N1 disease, but production limitations may not support timely vaccine availability. Even if pandemic influenza vaccine becomes available, production capabilities may only supply about 14% of the *worldwide* population.[39] The anticipation of a second wave of H1N1 disease in the fall of 2009 coupled with the arrival of seasonal influenza led response stakeholders, such as the American College of Emergency Physicians, to issue guidance on the necessary resource and surge capabilities for management of novel H1N1 outbreaks.[40]

The 2009 pandemic marked the highly unusual situation where two viruses co-existed in elevated phases in the WHO pandemic alert system (novel H1N1 at pandemic level and avian H5N1 at phase 3). Viral unpredictability precludes definitive expectations of a "double influenza pandemic." Nonetheless, such a situation has serious consequences on response capabilities; robust pandemic preparedness is especially important for resource management, continuity of operations and patient care.

Preparedness Practice Exercises

Infectious disease disasters are rare events, yet a state of complacency or underpreparedness by response stakeholders can result in increased casualties when one does occur. Preparedness is more than just having meetings and written plans. Practice exercises are the current state of the art in testing the readiness of response systems and in identifying areas that need reinforcement.

Some exercises are supplements to didactic lessons at institutions of higher learning, such as nursing and medical schools. Nurses and physicians may be the first to recognize that an infectious disease disaster is looming and/or they will be on the frontline of the response. It follows then that nursing and medical students should receive practice in the mechanics of the response during professional training. The exercises are usually in the form of case scenario discussions that address the clinical, operational, and ethical issues of infectious diseases disaster management.

Policymakers, resource managers, public health departments, first responders, and healthcare facilities often use tabletop exercises and drills to assess preparedness. These types of activities are useful for practicing coordination of efforts within and between different parties. The exercises usually involve the mock release of a biological agent such as the smallpox virus, with informational updates given by the exercise administrators to participants as the disaster unfolds. Factors such as resource availability and allocation, protection of healthcare workers, and public unrest are usually components of the exercise. Table 6.7 lists some of the criteria typically considered for the development of a practice exercise.

Since the anthrax attacks of 2001 and the 2003 SARS outbreak, regional preparedness drills are now commonplace throughout the world. In the U.S., there have been large-scale national disaster exercises such as Dark Winter and TOPOFF (for "top officials") 1, 2, 3, 4, and 5 starting even prior to 2001. These congressionally mandated exercises were designed to examine national preparedness. They involved officials and responders from all levels of government. All of these exercises substantiated the validity and importance of the preparedness factors that are outlined in this section. For example, TOPOFF 4, which occurred in October 2007, had over 15,000 participants and included the U.S. territory of Guam. It was designed to assess the response to multiple coordinated attacks with a Radiological Dispersal Device. TOPOFF 3, which took place in April 2005, included a bioterrorism component and participation from Canada and the U.K. It was the first national practice of a response based on implementation of the NRF (then known as the National Response Plan) and NIMS in the capacity of the Homeland Security Operations Center. Concerns raised by the DHS Office of Inspector General[41] after completion of the exercise included 1) insufficient understanding and training of participants on NRF and NIMS procedures, which resulted in "bureaucrat confusion" and operations under multiple different protocols, 2) confusion over the declaration of an Incident of National Significance and the consequences of such an action, 3) information collection and reporting, 4) inadequate collaborations between government and the private sector, 5) the high cost of TOPOFF 3 to participating states, and, importantly, 6) repeated weaknesses from TOPOFF 2.

Although not really "drills," recent outbreaks, epidemics, and events are arguably the most appropriate tools for assessing disaster responses. Public reaction, media relations, and interagency communication in a high-pressure situation are components not easily reproduced in an exercise. Response limitations in recent events such as the 2001 anthrax attacks (e.g., laboratory capacity), the 2003 SARS pandemic (e.g., contact tracing, implementation of quarantine, and healthcare worker safety) and Hurricane Katrina in 2005 (e.g., interagency communication) serve as reminders that certain aspects of preparedness plans are consistently deficient. Even local outbreaks of food-borne illness can inform health departments on areas in need of improvement. For exercises to be useful to a jurisdiction, government, or institution, they need to occur at regular intervals. Policies will change

Table 6.7: Considerations for Practice Exercises*

Participants
- Health departments/Public health
- Government officials (local, state, federal)
- Hospital workers
  - Management
  - Patient care providers
  - Laboratory technologists
  - Epidemiologists/Infection control
  - Pharmacists
  - Health information management
  - Support personnel (e.g., housekeeping, security)
- Law enforcement
- First responders
  - Emergency medical services
  - Fire
- Media representatives
- U.S. Federal Bureau of Investigation and equivalent in other countries (bioterrorism exercises)

Areas for response assessment
- Resource availability
  - Hospital patient care areas and supplies
  - Therapeutics and vaccines
  - Personal protective equipment
  - Personnel
- Resource allocation
- Response coordination/Incident Command
- Infection Control
  - Spread of the agent through the community
  - Protection of healthcare workers and responders
- Communication
  - Interagency
  - Among jurisdictions or regions
  - Among levels of government
  - Media relations/Information to public
- Triage
- Information management
- Personnel management
  - Within facilities and agencies
  - Mobilized for large-scale action (vaccine distribution, epidemiology)
- Management of public reaction
  - Public fear
  - Civil unrest
  - Mass gatherings for resources
- Psychological ramifications
  - Response personnel
  - Public
- Understanding of legal implications of decisions
- Cost of implementing decisions

Evaluation of the practice exercise
- Assessment of whether processes and outcomes of the response effort met goals
- Comparison of evaluation to previous exercises
- Cost of the exercise

* Adapted from Bardi[a]

[a] Bardi J. Aftermath of a hypothetical smallpox disaster. *Emerg Infect Dis.* 1999;5(4):547–551.

over time due to data from previous exercises and from new legislation. In addition, personnel turnover necessitates repeated practices so that new employees can function within the system. The utility of the exercises is also contingent on proper evaluation after they are completed. An exercise with flawed design and/or execution can lead to a false sense of preparedness. For example, participants in the TOPOFF 3 exercise noted that federal assistance was provided in an unrealistically fast manner and may not correspond to the timing in an actual disaster.

Modeling

Given the rarity of infectious disease disasters, a number of mathematical models are being developed for use as prediction and forecasting tools. Models use existing data from previous outbreaks, epidemics, or pandemics to provide insight into putative future transmissions of infectious diseases and/or ramifications of preparedness decisions. This is important because the process of designing and interpreting models can serve as a guide for discussions on the variables and assumptions involved in controlling disease. The uncertainty regarding use of various inclusion and exclusion parameters and the potential errors in selection of data values brings into question the significance of the models.

Epidemic emergence models using climatic data have been developed with success for *V. cholerae* O139, a pathogen endemic to certain regions of the world.[42] Modeling of novel or rare pathogens, such as pandemic influenza or intentionally released smallpox, is more problematic. Here, specific characteristics of the agent (transmissibility or drug resistance) and the host (susceptibility, super spreaders, public reaction and compliance) are unknown and must be assumed.

Modeling is also used for preparedness plans to determine how decisions will affect the progression of the epidemic. Models related to resource allocation, antimicrobial use, vaccination strategies, health economic implications, and public control (quarantine, isolation, social distancing) have all been published.[43–47] How to best validate these models (and the decisions they support) and incorporate their recommendations into the formulation or optimization of preparedness plans remains a challenge.

Evaluation

Since 2001, many countries have spent large amounts of money on public health preparedness for a biological event. For example, the U.S. has spent billions of dollars on surveillance, workforce preparedness, response strategies, and exercises and drills in preparation for an attack using biological weapons. Formal evaluation of these activities is crucial to ensuring that outcomes are properly reviewed and that funding is being used effectively. This mandates more than the simple creation and publication of after-action reports. Preparedness programs should be *designed* with the inclusion of specific evaluation components to determine empirically whether goals are being met and provide data for improvements. The type of evaluation is critical because some assessment questions may give a skewed sense of readiness. For example, in assessing a workforce readiness training program, asking whether or not people are trained (a structural measure) is different from asking how well employees perform their duties after training (a process measure) or even if the training was successful in reducing the morbidity and mortality of an infectious disease disaster (an outcome measure). This last type of assessment is challenging given the rarity of infectious disease disasters and the difficulty of defining "success."[48]

The complexity of preparing for infectious disease disasters lies in the unknown nature of future threats. Because of this, many individuals involved in the response may not agree on the necessity and requirements for effective preparedness plans. This is particularly true for bioterrorism preparedness, because the perceptions of the necessity for such specific plans vary widely.[49,50] For example, the campaign in the U.S. in 2003 to vaccinate 500,000 healthcare workers against smallpox met with very low compliance. This was due, at least in part, to perceptions that the threat of a smallpox bioterrorist attack was low and concerns over the unknown safety of the vaccine in adults.[51] Evidence-based assessments of the needs and priorities of response preparedness efforts and the probability of success (from sociological and scientific perspectives) are critical to preventing this type of program collapse. This is particularly important because the failure of these large programs causes the public to question the utility and funding of any EID preparedness initiative.

RECOMMENDATIONS FOR FURTHER RESEARCH

As a better understanding of the relationship between humans and the microbial world is gained, the war analogy in approaching EID management has become insufficient.[52] The traditional paradigm regarded pathogens as enemies to be battled as they emerged. It is clear, however, that relying on the current antimicrobial arsenal to react to EIDs is proving inadequate. With the exception of postexposure prophylaxis, this is predominantly a treatment strategy for those who have already developed disease. Preventing acquisition of infection or disease is preferable to avert potential disaster situations. There have been successes with preventive mechanisms, such as vaccines to specific infectious diseases agents; however, the diversity of EIDs and the potential for microbial adaptation and change precludes using current strategies against all known pathogens, to say nothing of the still undiscovered or yet-to-emerge agents.

The emergence of infectious diseases, largely fueled by human practices, still pose worldwide disaster threats. Immediate needs to expand the local and global public health infrastructure and workforce are obvious. The ultimate future of infectious diseases management rests on improving two broad but interrelated areas:

1) Preparedness strategies that surpass the usual unresolved obstacles by promoting multidisciplinary program design, and by substantiating early surveillance/detection and prevention of disease;
2) Research into novel countermeasure development, host–microbe relationships, host–immune responses, surveillance tools, and analysis of how behaviors of the human host and perturbations of the environment (whether at the macro- or micromolecular level) affect infectious diseases emergence. These essentially encompass a fresh perspective reevaluation of the approach regarding the understanding of the epidemiology of infectious diseases.

Preparedness

Preparedness Strategies

Repeated drills are used to determine areas for preparedness plan improvements; however, the usefulness of drills diminishes when identified obstacles are not addressed. Areas consistently identified for further improvement include resource allocation, communication between response stakeholders, and understanding of governmental roles. Current templates for planning need modification to first address why these "lessons learned" are not, or cannot be, actually implemented. This necessitates the study (not merely discussion) of the barriers to incorporation of findings from previous drills and disasters by multidisciplinary teams that include social scientists, communications experts, and human factors specialists. Ultimately, drills should be used as a rehearsal tool for workforce training (i.e., to identify improvement goals on an individual basis), not as a mechanism for developing preparedness plans.

EID Surveillance

Although improved response preparedness is reassuring, preventing disease transmission will do much to reduce the dependence on limited resources and other preparedness obstacles. EID management needs to be changed beyond the state of relying on disease treatment when cases appear at the hospital doors. In essence, it must move from the conventional reactionary EID response to a more proactive approach.[53] Improving early EID detection can reduce the "incident threshold" and expedite agent characterization, assessment of response needs, and education of the public. This must be a global effort. Although new agents can emerge from any area, developing countries bear the burden of global infectious diseases incidence and the likelihood of witnessing the development of new pathogens. The developed world has a responsibility to provide assistance in surveillance for both humanitarian reasons and the need for self-protection. Great strides have been made in global surveillance, especially after the infectious disease events of the new millennium, but there are still political, social, and economic obstacles to further advancement.

In addition to improving methods for achieving better surveillance, *what* is monitored needs to be broadened beyond human symptom and disease reports. Many EIDs are zoonoses; past evidence shows that understanding animal infectious disease trends can benefit human health. For example, the first West Nile virus encephalitis cases in North America were preceded by disease in birds. Linking animal disease surveillance (including zoological, agricultural, wild, and companion animals) with human disease surveillance clearinghouses can alert public health officials sooner to potential human infectious disease disasters, whether global in nature or constrained to a small location. The specificities of such tactics are complicated, given the current inconsistencies in animal disease surveillance and reporting and the unproven value of many human disease surveillance systems. In the U.S. for example, the National Biosurveillance Integration System aims to coordinate human, animal, and plant surveillance. Much of the work will entail assessing the scope of surveillance necessary and standardizing surveillance systems for uniformity to facilitate data integration. The ultimate benefit of putative zoonoses detection is the interruption of agent transmission to humans to prevent disease.

Research

Basic Research

The understanding of pathogens has been transformed by genomics and proteomics, fields of molecular biology that study the overall functions and regulation of the genes and proteins of an organism in an environment. These technologies allow scientists to identify disease-causing agents and comprehensively characterize microbial pathogenic mechanisms in a fraction of the time than in previous decades. Future efforts must include the development of technologies to translate this knowledge into functional applications such as rapid screening of people and/or animals during an EID disaster, the development of sensitive handheld devices for remote screening applications, and more rapid determination of antimicrobial resistances and application of therapies. Chapter 11 further describes future goals in molecular surveillance research.

For effective EID management, other areas of basic research must be enhanced to complement the more common agent-specific programs. Namely, there is a need to expand research on diverse biological disciplines associated with zoonotic and vector-borne diseases, such as reservoir ecology and entomology. Ideally, these specialties would be housed in interdisciplinary academic EID departments that include infectious diseases, molecular biology, and conservation medicine experts to foster a collaborative atmosphere.

Drug and Vaccine Development

Improved pharmaceuticals alone will not be adequate to change the burden of EIDs on society, but they have an important role in mitigating disease severity, human suffering, and infectious agent transmission. The need and incentives for antimicrobial drug development has already been outlined. The future lies in the discovery of novel targets and mechanisms active against a broad spectrum of agents. This requires a more comprehensive understanding of host–pathogen relationships: how the host recognizes an invading pathogen, how pathogens evade host defenses, how hosts and microbes interact in nonpathogenic relationships (symbiosis), and how host–immune responses to pathogens can be modulated by drugs or by beneficial bacteria.

Vaccine development is making revolutionary advances. Scientists are on the brink of unlocking the secrets of improving vaccine efficacy by targeting both the innate and adaptive immune response.[54] DNA vaccines hold promise as future EID countermeasures because they can be designed and manufactured relatively rapidly, they can induce cross-strain immunity, and they can be administered by different routes.[55] Progress must be made in moving these types of technologies to product development and clinical trials so that options are in place before the next EID.

The international community must take a more collaborative approach to drug and vaccine design for EIDs. Nowhere is this more evident than in the case of pandemic influenza vaccine. Current production capabilities may limit the number of courses available during an infectious disease disaster. Scientific research is necessary to 1) develop rapid in vitro methods for vaccine component production, 2) increase vaccine efficacy at lower doses, 3) investigate less-specific vaccines that can be made and stockpiled prior to a pandemic, and 4) increase the shelf-life of vaccines. Advances in all four of these areas can benefit both influenza pandemic preparedness and vaccinology in general. The WHO has convened meetings with international stakeholders to formulate plans for increasing the international production capacity of influenza vaccine. Such plans will need to address international differences in complicated issues such as production regulations, acceptable clinical safety data, and intellectual property.

EID Surveillance Research

A more expansive approach to surveillance that encompasses monitoring beyond human and animal health is under investigation. Sometimes termed "conservation medicine," it utilizes interdisciplinary networks that examine the ecology of microbial interactions with animals, plants, and humans in the context of the drivers of disease emergence.[56] These networks should include the expertise of health workers, veterinarians, plant biologists, epidemiologists, ecologists, climatologists, and conservation biologists. Environmental specialists and global geologists must be involved in such endeavors to ensure inclusion of environmental aspects that may affect EIDs. Computational and theoretical biologists, and epidemiologists with expertise in transmission, host–agent interaction, host–environment interaction, and agent–environment interaction, need to develop cooperative research programs among themselves and with other specialists. The goal of such collaboration is to produce, and more importantly, validate, predictive models of disease occurrence. This holistic approach to surveillance is exemplified by geographical information systems that integrate infectious disease incidence, prevalence, and distribution data with satellite environmental data to predict disease emergence in other locations with similar conditions.[57]

The ultimate goal is the capability to predict human EIDs before they occur or at least to recognize an emergence sooner. These types of broad surveillance tools that include environmental components have been used for years by plant biologists to predict disease emergence in agricultural crops. Indeed, the oft-used basic epidemiological triangle of host, agent, and environmental interactions described earlier in this chapter was officially conceptualized decades ago by plant biologists.[58] The link between environmental factors and plant diseases may be obvious, but the time is overdue to integrate this same approach to understanding human infectious diseases.

Infectious disease disaster medicine is itself a growing field and has been the focus of extensive preparedness efforts. Further research on the impact of politics, international relations, social behavior, and public health policies on EID disaster management is warranted to develop sound and realistic action plans. As noted throughout the chapter, this multidisciplinary focus of effort toward the fields of infectious diseases biology and epidemiology is a nascent application that holds promise for the future of both infectious diseases and disaster medicine.

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7

Disaster Mental and Behavioral Health

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OVERVIEW

> Communities exposed to disasters experience multiple traumatic events including threats to life, loss of property, exposure to death, and often economic devastation. Disasters by definition overwhelm institutions, health care, and social resources and require from months to years for both individuals and communities to recover.[1]

In the aftermath of disasters, human-caused or otherwise, a range of behaviors and symptoms emerge with profound clinical and population-level public health implications. A number of terms have been used to describe the social, psychological, and emotional health of affected populations in the aftermath of disasters and acts of terrorism. "Behavioral and mental health" has emerged as the phrase meant to embrace the broad range of human reactions to disasters. The use of the term "behavior" captures the actions people take to reduce perceived threats to safety, health, and well-being. These coping behaviors also have social and emotional impacts that may alter the extent of loss and change triggered by the disaster or its aftermath.

Characteristics of the disaster event may greatly increase the stress experienced, such as lack of familiarity with the prevailing hazard (e.g., anthrax in the U.S. mail in 2001), use of fear as a weapon (i.e., terrorism), intensity of impact (e.g., degree of direct exposure to harm, loss, and change), predictability of the event (e.g., no warning, inability to avoid, unclear targets, protracted or stuttering course), or caused by human action (purposeful intent to harm vs. accidental). This chapter describes the 1) range and timeline of typical reactions, 2) approaches for screening, triage, and referral, 3) preventing and managing psychological injuries, and 4) integrated strategies to support disaster responders.

RANGE AND TIMELINE OF TYPICAL REACTIONS

Disasters and acts of terrorism produce a spectrum of common physiological, psychological, social, behavioral, emotional, cognitive, and spiritual reactions (see Table 7.1 for adult and Table 7.2 for child reactions). Broadly speaking these involve anxiety (notably posttraumatic stress), affective symptoms (notably depression), and medically unexplained symptoms involving multiple organ systems.[2,3] The Institute of Medicine (IOM) Committee on Psychological Aspects of Terrorism provided a useful framework capturing a range of social and emotional impacts to help disaster and emergency planners prepare for and manage anticipated clinical and population-level effects across the life cycle of the event (including pre-event, event response, and recovery phases).[4] In their report, the IOM committee illustrates three overarching, time-phased, and interrelated aspects of population-level impact: 1) distress responses (acute and short term); 2) changes in behavior; and 3) clinically significant psychiatric disorders and impairment. Direct disaster exposure includes the following: 1) serious injury; 2) traumatic bereavement (e.g., loss of a spouse, child, or parent); 3) loss of home or other critical resources (e.g., social support networks); 4) witnessing severe or mutilating injury or death of others; 5) perceiving one's life to be in danger; and 6) managing prolonged uncertainties about imminent threats to health, safety, and well-being.[1,2,5]

Distress Reactions

For people who are directly exposed to a disaster, acute posttraumatic reactions such as hypervigilance, difficulty sleeping, and feelings of anxiety, event-specific fears, anger or rage, and vulnerability, are prominent and tend to emerge quite early. Recovery can be rapid for most, slower for others, or for some, may not occur at all. Chronic performance problems may develop at work, school (children), home (family roles), or socially. Aside from those directly exposed to the disaster, many other individuals may be traumatized by the event either through close ties with directly affected persons, intrusive and high-intensity media coverage, or cascading changes (e.g., business closure, destruction of local facilities, parks, or neighborhoods) evoked by the disaster. For example, days after the September 11, 2001 terrorist attacks in the U.S., a national survey found that 44% of adult respondents had one or more symptoms consistent with posttraumatic stress disorder (PTSD), and one third of respondents with children reported their children to have at least one traumatic stress symptom.[6] Psychological distress may extend broadly to residents

Table 7.1: Common Adult Responses to Disasters and Traumatic Events

Physiological Responses	*Behavioral and Emotional Responses*	*Cognitive and Spiritual Responses*
Fatigue	Anxiety, fear	Memory problems
Nausea, vomiting	Grief, guilt, self-doubt, sadness	Calculation difficulties
Fine motor tremors, tics, paresthesias	Irritability, anger (sometimes displaced), resentment, increased conflicts with friends/family	Confusion in general and/or confusing trivial with major issues
Chest pain, choking, or smothering sensation	Feeling overwhelmed, hopeless, despair, depressed	Concentration problems, distractibility
Nonspecific joint or body aches or pain	Anticipation of harm to self or others; isolation or withdrawal	Crisis of faith, anger at God, questioning basic religious beliefs
Profuse sweating	Changes in usual eating, sleeping patterns	Recurring dreams or nightmares
Dizziness	Gait change	Decision-making difficulties, easily confused
Gastrointestinal upset (diarrhea or constipation, pain)	Hypervigilance, startle reactions	Preoccupation with disaster events
Racing pulse, heart palpitations	Crying easily, mood swings	Lessened ability to handle complexities
Headaches	Gallows humor	Fear of crowds, strangers, or being left alone
Environmental tolerance (temperature, sound, smell)	Poor performance of usual roles (home, work, social)	Anomia
	Regression to less mature or risky behaviors	Slowed rate of thinking, speech difficulties
	Ritualistic behavior	

Table 7.2: Age-related Responses to Disasters by Children

Children of All Ages	*Preschool Age (1–5 y)*	*Early Childhood (5–11 y)*	*Adolescence (12–14 y)*
Anxiety and irritability	Changes in eating habits	Increased aggressiveness	Abandonment of chores, schoolwork, and other prior responsibilities
Clinging, fear of strangers	Changes in sleeping habits	Changes in eating/sleeping	Disruptiveness at home or in the classroom
Fear of separation, being alone	Clinging to parent	Difficulty concentrating	Experimentation with high-risk behaviors such as drinking or drug use
Head, stomach, or other aches	Disobedience	Regression to earlier behavior	Vigorous competition for attention from parents and teachers
Increased shyness or aggressiveness	Fear of animals, the dark, "monsters"	Competing more for the attention of parents	Resisting authority
Nervousness about the future	Hyperactivity	Fear of going to school, the dark, "monsters"	
Regression to immature behavior	Speech difficulties	Drop in school performance	
Reluctance to go to school	Regression to earlier behavior (thumbsucking, bedwetting)	Desire to sleep with parents	
Sadness and crying			
Withdrawal			
Worry, nightmares			

and workers within affected communities and beyond (e.g., to the nation) by intense media coverage.[7] From a developmental perspective, children's distress reactions are somewhat unique and embedded in the context of parental coping.[8,9] These reactions may include regression from previously achieved developmental milestones and the emergence of problems with separation, night-time behavior, or learning. Many disaster research studies have observed nonspecific indicators of distress[10,11] or perceived stress,[12] demoralization,[13] changes in world view,[14] physical health concerns,[3,15–19] healthcare utilization, and changes in perceived safety and security.[20]

Changes in Behavior

A proportion of people exposed to disasters are affected to the point of changing their health-risk behaviors.[4,21] In the immediate aftermath of a disaster or mass violence, individuals may respond in adaptive, effective ways or they may make fear-based decisions, resulting in maladaptive behaviors. Individuals exposed to terrorism and other disasters have been found to increase their use of alcohol, tobacco, and other drugs, especially those with preexisting alcohol use or other psychiatric difficulties.[22–24] Additionally, prior studies have noted a surge in demands for medical evaluation induced by a significantly sized outbreak of infectious disease, or complicated by fear evoked by a mysterious or potentially toxic exposure. This surge in help-seeking behavior may merely be a consequence of the stress involved in managing uncertainty; however, the increased demand for medical evaluation can easily overwhelm local healthcare systems.[25–28] Other reactive behaviors exert significant influence on health, safety, and well-being: these include driving at high speed without seatbelt restraint or under the influence of alcohol or illicit substances; poor lifestyle choices (e.g., no exercise, poor nutrition, and promiscuity); provocative and assaultive behavior; work absenteeism or declines in performance; poor decision-making; and reactive alterations in personal family plans. Behavioral changes may emerge even when disasters threaten but fail to materialize (e.g., threats of more aircraft bombs in carry-on luggage; a menacing hurricane that shifts course and does not make landfall; the stigmatizing reactions of those in the U.S. facing the severe acute respiratory syndrome [SARS] epidemic).

STATE OF THE ART

Adherence to Public Health Measures

There is a wide gulf between desiring that the public behave in a certain manner and having this actually occur. The involvement of the public as a key strategic partner has only recently been described and is in need of serious attention.[29] This highlights a critical disconnect in emergency planning efforts in that the behavioral aspect of adherence has not been adequately included in planning and scenario development.[25,26,30,31] The degree to which adequate proportions of the population comply with or adhere to public health directives (e.g., quarantine, movement restrictions, mass prophylaxis, school closures, appropriate seeking of healthcare) may directly impact the success of public health and emergency medical response efforts. Numerous individual, group, and population-level behavioral changes may occur in response to all types of hazards that, in turn, have profound impacts on the success of public health emergency response efforts, economic trends, and the resilience of a nation as a whole.

There appear to be "disaster myths" embedded within response plan assumptions across many levels of government.[32] One such myth is that the public will "panic" (albeit, not defined) in response to emergencies. There has been significant concern and confusion about the term "mass panic," aggravated by a lack of basic science to inform policy. It is actually uncommon for individuals to act without an underlying concern for others (i.e., totally self-focused or violent). In fact, neighbors or coworkers are most likely to be the "first responders" on the scene (for events with a scene), willing and able to help constructively and collectively.[33] Although paniclike behavioral phenomena are rare, the potential for this reaction has been tied to

- Beliefs that there is little chance of escape (e.g., engulfing fire in a crowded room)
- Perceived high risk from event (e.g., running from a collapsing building)
- Available, but limited, treatment resources
- No perceived effective response
- Significant loss of faith in authorities

Another, more recently prevailing view suggests that the public need only be clearly "instructed" by credible sources and they will comply. This perspective discounts the impact of a plethora of mediating factors and "tipping points" such as culture, special needs, or the impact of specific hazard perceptions of risk and protective actions.[21,31,34] The potential massive impact of events contained in governmental planning scenarios requires deliberate attention to anticipate and mitigate predictable triggers of panic-like behavior at the population level. For example, evacuation orders in response to the Three Mile Island nuclear accident resulted in massive gridlock from surrounding areas that were not instructed to leave. Following the SCUD attacks in Israel, approximately 70% of hospital emergency department visits were tied to psychological factors including 230 (27%) individuals who self-injected themselves with nerve agent antidote – even though they had not actually been exposed to a nerve agent, and 544 (44%) with admitting diagnoses of "acute stress reactions."[35] Although the evidence base is limited, prior experience, personal beliefs, and actions or beliefs shared by loved ones or local thought leaders are believed to greatly influence adherence behaviors.[36] Additionally, the content of risk communication, trust or faith in social institutions, and a host of event- or risk-specific contextual features influence adherence to governmental directives for protective action from a population perspective.[37]

Governmental efforts directed at planning for pandemic influenza are beginning to address the potential for societal disruption and dysfunction, with attention directed at business and government operational continuity. Collective reactions may involve behaviors to demand, hoard or otherwise procure (in competition with public health channels) antiviral prophylaxis or other perceived life-saving treatments. In some recent modeling studies of community measures to contain the spread of pandemic influenza, prompt closure of schools (requiring the active collaboration of public health, school districts and, notably, parents) resulted in a case rate reduction of approximately 14%. This represented the largest single reduction in rates of influenza, and this action led to a "decompression of the peak burden."[38] Together with other strategies such as social distancing, a 40% reduction in peak burden was achieved. Clearly, strategies to enhance behavioral compliance with community mitigation strategies may significantly reduce the impact of the next influenza pandemic.

Understanding the impact of population compliance or adherence to instruction in controlling the spread of infectious diseases is informed by studies of those quarantined due to the SARS outbreak. Approximately 30% of those placed in even a relatively brief quarantine (up to 10 days) had symptoms of PTSD and depression.[39] Key risk factors for developing these outcomes included the duration of quarantine and knowing someone or direct exposure to someone with a diagnosis of SARS. Compliance with quarantine in Toronto was associated with

- Fear of loss of income while quarantined
- Inconsistencies in local application of quarantine from area to area
- Inconsistencies in monitoring of compliance
- Logistical support (e.g., access to groceries, transportation of family members)

Approximately 57% of Canadians neither in quarantine nor exposed directly in Toronto also had fears about acquiring the illness but did not report clinical levels of disorder. Taken collectively, the findings suggest that social distancing strategies used to contain disease resulted in pronounced behavioral health effects in the form of fears, isolation, stigma, and boredom, all of which *negatively impacted compliance* with quarantine and may be exportable to other scenarios. A practical implication for public health emergency response planning is that public acceptance and adherence is greater in voluntary as opposed to mandatory strategies and where income protections are provided for those in quarantine.[36] These data are from the United States however, and effective strategies may vary in different countries with other cultural norms.

Management of Demand Surge

Acute demand surges for medical evaluation have been observed in reaction to disasters, mass violence, and traumatic events. The nature of the health complaints appears to be related to: 1) toxic exposure, 2) specific symptoms related to the current health threat, 3) exacerbations of underlying chronic disease (in part due to lack of access to regular medications including psychiatric drugs), or 4) troubling and nonspecific symptoms that may be related to distress or fear. This last issue often leads to dissatisfying provider–patient relations.[23] The proper triage and management of this demand surge has critical bearing on the following: 1) systemic ability to provide timely life-saving interventions for those with acute medical/surgical needs; 2) prevention of chronic psychiatric disorders and life dysfunction; 3) organizational chaos and cascading inefficiencies; 4) healthcare staff stress and burnout; and 5) customer (community) satisfaction. Nonspecific health complaints associated with disasters and mass violence have been called "multiple unexplained physical symptoms" or "disaster somatization reactions."[3,9] People with multiple unexplained physical symptoms or disaster somatization reactions, in special circumstances, outnumbered direct medical casualties with ratios as high as 1,700:1.[3] Following a nonionizing radiation event in Brazil with quite limited exposure in which four people died, approximately 130,000 unexposed individuals presented acutely to be screened for radiation illness and approximately 5,000 *displayed symptoms* of acute radiation sickness. Other collective demand surges may emerge in attempts to obtain protective equipment (masks, gloves) or medical prophylaxis (e.g., distribution of pharmaceutical stockpiles), especially if there is high mortality, limited availability of effective treatment, or little warning and short window of opportunity for prophylaxis. Survey data conducted in November 2005 suggests "only 35% of the American public is confident in the health care system's readiness to respond effectively to a deadly flu pandemic".[40] Furthermore, only 53% indicated that they feel "prepared for a natural disaster or weather emergency." This highlights a need to better understand, integrate, and prepare for the emotional, behavioral, and social factors involved in demand surge and adherence to public health measures.

Psychiatric Dysfunction and Clinical Disorders

A smaller but significant fraction of disaster-exposed persons progress to incident or recurrent psychiatric illness. Norris and colleagues reviewed the disaster literature and summarized 225 studies pertaining to 132 distinct, acute, collectively experienced events with sudden onset that were quantitative in approach and published in English between 1981 and 2004.[2] Assessments of symptoms consistent with clinical disorders such as PTSD, general anxiety, or depressive disorders were the most commonly published findings. It is important to consider the community-wide magnitude of mental and behavioral health needs to enable appropriate planning and resource allocation. Children and adolescents have been found to be among those at highest risk of adverse mental health outcomes, including PTSD, depression, disruptive behavioral disorders, impairments in learning, and disaster-specific fears.[8,9,41] In addition to costs for provision of mental health care, there are also healthcare costs associated specifically with PTSD.[42]

Understanding Community and Social Support Factors

Empirical observations by various disaster experts were compiled to describe time-phased patterns of community-based responses after sudden-impact disasters such as hurricanes (or other extreme weather events), floods, or earthquakes.[43] Although oversimplifying the underlying social tensions before a disaster strikes, this phased approach helps planners, response and recovery workers, and healthcare providers anticipate common collective reactions based on elapsed time since the event. Inadequate disaster planning, preparedness, and response (e.g., Hurricanes Katrina, Rita, and Wilma) or faulty warning systems (e.g., Indian Ocean tsunamis, 2004) exert lasting effects on the population's overall psychosocial and behavioral health. Early in the aftermath of disasters (circumscribed in time and geography), people are mobilized to work together, with collective action (i.e., prosocial behavior) including heroic acts and a bridging of social divides to help with search and rescue and early recovery activities. A period of disillusionment then emerges as barriers to rebuilding and economic and social recovery exacerbate underlying social discord. Such barriers include inadequate insurance payouts, business relocations, loss of "neighborhood," and perceived disparities in the distribution of public goods and services. The process of reconstruction or coming to terms with multiple layers and cycles of loss and change may take years, marked by anniversary reactions and other reminders of the traumatic events. The model captures useful phases for disasters within prescribed time periods and geography, but not all communities will proceed in the same fashion; phases may be skipped, prolonged, or revisited given the prevailing sociopolitical context. This model may not be useful for other types of disaster events, such as those caused by human action or inaction, (whether by accident or with the intention to cause harm) or those involving biological (e.g., SARS, pandemic influenza) or carcinogenic hazards.

Kaniasty and Norris analyzed social relationships as a critical determinant within communities impacted by disasters.[44] These disaster researchers contend "disasters exert their adverse impact on emotional distress both directly and indirectly, through disruptions of social relationships and loss of perceived social support (p. 207)." For "natural" disasters, the initial mobilization of social support is following by a prolonged resource drain and expectations that are mismatched with postdisaster realities, and subsequently disrupt social support networks and cause loss of social resources. Kaniasty and Norris observed fragmented, polarized, mistrustful, and antagonistic community social patterns after "human-caused" disasters (technological) and highlighted the conflicting and insufficient information surrounding such events. Psychosocial impacts are even more pronounced when harm is intentionally wreaked by human actions. Terrorism occurring in the U.S. in 2001 resulted in: 1) anger, stigma, and violence sometimes under the guise of patriotism; 2) a historical reorganization of federal assets for homeland security;[45] and 3) a multitude of alterations in travel, banking, and business practices. The next section will address the continuum of screening, triage, and referral for treatment.

APPROACHES FOR SCREENING, TRIAGE, AND REFERRAL

Many responses to trauma and disasters can be expected, but the following symptoms signal the need for further evaluation by mental health and other medical and human service professionals

- Disorientation (dazed, memory loss, unable to give date/time or recall recent events)
- Suicidal or homicidal thoughts, plans, actions
- Domestic violence, child or elder abuse/neglect
- Acute psychosis (hearing voices, seeing visions, delusional thinking)
- Inability to care for self (not eating, bathing, changing clothing, or handling daily life)
- Severe anxiety (constantly on edge, restless, obsessive fear of another disaster)
- Problematic use of alcohol or drugs
- Depression (pervasive feeling of hopelessness and despair, withdrawal from others)

Longitudinal Incident Management

From a population health perspective, time-limited distress is very common and behavioral changes can influence health and safety outcomes over much longer periods of time.[1,4,8] A smaller, yet significant, proportion of the affected population will be at risk for clinically relevant psychiatric disorders and dysfunction in various life roles. Psychiatric disorders require that symptoms and dysfunction persist for varying durations of time to meet diagnostic criteria. Risk for severe reactions and impairment will be predicted by a complex interaction among the following factors[41]

- "Dose of exposure," which is tied to individual experience (e.g., injury or illness, fearing death, and separation from family)
- Death of loved ones (traumatic loss)
- "Secondary stress," such as impact of or worry about long-term health risks, loss or difficulty with access to key services tied to housing, employment, insurance, stigma, reduced social support, and not being able to engage in valued pre-event activities (e.g., school, faith based, and sports)
- History of mental illness or traumatic stress
- Ensuing life stressors (job change, marriage/divorce, relocation, loss of loved ones, children moving away)

Relatively small increases in prevalence rates of psychiatric disorders within affected populations may result in a significant surge of absolute numbers of individuals requiring definitive mental health care and increase long-term demands on an already overtaxed and dysfunctional public mental health care system. This longitudinal model of impact suggests the need to align the delivery of disaster mental health services along a more appropriate timeline of need. The prospect of a mass casualty event, with unparalleled behavioral health impacts over an extended period, would clearly tax traditional behavioral health approaches and unleash population-level psychological morbidity for many years to come. A combination of proactive risk communications, public health education and information campaigns, skill building for sustainable resilience, and rapid behavioral health triage and incident management hold the promise of mitigating the community-based behavioral health effects of an emerging global health threat such as pandemic influenza.[5,31,41]

In the absence of rapid triage and coordination between systems, those with the greatest needs may not be located until clinical levels of distress and impairment have become entrenched.[5,41] As large numbers of children move across different systems of care, inconsistent approaches to definition and assessment of acute need may further hamper critical provision of psychological assistance and definitive care. For example, following the 1994 Northridge earthquake in California, many children at high risk due to intense event exposures were not identified until months and, sometimes, years later.[46] These included children injured and/or trapped inside structures. Evidence from New York City also found that only 27% of children with *severe or very severe* posttraumatic reactions received any mental health care 4–5 months after the U.S. terrorist attacks of September 11, 2001.[47] Acute-phase triage and incident management are critical because there is emerging evidence that certain types of acute-phase interventions, applied early after the traumatic event, might afford a unique window of opportunity to interrupt the trajectory of risk, disorder, and impairment for those at high risk and who are already symptomatic.[48,49] Mental health workers should apply timely, evidence-based standards of postdisaster care to individuals at risk. Optimally, there needs to be a seamless system of triage, needs assessment, clinical care, and long-term surveillance for disaster-related mental and behavioral health.[5,41]

One new approach involves innovative partnerships among many entities including public health authorities; public information officers; emergency medical services; primary and advanced medical and behavioral health care facilities; medical examiner and mortuary services; faith-based communities; schools; businesses; and nongovernmental relief organizations (e.g., International Red Cross). These "disaster systems of care" could help significantly mitigate adverse outcomes on a population health scale if appropriately pre-event positioned and coordinated.[5] This requires dynamic and continuous coordination, communication, and resource (goods and services) delivery targeted to those at highest risk of adverse outcomes. A paradigm shift in disaster recovery planning is needed to manage the continuum of risk and adverse outcomes over the extended course of recovery. An emerging incident management model (PsyStart) for disaster mental and behavioral health is composed of three major components to enable a common operational picture for participating entities and jurisdictions.[5] The components include community-based "disaster systems of care," a common system for incident/event-specific *rapid triage*, and information technology for near-real-time data linkage.[41] In the PsyStart model, each participating system of care would use the same triage tag, which is based on objective evidence-informed exposure risk factors (not symptoms) for adverse mental health outcomes postdisaster. In field applications, the triage tags were found to predict appropriately PTSD and depression among exposed children in the Indian Ocean tsunami[50] and the Laguna Beach, California wildfires.[51] The rapid triage system can flexibly incorporate event- and hazard-specific exposure factors such as decontamination, mass prophylaxis or vaccination, shelter in place, quarantine, and/or evacuation. The triage data are used to inform incident managers of resources needs, match high-risk adults and children to available screening and clinical resources, and provide estimates of burden. In this way, stratified rapid triage data correspond to the concept of disaster medical triage and connect level of need with appropriate level of evidence-informed intervention throughout an extensive period of community recovery.[5,9]

PREVENTING AND MANAGING PSYCHOLOGICAL INJURIES

Estimates of Disaster-related Behavioral Health Casualties

In catastrophic earthquakes that threaten many parts of the world, rates of disorder in the vulnerable child population have been found to be extremely high. For example, in a large earthquake in Armenia, villages in which nearly half of the children died, the surviving children exhibited comorbid psychiatric disorders approaching 90%.[52] Severe flooding in Mexico caused extremely high levels of traumatic loss and infrastructure damage (home loss) and half the population had either PTSD or Major Depressive Disorder 6 months postevent. In recent surveillance of U.S. survivors of the September 11, 2001 terrorist attacks who were in collapsed and damaged buildings, 64% of the 5,383 building survivors reported new-onset depression, anxiety, or emotional problems after the event.[53] Estimates of disorder within months of the event in New York City schools revealed an incidence of approximately 100,000 new mental health cases in school-aged children alone.[54] In other catastrophic events, significant rates of behavioral health morbidity have been reported. For example, approximately half of those most severely impacted by Hurricane Katrina had clinically significant levels of distress, leading to U.S. federal funding requests for "enhanced services" beyond typically funded crisis counseling programs.

Psychological impact and resulting levels of psychiatric disorders may vary as a function of event characteristics, such as terrorism using weapons (biological, explosive, chemical, nuclear, or radiation) that can cause mass casualties and societal disruption.[1] Weapons that involve sustained health risk over time may induce particularly pernicious mental and behavioral health morbidity on a population scale. Planning for mental and behavioral healthcare needs must anticipate demand surges during acute-phase distress and behavioral reactive phase, followed by an extended *trajectory* of needs continuing and emerging throughout the duration of recovery, especially after mass casualty events.[5,21]

Basic Disaster Mental and Behavioral Health Intervention

Much of the initial on-site disaster mental health response focuses on 1) dampening anxiety and arousal by providing safety, comfort, and consolation; 2) assisting those directly affected to function effectively (reality testing and concrete problem solving); and 3) providing clear guidance and information to ensure that basic individual and family needs are met (e.g., safety, medical attention, water, food, shelter, clothing, essential medication, supervision of children and other dependents, and reunification of families).[43,55] An extensive review of the evidence-based literature was conducted, including two consensus development workshops to define key components of early intervention for survivors of mass violence[55–57] Regardless of the type of disaster, it is important to continually assess needs, monitor the recovery environment, and provide outreach, screening, triage, and treatment services. The goal is to foster resilience, effective coping, and recovery.[49,58]

Early Intervention

From a population health perspective, the following groups stand to benefit from early intervention: 1) persons with direct disaster exposure (see "Approaches for Screening, Triage, and Referral"); 2) persons demonstrating extreme acute stress reactions (e.g., panic attacks or dissociative symptoms), extreme cognitive impairment, or prolonged and intense distressful emotions; and 3) persons having a prolonged inability to sleep.[1,4,9,55,58] Risk factors in the early disaster aftermath include loss of personal and financial resources, loss of social support, displacement, loss of home, and proliferation of secondary stressors. Also at increased risk for psychiatric outcomes following disasters are persons living in poverty, low visibility groups (homeless, migrant, impaired mobility, institutionalized), and persons with trauma, psychiatric, or illicit substance use history. The goal is to deliver a compendium of pragmatically oriented interventions as soon as possible for individuals experiencing acute stress reactions or who appear unable to regain function.[56,58] In general, interventions are designed to aid adaptive coping and restore problem-solving capabilities as quickly as possible. During the 1980s and early 1990s, critical incident stress debriefing surged in popularity and was widely adopted by disaster response personnel. During this period, critical incident stress debriefing was applied (albeit, indiscriminately) with increasing frequency to disaster survivors; however, the technique was found to have equivocal effects and in some applications, to have the potential to cause harm.[56–58]

Psychological First Aid

Psychological first aid (PFA) is emerging to capture essential components (core constructs) of empirically supported early disaster mental health interventions, ranging from meeting basic needs to more sophisticated interventions requiring an appropriately trained mental health professional. In some cases, either PFA or "Psychosocial Support" is being used, sometimes interchangeably, as what appear to be social marketing catch phrases by disaster and humanitarian relief organizations (e.g., American Red Cross, World Health Organization) and U.S.-based trauma specialists (National Center for Posttraumatic Stress Disorder/Department of Veterans Affairs). The specific products and services delivered vary by the training and experience of the provider, the context of the disaster setting (e.g., mass casualty vs. displaced into a shelter by a severe weather event), and the population being served (e.g., children, responders). Although each of these interventions cites empirical evidence as the basis for application, applied research is critically needed to determine intervention effectiveness and efficacy in realistic settings and the national and international planning scenarios.

Given the advent of the September 11, 2001 U.S. terror attacks, the anthrax bioterrorism acts, and a prolonged event with serial sniper attacks (Washington, DC metropolitan area), a core group of international traumatic stress and disaster experts was commissioned to amplify and expand the review of evidence and seek essential intervention elements to apply in the context of scenarios with ongoing threats.[59] This process yielded five empirically supported intervention principles for application at the early to mid-term stages of such scenarios. These elements are especially relevant to pandemic influenza planners to aid in communications and community mitigation strategies.[31] The goal is to move impacted populations along the following domain pathways[59]

- From Risk to Safety
- From Fear to Calming
- From Loss to Connectedness
- From Helplessness to Efficacy
- From Despair to Hopefulness

One PFA model undergoing continuous development and refinement incorporated these and other empirically supported intervention principles into a manual and toolkit, which were first released as the devastating Hurricane Katrina impacted the Gulf Coast of the U.S.[60] This resource is designed for delivery by mental health professionals and other disaster response workers who provide early assistance to affected children, families, and adults as part of an organized disaster response effort.

The American Red Cross has also revised their disaster mental health training curriculum and developed PFA strategies for use by all of their disaster relief workers. This includes use of a triage tag to link disaster clients with a Red Cross disaster mental health worker that would improve referral efficiency in mass casualty events (S. Hamilton, personal communication, January 10, 2007). Another emerging PFA model specifically targets the needs of children, parents, and their systems of care. It has been highlighted on the U.S. Department of Homeland Security website.[61] In this model, parents and teachers are taught the basics of PFA to assist children by using the ideas of "listen, protect and connect." New extensions of this model have been developed for schools and medical care settings.[62]

At the population level, effective psychological benefits may accrue in a systemic manner such as bridging primary care and mental health systems together and improving access to the broad range of human service needs (including housing, employment, schooling, and child care – to name a few). Such approaches, although not direct mental health interventions by mental health providers, may be the most effective manner to provide PFA and improve coping.

BEHAVIORAL PREPAREDNESS FOR DISASTER RESPONDERS

The finding that resilience is common and expectable, even in the face of severe adversity, has been described as "ordinary magic."[48,63] Resilience is not a fixed attribute; instead, resilience is a process and it changes with changing disaster circumstances and experiences. The disaster experience may be transformative, enabling more constructive ways of dealing with adversity and stress.[64] In this application, responder resilience refers to the capacity to adjust rapidly to the stresses of deployment, to successfully respond to adverse cultural and situational challenges, and to reintegrate to routine work in a healthy and adaptive fashion.

Responder Resilience

Focusing on resilience within the workforce makes good business sense for disaster response agencies.[65] Responding optimally to mass trauma and mass casualty incidents requires a culture that prioritizes both physical health and psychological well-being for those who are called on to respond to incidents ranging in magnitude from crisis to catastrophe. Psychological preparedness improves disaster response. Enhancing resilience skills in the workforce will diminish the likelihood that 1) critical infrastructure personnel (e.g., healthcare workers) refuse to work during a disaster – a major concern for an influenza pandemic;[31] 2) workers would quit, requiring massive retraining and rehabilitation (a crippling reality following SARS in Toronto); and 3) loss of productivity, thus dampening the economy in a potentially cascading fashion. In the face of all-hazard planning and the need to maintain critical infrastructure and key resources, responder health, safety, and resilience must be integrated into organizational culture for public safety, health, and security.[66]

Hazards and risks to responders may be directly related to the reason for the deployment (e.g., infectious disease outbreak) or incidental to the deployment (endemic diseases, lack of medical facilities, and physical security hazards). Proper identification of hazards, assessment of the risks presented by these hazards, and appropriate control measures can, in most cases, reduce exposure to hazards and the consequent risks associated with the hazards that are present. Emergency response personnel are often required to work extended hours in high-risk environments, where alertness and attention to detail are an absolute requirement for safe work practices. Elevated stress and fatigue can lead to faulty decision making, unsafe work behaviors, and increased exposures to health hazards.[67]

Organizational policy can prevent or mitigate injuries and illnesses from environmental, occupational, and operational threats including biological, psychological, and traumatic stress. Effective deployment health and safety policy requires coordination and cooperation with appropriate occupational safety and health authorities to ensure continual refinement and implementation of effective worksite health and safety plans.[66] These plans need to be professionally designed and tailored to specific worksite conditions to protect deployed personnel by using a hierarchy of exposure controls (engineering technology, administrative policies, and judicious use of personal protective equipment) and safe work practices. A comprehensive policy would cover predeployment preparation, deployment support, and postdeployment services based on the best available information and protective measures. Before deployment, personnel must have completed all the elements to achieve a state of readiness. These include a medical determination of fitness for deployment, training on safe work practices, use of appropriate personal protective ensembles, self-care (psychological, social, and behavioral dimensions), and other specialized training as needed to fulfill job-related responsibilities. Pre-deployment briefings should provide information about anticipated exposure hazards, including psychological, social, and behavioral hazards from response activities and occupational stress factors (e.g., pace of work, magnitude of demands, and safety climate). Planning for continuity of operations and interoperable mutual aid (for demand surge) are also essential organizational preparedness responsibilities, as demonstrated by the devastating loss of the New York Fire Department Command Center in the September 11, 2001 World Trade Center collapse, and preparedness efforts for pandemic influenza.

Optimally, the responder has emergency plans and systems in place to handle concerns about the safety and welfare of family and other loved ones to avoid fractured attention on the job and increased likelihood for accidents, improper work practices, or poor decision making. Employers can assist with "concierge" services for families that are directly impacted.[68] Healthy lifestyles (good nutrition, exercise, and sleep habits) and constructive social, spiritual, and family support are important to overall psychological well-being and resilience. Training and maintenance programs can be instituted for peer support, team building, and crisis leadership, with skill-building to improve stress, anger, and grief management.[31]

RECOMMENDATIONS FOR FURTHER RESEARCH

A number of key areas within disaster mental and behavioral health require research attention. Quantifying the psychological, behavioral, and social consequences and management strategies for disasters and mass violence is critical. Future efforts are needed to

- Test emerging rapid mental and behavioral health assessment tools for population-based, facility-based, and clinical contact surveys, including assessment for mass casualty settings.
- Integrate psychological and behavioral elements into population-based surveillance systems.
- Implement an interoperable disaster mental health incident management strategy using evidence-based triage metrics and a continuum of stepped care.
- Better understand the longitudinal trajectory of risk and impairment to improve interventions for persons with traumatic grief during disasters and mass casualty events.
- Identify and refine modifiable risk factors to help design effective intervention programs.

Despite the knowledge that early intervention mitigates risk for extended traumatic stress syndromes, the field has been hampered by misapplication and misrepresentation of early intervention strategies. Applied research is needed to identify useful early interventions (i.e., prove their efficacy) for those directly impacted by disasters and mass violence. Such studies need to include

- Research to establish international best practices for a continuum of care through intervention strategies (i.e., PFA, incident-specific stress inoculation, and trauma-focused cognitive–behavioral therapy)
- Determination of optimal timing of strategies to implement interventions
- Component analysis of multifactorial interventions
- Training and proficiency requirements for successful implementation of interventions (mental health and nonmental health professionals)

Research is also needed to evaluate the impact of efforts to increase preparedness and adherence to public health emergency response strategies including incident-specific disaster response strategies, such as sheltering and evacuation. More research and program evaluation efforts are needed to understand the key ingredients of resilience of professionals performing emergency response, disaster recovery, and remediation work. Naturalistic longitudinal studies would enable better anticipation of psychological and behavioral hazards for future preparedness and response planning. Furthermore, research is needed to evaluate the effectiveness of organizational approaches to enhancing resilience among response professionals and other personnel who are mandated to serve during disasters.

CONCLUSION

Planning for the behavioral and mental health needs of disaster-exposed individuals, families, communities, and responders is a critical need in public health and medical service planning. Without such planning, the available resources, monitoring efforts, and healthcare services may be overwhelmed. Although "panic" is ill-defined and not often a concern, anxiety, fear for one's children, and the absence of feeling safe can create community confusion and disillusionment with leadership that has substantial political consequences. Planning must address the range of responses from distress to risky behaviors to traditional mental illness. Unexpected service burdens may arise within receiving communities due to the migration of endemic risk and existing chronic conditions from displaced populations, in addition to newly emergent and chronic conditions aggravated by the disaster and relocation experience. Triage, protection from secondary stressors, restoration of families and social networks, and the application of the principles of PFA are the primary population-level interventions for the behavioral and mental health consequences of disaster and mass violence. Public messaging and leadership presence are critical to convey and implement these principles. At appropriate times, grief counseling – an important task in advancing communities to recovery – becomes the focus of all community leaders. First responders are always a target for planned mental and behavioral health support and surveillance to ensure their individual health status and, by doing so, community protection. Addressing our knowledge gaps, applying scientifically supported interventions, and tracking the trajectory of unresolved needs are important objectives. Using leadership, public messaging, and education will greatly improve the mental and behavioral health of communities impacted by disasters and mass violence.

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8

Special Needs Populations

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OVERVIEW

In studying the impact of disasters, concern has developed regarding populations that demonstrate a greater vulnerability to injury, death, and/or property loss. The term "special needs," as well as vulnerable populations or populations at risk, has been applied to this group. These terms broadly cover a range of people who might need particular kinds of assistance in emergencies and disasters. Vulnerable populations include people with disabilities, senior citizens, pregnant women, infants and children, single parents, women, low-income families, and racial and ethnic minorities. Examples of unique interventions for such individuals are specially crafted warnings (in various languages and literacy levels), evacuation and transportation assistance, priority rescue, medical treatment, accessible sheltering, and assistance with rebuilding.

A broad-brush approach to vulnerability has certain benefits. First, a wider inclusion means that a given jurisdiction, organization, or community may contextualize the term. In some locations, it may be that the most vulnerable population includes senior citizens. In another location, it could be recent immigrants. Second, a broad approach captures a more complete list of those potentially at risk. Doing so allows emergency managers to understand the complexities of people's lives and circumstances. Sex, for example, can greatly increase risk in some contexts. Pregnancy may further complicate the ability to escape danger or can, itself, endanger both mother and fetus. Low-income households may lack the resources to afford protective action. If such households include seniors on fixed incomes, additional complications arise including transportation assistance and nutritional and medical support. Because the prevalence of disability increases with age, seniors in these fixed-income households could suffer from mobility or cognitive disorders and require additional support.

The use of broad inclusive terminology generates misclassifications. First, one cannot assume that people have special needs simply because they fall into a given population. For example, a person with a disability can maintain an independent life, make contributions to society, and respond adequately to a disaster event. Women experience differential vulnerability that is usually tied to income levels or developmental status.

Second, vulnerable populations are dynamic. People move into and out of poverty, experience temporary or new disabilities, and immigrate routinely. Local populations can shift and change.

Third, disasters generate new risks. For example, individuals with asthma may manage their condition well on a daily basis and not be considered to have a special need. In a high-rise fire and evacuation, such as occurred on September 11, 2001 in the U.S., that condition may cause significant challenges however. Consider the situation of a Muslim diabetic seeking refuge in a public shelter after Hurricane Katrina. With the only food available being ham and white bread, the evacuee would face a choice of violating religious customs or following medical advice. Rapid deterioration can result. Similar problems result when disasters disrupt access to medications, medical care, and other health-related services. Losing access to dialysis, cancer treatment, or to social services such as home healthcare or meals to the homebound can rapidly move someone into life-threatening circumstances. When a disaster strikes at the end of the month, those relatively dependent on social security or disability-related incomes may have to make hard choices between affording medications or food and between staying at home and evacuating. People can also sustain major, permanently disabling injuries in disasters. After the 1999 tornado outbreak in Oklahoma and the 1995 bombing of the Murrah Federal Building in Oklahoma City, a number of victims survived, albeit with newly generated mobility and sensory disabilities. The same was true for the attacks on September 11, 2001, particularly for victims sustaining burn injuries and other conditions requiring extensive medical treatment and rehabilitation.

Fourth, a broad view may hide diversity. For example, it may be difficult to identify "people with hidden disabilities, people with serious mental illness, people with intellectual and cognitive disabilities, people with a variety of visual, hearing, mobility, emotional and mental disabilities and activity limitations."[1] Similarly, considerable diversity exists within any racial or ethnic group.

Finally, although planners can identify those likely to bear disproportionate risk, issues generated by circumstances and locations must be considered. The type of hazard could create new demands. Lack of preparedness or insight into what people truly require to survive can also produce new unmet needs. To illustrate, consider these examples.

- A low-income hotel burns to the ground and the local Red Cross opens a shelter. A woman, eight months pregnant, arrives but no one realizes that she is pregnant due to chronic malnutrition.
- A teenager who is deaf and home alone does not get warning information about an impending hurricane and must wade out through water contaminated with feces, chemicals and petroleum. Over the coming weeks many that waded out through the water develop serious, persistent skin and wound infections.
- A paraplegic is airlifted to a safe shelter in another state but his wheelchair, which cost nearly $30,000, remains behind. When he arrives at the general population shelter where he could have been independent, he is sent to a medical needs facility that is already overrun and understaffed. His medical records are destroyed by the disaster and his medications have been lost during the storm.
- A Vietnamese-American family arrives at a shelter that is serving unfamiliar foods. The children, already upset by the events, refuse to eat. When they do begin to eat, several experience intestinal distress.
- Immigrant workers help to clean dust and debris from homes and offices damaged by a terrorist attack. They are not given protective clothing or equipment. They do not speak much English. Over the next year, they develop a persistent condition that comes to be known as the "World Trade Center cough."
- Insufficient numbers of accessible, Americans with Disabilities Act–compliant Federal Emergency Management Agency (FEMA) trailers are available after a major disaster. A local disability organization sues FEMA to establish a hotline and case management procedures to move people out of hotels and shelters and closer to their healthcare and social service providers.

The magnitude and scope of an event matter as well. In 2005, Hurricane Katrina laid bare the problems of specific populations in the United States. More than 50% of those who died were older than the age of 75.[2] A disproportionate percentage of these individuals were racial and ethnic minorities.[3] Horrific images linger of people who died due to heat exhaustion, lack of food or water, power losses, poor evacuation planning, transportation failures, and unavailable medications. They died stranded in nursing homes and hospitals, and on rooftops, overpasses, and in places of last refuge. They died in their wheelchairs. These problems were not unexpected.[4] Hurricane Katrina revealed deeply embedded problems within the practice of emergency management, particularly the understanding of how to reduce risks for vulnerable populations.

Recognizing and addressing a group's increased vulnerability to disasters can achieve significant reductions in risk.

- In Victoria, Australia, firefighters sought a reduction in the number of fires and subsequent burns among senior citizens. Recognizing a pattern in the fires, five firefighters learned Turkish, formed a partnership with the local Migrant Resource Center and Islamic schools, and provided information for Turkish senior citizens and the Turkish media. Fewer fires and injuries resulted.[5]
- As Hurricane Gustav neared the U.S. coast in 2008, the U.S. Postal Service released social security and other entitlement checks early to spur evacuation among low-income households and senior citizens across the Gulf Coast. This was especially important for people waiting on checks to refill medications (Figure 8.1).
- When a shortage of influenza vaccinations occurred in the U.S., public health officials prioritized who should receive immunizations first including the elderly, people living in congregate facilities, children, and people with chronic health conditions and their partners.
- During Hurricane Katrina, medical needs shelters were overrun by the inappropriate diversion of people with disabilities who did not require medical support to these locations. The Department of Justice issued a set of guidelines to make general population shelters accessible.

Figure 8.1. Corpus Christi, Texas, September 9, 2008 – Firefighter assists nursing home evacuees prior to the arrival of Hurricane Ike. Patsy Lynch/FEMA News Photo. See color plate.

The next section reviews populations at risk and identifies the special needs that each might experience. Personnel with responsibilities for managing disasters should reflect on how each population might be present in their practices or jurisdictions. This chapter then concludes with a consideration of practical strategies and includes recommendations for future research and a resource section.

STATE OF THE ART

A Social Vulnerability Perspective

Social vulnerability theory examines how economic, social, cultural, and political conditions foster disproportionate impacts and generate special needs.[6,7] Vulnerability theory suggests that special needs arise because of the ways in which society has constructed social systems. Risk develops as a consequence of failure to collectively address social conditions such as affordable housing and healthcare, prejudice, or interpersonal violence. As a brief example, low-income housing usually sustains more serious damage following a disaster, causing more injuries and deaths and resulting in a significant loss of assets. Remediation for these conditions is deemed necessary at the policy level and requires broad systemic change that tends to occur slowly. As a means to affect change more rapidly, vulnerability theorists advocate for empowering those at risk to participate not only in their own risk reduction, but through informing those responsible for disaster management. The insights of those at risk are deemed valuable and potentially transformative. Therefore, solutions to the challenges of special needs include building capacity among those at risk and establishing partnerships among organizations that link to people with special needs.

Historically, individual attention has been paid to specific demographic groups. In general, knowledge about vulnerable populations has increased as the result of a major event that reveals problems, such as Hurricane Katrina, or as the result of a push forward by lines of academic research or advocacy groups. Researchers have launched multiple lines of literature dedicated to specific demographic groups in an effort to understand and reduce vulnerability. The following sections examine a number of the populations considered vulnerable by generally following the emergence of that literature as it has unfolded over the past few decades. Key citations are included here. Web page links to extensive bibliographies and literature reviews can be found in the resource section.

Age

Age clearly relates to vulnerability. Concern has developed that the very young and the elderly, especially frail elderly, are susceptible to sudden deterioration when placed under adverse conditions. This section looks at both groups and identifies general areas of concern.

THE ELDERLY

Two general divergent points of view have emerged regarding seniors. The first is that disasters disproportionately deprive the elderly relative to younger counterparts, causing them to sustain greater losses.[8] The second perspective is that they demonstrate some degree of resilience by virtue of knowledge gained through prior life experiences.[9,10] In other words, they are somewhat inoculated against disaster adversity based on what they have learned. Evidence supports both perspectives to varying degrees. Hurricane Katrina, for example, resulted in a significantly higher rate of mortality among the elderly, with at least 50% of the fatalities being older than the age of 75. The relative deprivation hypothesis would direct attention to the lack of resources for transportation and evacuation, a higher prevalence of disabilities that required additional evacuation support, and a reduced ability to withstand the high heat and humidity during rescue operations. It is also true, however, that the elderly can and will respond when directed to do so. For example, warning and evacuation compliance is fairly high when the messages are received and resources are made available.[11] Furthermore, psychological researchers have found that "the significance of the event becomes relative to a lifetime of circumstances experienced by the individual."[12] The inoculation hypothesis thus holds some merit.

The recovery period also presents challenges for the elderly. Seniors appear to be reluctant to access relief and other recovery programs. Part of the problem apparently stems from fear of institutionalization if it is assumed they cannot meet their own needs. Resistance may also result from pride, self-reliance, and an unwillingness to accept charity. Burdensome paperwork that challenges and fatigues some seniors has also been blamed. Elders who are socially isolated are at particular risk for not accessing disaster resources.[13] In addition, the digital divide (Internet, text messaging, pagers often used for warning messages, and online aid applications) may increasingly segregate elders. The online FEMA application times out for security purposes, a problem for those with slower responses or who are unfamiliar with the Internet, cannot type, and have limited eyesight or cognitive challenges.

Vulnerability theory suggests building capacity and establishing partnerships as a remedy. These solutions were embraced by the Baylor College of Medicine and the American Medical Association. Together, they produced a set of recommendations for assisting elderly disaster victims.[14]

- Involve gerontologists, geriatricians, geriatric nurse practitioners, and others in emergency operations planning.
- Conduct predisaster planning with local social services, public health services, and other key organizations, especially aging organizations, senior centers, and faith-based organizations.
- Offer specific training to those who interact with elderly disaster victims, including transportation personnel, shelter staff, and case managers.
- Protect seniors from abuse and fraud. Adult Protective Services can be a partner in this activity.
- Plan carefully for the frail elderly, the homebound, and those in nursing homes.

CHILDREN

Children's reactions to disasters vary by age. Younger children react well to being physically comforted after a frightening experience. Reactions of older children depend on how adults behave.[9,10,14] Because children lack a referential framework for behavior, they tend to look to trusted parents, childcare workers, and significant others for behavioral cues. If parents react with inappropriate actions or acute distress, children are likely to respond similarly. Children home alone at the time of a disaster may experience greater challenges than those in the presence of adults unless they have been trained for the anticipated hazard.[15]

Behavioral responses that are typical for younger children and usually diminish with time include being upset over losses (blankets, toys, and pets), loudness or aggression, fear of sleeping alone, nightmares, fear of similar events (wind, rain, and storms), crying, enuresis, thumb sucking, and psychosomatic responses including headaches, gastrointestinal distress, and even fevers.[9,10,15] Older children and adolescents may experience more difficulty coping with the disaster because of their enhanced capacity to grasp the meaning of the event. Psychological treatment, school programs, and even volunteer work are typically recommended as intervention strategies for older children.

Psychological responses are also affected by exposure to certain stimuli, particularly personal injuries or harm to others around them, loss of loved ones, and the ways in which parents or guardians handle psychological trauma. Extreme events, such as the attacks on September 11, 2001, or Hurricane Katrina in the U.S., are likely to create a more complex range of problems including school disruption, displacement, separation from families during evacuation, and living in temporary locations as well as loss of medical records, medications, and familiar healthcare providers. These difficulties may be particularly acute for children in households experiencing domestic violence pre- or postdisaster. Recommendations typically include reestablishing routines, reintegrating children into school, and providing mental health support at shelters and other temporary locations.[16] By getting children back into a routine, a "ripple effect" is believed to occur that moves through families, households, and into the broader community to generate recovery.[16]

Support from trusted adults, including parents, teachers, childcare workers, disaster volunteers, and shelter workers, is key to helping children.[17] Mental health providers may need to offer a range of services to children. After the bombing in Oklahoma City, for example, trauma counselors created "Project Heartland" that trained teachers and others to recognize and manage signs of long-term trauma. Over 60,000 students received interventions.[18] Services to teachers and students included counseling and training for stressor identification and coping mechanisms. Researchers examining the attacks of September 11, 2001 found that approximately 10% of all children in New York City received counseling.[19] Schools served as the most common setting (44%) followed by professional treatment (36%) or spiritual care/other (20%). Children were more likely to receive counseling if parents also experienced traumatic reactions.[19]

Health concerns for children depend on the type of event. Concern for dissemination of severe illnesses erupts in refugee camps and mass evacuation locations, particularly in developing nations. In the Philippines, for example, mothers express concern over the potential for epidemics in unsanitary evacuation centers, where "children are exposed to . . . lack of food and clean drinking water, unsanitary shelter, closed schools and poor health services . . . they face hunger and epidemics, perhaps even death."[20] In an event such as Hurricane Katrina, concerns arose over toxic contamination of schools, homes, and playgrounds.[17] The dust from the World Trade Center has prompted concern for long-term effects on all ages including pregnant women, newborns, and people with both existing and newly appearing related respiratory conditions.[21]

Recovery proves especially challenging for some families with children. FEMA disbursements in the U.S., for example, have been critiqued for their "one size fits all" approach in which a single mother with several children will receive the same funds as an adult man without any children.[16] Living in cramped, temporary housing is also difficult for any family. For larger families or for single parents, the situation may create extra stress. Families in trailers often refer to themselves as "spam in a can" and few disaster trailer parks can establish amenities like playgrounds or after school programs.

Yet similar to the elderly, children can also prove to be resilient. Children developed coping skills after Hurricane Katrina while living in shelters and formed strong bonds with shelter workers.[17] Children in the Philippines are considered "indispensable helpers . . . the potential of elder children could . . . be developed and maximized through community daycare and other collective activities."[20] Structured environments, play and therapeutic activities, and effective role modeling appear valuable in helping children cope with disasters.

Income

Income level impacts all aspects of disasters. Lower-income households cannot afford to purchase or create emergency preparedness kits. Single mothers, of whom approximately 33% fall below the poverty line in the U.S., cannot purchase mitigation measures such as hurricane shutters to protect the contents of their homes.[22] Those living on fixed incomes have particular difficulties. For example, Hurricane Katrina occurred at the end of August, which meant that social security and disability checks had not yet arrived. Many people were waiting for checks to refill prescriptions. Furthermore, they could not afford gasoline or food to evacuate. Buses that should have been dispatched to evacuate people needing transportation did not arrive. Reluctant to leave a familiar environment and family on which they could depend, a disproportionate number of low-income households remained behind. Extensive damage occurred to many low-income homes that were located in floodplain areas. For hundreds of families, this meant the loss of a home that had been in their possession for generations and could no longer be replaced due to financial hardship. In a postdisaster context, low-income households face hard choices between recovery and ongoing needs. To survive, they may pawn remaining possessions, relocate to more affordable areas away from familiar healthcare providers, move in with other families, skip meals or eat poorly, delay healthcare, cut medications in half, or not follow through on expensive medical regimens.

Low-income homeowners often face serious rebuilding challenges. Because many are underinsured or cannot afford hazard-specific insurance, they cannot rebuild without assistance. At the time of this writing, maximum federal loans in the U.S. totaled only $28,800. For most low-income households, choices must be made about rebuilding or relocation. Without assistance from volunteer disaster organizations, many cannot return home. Most will enter into a local case management process and await help from faith-based and civic organizations.

Renters encounter similar challenges. After the 1994 Northridge earthquake in California, renters faced extensive displacement due to the time required to rebuild multifamily dwellings and the state of the regional economy.[23] After Hurricane Katrina, public housing in New Orleans was condemned; the process of rebuilding will take years. Protests have erupted, with concern that a new design integrating mixed-incomes into the rebuilding plans will displace low-income residents. The U.S. Housing and Urban Development agency has offered relocation for low-income households across the U.S., often far from Gulf Coast states. Social networks are especially important to low-income families, particularly in neighborhoods where families have lived for some time. Their neighborhood and familial relationships help sustain them. When disasters force relocation, those social resources diminish and life circumstances become even more difficult. This appears to be particularly true for minority communities, especially those with long-held ties to the land such as Native American households.

Race and Ethnicity

Although studies find similarities both within and across racial and ethnic groups, important differences exist.[24] Studies of rapid-onset events demonstrate those differences with clear implications for warning those at risk. For example, in a study of a massive tornado that damaged a neighborhood near Birmingham, Alabama, 80% of white residents heard the warning from television compared with only 67% of African Americans.[25] Hispanics appear more likely to get warning information from the radio or from social networks.

The consequences of not receiving warning information can be significant. Ethnic groups may experience cultural barriers, such as when warning messages are not distributed in relevant languages.[11] Translation must also be done correctly. As a tornado approached the small town of Saragosa, Texas in 1987, efforts failed to translate warnings into the correct Spanish words. Rather than learning of an approaching risk, the few listening to the radio heard "news" about a tornado.[26] Those watching cable television originating far away from their location received no warning. Twenty-nine people died and dozens sustained injuries. After the 1989 Loma Prieta earthquake in California, local Latinos alleged discrimination due to a lack of information and other concerns in the city of Watsonville.[27] The U.S. Department of Justice investigated and, although finding no overt discrimination, suggested some changes. As a result, the city hired an ombudsperson to liaise with Latinos and Latino organizations. One year later, a unity parade was held.

Ethnicity has also been associated with income discrimination and segregation patterns that impede abilities to secure adequate housing in areas safer from local hazards.[28] Lower-income housing tends to fare poorly in areas of high risk. For example, affordable housing is more likely to be located in floodplains and closer to hazardous materials sites. In earthquake prone regions, such housing is more likely to lack seismic retrofitting.[11,28] Such exposure increases the likelihood of injuries, property loss, and psychological trauma.

Gender

The bulk of published vulnerability research concentrates on gender issues. This body of research has resulted from a concerted effort by investigators often linked through the Gender and Disaster Network (www.gdnonline.org). Researchers have demonstrated differential results in survival rates as well as in the methods women and men use to respond and recover from disasters. The 2004 Indian Ocean Tsunami, for example, resulted in approximately 300,000 deaths and displaced at least 1.6 million people across 13 nations. More than 80% of the fatalities were women and children.[29] This was due in part to the fact that, in many nations, women waited on the shore for fishermen to arrive with the daily catch, which they would then clean and sell at market.

As a leading nongovernmental organization reported after the tsunami, "disasters, however 'natural', are profoundly discriminatory. Wherever they hit, pre-existing structures and social conditions determine that some members of the community will be less affected while others pay a higher price. Among the differences that determine how people are affected by such disasters is that of gender."[29] The same is true across the Caribbean, where sex differences result in health risks that increase in disasters, such as sexual abuse and violence as well as "malnutrition, anemia, maternal morbidity and mortality, complications in pregnancy, sexually transmitted diseases, and mental and psychological conditions that cause loss of healthy life and wellbeing among women."[30]

In some contexts, men experience similar difficulties. Hurricane Mitch generated higher fatalities among Honduran men than women. Sex socialization patterns produced the differential mortality rate, as men felt compelled to remain behind and try to protect livestock and property from storm damage. Hurricane Katrina statistics also demonstrate risks, especially for elderly African American men who experienced a death rate disproportionate to their population.[3]

Other disaster dimensions demonstrate sex bias as well and unequally affect women. In a shelter environment, for example, women's needs may include maternity support, privacy for hygienic and religious reasons, nutritional supplements, child care, trauma counseling, and an environment free from violence. Sex differentiation also occurs when warnings are issued, as women appear more likely to disseminate the warning among others, to respond positively when instructions are given, and to gather the family for evacuation.[31–33] Small businesses and home-based enterprises, which are more likely to be owned by women, tend to sustain higher losses.[34,35] Women also tend to be the family member most likely to access recovery assistance and to link older family members to aid.[36]

Response and recovery organizations have been critiqued for failure to include women.[36] In Central America, increasing women's capacities and roles in disaster preparation and aid is strongly recommended. "Women's societal role is multifaceted . . . this is extremely important in the health field where women are often employed and, at the same time, are generally responsible for family health and well-being."[37] In the Caribbean, sex-based social capital brings local knowledge, social networks, and critical links to others at risk. Vulnerability can be mitigated by leveraging women's resources through increased representation, mobilization, education and training, recognition of their needs, and direct involvement in emergency management activities.[30]

Disability

Research exploring the relationship between disability and disaster has lagged behind studies of other vulnerable populations in all dimensions. Recently, experts in disability evacuation reported that "faced with a significant lack of data, professionals are unable to suggest alternatives."[38] Part of the difficulty stems from how disabilities are perceived and, consequently, how they are addressed. In a book on earthquake hazards and disabilities in California, three approaches to disabilities and disasters were discerned: the medical, economic, and sociopolitical models.[39] In the first two models, attention is focused on the individual. The medical model, for example, views disability as a "physiological or mental condition caused by an illness, impairment or other factor."[39] The medical approach addresses the problem at the individual level through treatment, prostheses, assistive devices, and/or rehabilitation. The economic model views the disability as a work limitation and defines the individual in terms of perceived abilities. The individual approach for the economic model uses rehabilitation for "gainful employment."[39]

Although researchers acknowledge the appropriateness of providing medical and economic support to those in need, they express concern that these models are blinded to the social dimensions of disability. A social perspective requires examining the way in which society circumscribes and "shapes the life chances of disabled individuals."[39] The sociopolitical model looks at how disability results not from physical limitations but from barriers that limit possibilities. In the U.S. for example, the Americans with Disabilities Act directly targeted the distinctions between the individual and social perspectives through an emphasis on accessibility and reasonable accommodations.

Since then, disability organizations and advocates have worked to apply those standards to disaster contexts. The bulk of progress has occurred after major events such as the World Trade Center bombing on September 11, 2001 and Hurricane Katrina.

After the terrorist attacks in 2001, the National Organization on Disability (NOD) launched an Emergency Preparedness Initiative. Initially, they conducted surveys asking people with disabilities if plans were in place at work for evacuation. In 2001, 50% of the respondents said "yes" followed by a decline to 34% in 2005.[40] Subsequently, NOD crafted a booklet of recommendations for emergency managers and posted downloadable disability-specific preparedness brochures on their website (see resource list at end of chapter). After Hurricane Katrina, NOD commissioned a task force to examine shelter concerns for people with disabilities. Known as the SNAKE report (Special Needs Assessment of Katrina Evacuees), NOD identified these concerns.[1]

- Problems with the intake process at shelters. Procedures did not identify disability, medical, or nutritional issues sufficiently
- Inappropriate transfer of people with disabilities to special needs and medical shelters
- Failure to evacuate people with durable medical equipment, assistive devices, and service animals
- Lack of accessible transportation and equipment at general population shelters
- Not using the skill and expertise of support organizations
- Inability to provide adequate interpretation services
- Lack of accommodation of service animals at shelters

Many people with disabilities are, or can be, independent in a disaster context. Thus, from a sociopolitical perspective, problems emanate from a societal failure to structure emergency and disaster procedures with accessibility in mind. U.S. Presidential Executive Order 13347 established that emergency preparedness measures must take people with disabilities into consideration and "increase the rate of participation of people with disabilities in emergency planning . . . preparedness, response and recovery drills and exercises." Since then, a number of new policies have emerged to address gaps in planning and preparedness (for example, see Department of Justice shelter protocol in an upcoming section). The emphasis is on building capacity among those with disabilities and bringing people with disabilities, disability organizations, and knowledgeable advocates into the planning process. Partnerships are the key. Disaster resilience can be increased and new insights generated by strengthening individuals through personal preparedness planning and inviting disability organizations to the broader planning table. As with other populations, risk reduction requires active participation and involvement by those individuals believed to be vulnerable.

Language and Literacy

Language influences the ability to obtain information of all kinds, from warnings on water quality to pandemic announcements. Within most nations, this kind of information is usually disseminated in the most commonly spoken language. Efforts to translate information must be made to reach the full population, from people with low levels of literacy to people fluent in sign language.

Low levels of literacy can impede the capability to understand and respond as directed. Written materials present obvious problems. The manner in which communication occurs can also impact response. The National Hurricane Center in the U.S. has struggled with providing understandable information to the public as well as to emergency managers.[41] Because hurricanes vary and can change quickly, forecasts must be issued in terms of probabilities and risks. Understanding probabilities and how they apply to one's personal risks can be challenging. When making a decision to evacuate, understanding those risks is crucial. During recovery, the federal aid application requires the ability to understand and complete multiple forms. Social workers and case managers report that low-literacy applicants denied benefits tend not to challenge the decision without encouragement and assistance. Benefit loss among low-literacy applicants appears to be higher as a result.

Sign language varies across geographical areas and nations and must be adapted to incorporate cultural differences. As noted in a breakthrough study, warnings fail to reach people who are deaf or hard of hearing.[42] Although U.S. Federal Communications Commission policy dictates that closed-captioning must occur during emergency time periods, few stations can afford this service and frequently fail to provide closed-captioning during rapid-onset events. Meteorologists tend to turn their backs or their sides to the camera during on-air coverage and graphics often scroll across closed-captioning. Few schools of meteorology offer instruction regarding vulnerable populations or prepare students to work with the deaf.[41] Thus the problem is not individual culpability, but one reflecting larger societal problems. Although technologies address some warning distribution issues, the cost of those devices can be prohibitive for some.

Increasing diversity within the U.S. has prompted the integration of pre-event messages and interpreters into emergency operations plans. In the San Francisco, California area alone, at least 112 languages are spoken.[43] The most frequently spoken languages include English, Spanish, Chinese (various dialects), Portuguese, and Punjabi. Issues with language and literacy can be addressed. As an example, FEMA issued informational brochures in dozens of languages after September 11, 2001. A hostel fire that occurred in Queensland, Australia during the year 2000 caused the deaths of 15 backpackers from six nations. Agencies developed a fire safety brochure in multiple languages to address this communication issue.[5] Pictorial brochures can be offered in place of written materials, with the added benefit of spanning both literacy and language issues.

Congregate Facilities

Special needs exist also for those in congregate facilities. These situations include assisted living, nursing homes, adult daycare centers, schools for students who are blind or deaf, and facilities for veterans or adults with cognitive disabilities. Very little empirical work has been performed on any of these populations in a disaster context.

More is known about nursing homes than other facilities. Transferring such populations to other facilities carries risk even though evacuation may be the safest choice overall. Nursing home administrators make the decision to evacuate and failure to do so, as seen after Hurricane Katrina, may have fatal consequences. The U.S. Government Accountability Office found additional problems. There is no national system to evacuate patients in nursing homes and "states and localities face challenges in identifying these populations, determining their needs, and providing for and coordinating their transportation." Those challenges include finding transportation resources, contractors

Figure 8.2. Caddo County, Oklahoma, August 20, 2007 – Damage to a nursing home as a result of a tropical storm. There were no injuries. Patricia Brach/FEMA News Photo. See color plate.

to drive the vehicles, and staff to escort patients. It is likely that in a major disaster, the "local demand for transportation would exceed supply" of vehicles.[44]

Hurricane Rita, which occurred shortly after Katrina, prompted massive evacuations and resulted in gridlock on Texas highways. In the worst tragedy of the evacuation, a nursing home bus caught fire and 24 patients perished. Nursing homes most likely to evacuate belong to chains that are capable of providing patient care at alternate facilities. Independent facilities are less likely to evacuate, to have adequate transportation assets to do so, and to have the staff necessary to travel with patients (Figure 8.2). The evacuation itself can be associated with increased morbidity, including what appears to be a higher potential for death, a reaction called "transfer trauma." Other challenges include the patient's ability for adapting to changes in heat or cold or obtaining proper nutrition especially in relation to medication protocols. Facilities face challenges for ensuring that support systems remain in place during evacuation, including transfer of medical records.[45,46] Efforts that were effective during the evacuation for Hurricane Katrina included actions by emergency managers working closely with home healthcare agencies, doctors, and other community organizations to disseminate messages about the impending disaster, transportation options, and shelters.[44] Studies also recommend that families and patients remain together to provide social support and lessen transfer trauma.[46]

Medical facilities that offer outpatient care can also sustain damage during an event, altering the availability of crucial services to vulnerable populations. Disruption in treatment can occur for patients receiving dialysis, cancer therapy, and human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome–related interventions as well as those with significant respiratory conditions who require assistance. In addition, the loss of facilities that provide critical resources such as oxygen and tube feeding prompt concern for rapid restoration of such services.

Immigrants and International Visitors

People who have recently arrived in a new location are among the last to receive disaster information. International students, for example, face different hazards than in their native country when they begin their studies at a new university. They will need to acquire new skills to survive an event. Similarly, recent immigrants will require outreach to teach them about local risks and appropriate protective actions. Because immigrants may include extended family members, those materials should be distributed in multiple languages and with consideration of literacy levels in those languages. An elderly immigrant may never learn the locally or nationally spoken language, putting that person at acute risk during an event. Outreach to people who are new to, or unfamiliar with, an area is crucial. These individuals include tourists, convention-goers, exchange students, or medical mission teams. The type of event can make a difference as well, for example, American Muslims experienced violent retributions and heightened fears after the events of September 11, 2001, putting them at considerable risk in some locations.[47]

After Hurricane Andrew in 1992, U.S. officials removed the name "federal" from FEMA signs to reduce fear of deportation among local immigrants. After the Loma Prieta earthquake in San Francisco in 1989, Central American immigrants relocated to a makeshift tent city as a result of fear of the National Guard presence at a formal Red Cross shelter. For these recent immigrants, the uniformed presence signified "death squad." In 1999, Darwin officials in Australia hosted over 1,800 evacuees from East Timor. Local officials worked with members of the existing East Timorese/Portuguese community out of concern for language, religious, and sex differences. Together, they established the Police Ethnic Advisory Group to operate a reception center. For more than 2 years, local fire, police, and Timorese leaders worked as partners to receive evacuees. Their efforts included utilizing local Timorese representatives to meet new arrivals and use their native language. Their "fellow country" people helped to establish and explain appropriate food preparation, sleeping, religious, and health procedures.[5] As with other groups, involvement of the "at risk" population in addressing the issues can provide crucial resources.

Intersected Vulnerabilities

As experienced researchers have delineated, it is empirically challenging to separate demographics and specify that only sex, income, or age creates a vulnerable condition. In reality, demographic conditions and the broader social, economic, cultural, and even political conditions in which people live create "entangling effects" that foster and exacerbate vulnerability.[48]

Although specific circumstances and/or conditions may generate vulnerabilities and special needs, it is likely that overlapping conditions also contribute and will require attention. For example, greater susceptibility to health issues such as osteoporosis means that women in general may be more likely to sustain injuries. Women's vulnerability is further exacerbated by age, which can be aggravated by disability. An elderly woman with a mobility, sensory, or cognitive disability bears disproportionate risk in a disaster context and merits a more comprehensive range of intervention strategies.

Elderly men are more likely to live in socially isolated conditions, away from important relationships and networks that may provide buffers against the consequences of disasters. In addition, their disability risk increases with age. Fifty percent of those older than 75 have some type of chronic condition and 75% of those older than 80 have "at least one significant disability."[46] Because disability is associated with lower wages, technological devices such as text messaging may not be affordable for a low-income individual with a disability or even appropriate for a senior citizen. To summarize, one "condition" or population demographic is insufficient to understand vulnerability. Rather, a complex set of conditions, circumstances, and contexts interact to produce vulnerability. Using a simple checklist of possibly affected population groups is a starting point. Understanding the intersected nature of vulnerability and the concerted efforts that must be made to address that complexity is necessary for real vulnerability reduction.

The Life Cycle of Emergency Management and Special Needs

Both emergency managers and disaster researchers tend to group the practice and knowledge relating to disasters into a "life cycle" of emergency management. Most nations organize their disaster activities around categories described in this cycle. In New Zealand, for example, they are known as the Four R's: readiness, response, recovery, and reduction. In the U.S., the National Governor's Association first organized the phases into preparedness, response, recovery, and mitigation activities. Regardless of the terms, the phases have influenced both practice and research. The remainder of this chapter will address special needs concerns within each phase. Each subsection will first define and illustrate the phase of emergency management and connect it to the topic of special needs. Ideas and practical strategies will then follow for each phase to generate reflection and practical solutions.

Preparedness

Preparedness is defined as "actions undertaken before disaster impact that enable social units to respond actively when disaster does strike."[48] Actions should be taken at the individual, household, organization, and community levels as well as within local, state, and federal governments. Activities might include building partnerships, development and dissemination of educational materials, training for specific tasks such as sheltering or triage, evacuation planning, the creation of special needs registries, writing emergency operations plans, and holding exercises. This section examines key areas starting with the advice most frequently given by emergency managers and social service providers to know the community.

Know the Community

Before any serious effort can be made to address special needs, emergency managers must first learn as much as possible about the demographic groups present in a community as well as the organizations with which partnerships can be built. The U.S. census provides data of local populations with general overviews. The census occurs every 10 years with more frequent assessments made through random sampling conducted by the American Community Survey. Both can be accessed at www.census.gov. General information gleaned by geographical location includes overviews of race, ethnicity, languages, sex and age distributions, disabilities, and income levels. The problem with the census is that it misses key population descriptors, such as recent immigration, literacy levels, and homelessness. Thus the census is only the first step in assessing localized and special needs (Table 8.1).

The second step in knowing the community is identifying the range of local community-based organizations. From these groups, it is possible to then learn more about those present in the community. Agricultural areas in southern Florida and parts of California, for example, have health and advocacy organizations dedicated to both migratory and resident farm workers. Urban locations usually host missions and other places dedicated to those who are homeless. Faith-based organizations extend services to new immigrants and may offer personnel who speak relevant languages. A key organization with which to link is the local emergency management agency. An increasing trend among emergency managers is to establish a Special Needs Advisory Panel. Becoming part of this partnership provides links to organizations with expertise including disability and rehabilitation agencies, health organizations, and senior networks.

Medical personnel represent a marginally tapped disaster management resource in many communities. Typically, hospitals and medical staff remain in a stationary location waiting to receive patients. Conversely, outreach by medical personnel into the existing or emerging partnerships that address special needs can make a considerable difference. Expertise on disabilities, movement of fragile patients or frail elderly, and insights into child and partner abuse can help emergency managers and other organizations to reduce risks. According to the U.S. Government Accountability Office, physicians and medical staff played an important role in identifying patients who needed transportation during Hurricane Katrina. A stronger link among individuals, the medical community, and emergency managers can make a measurable difference in reducing risks. Medical personnel who provide services to nursing homes, assisted living facilities, settings for people with cognitive disabilities, and other similar locations can encourage those facilities to train personnel frequently on emergency procedures. By getting acquainted and working with a broad array of partners, special needs can be identified pre-event for planning and building partnerships.

Table 8.1: Representative U.S. Census Data Depicting the Size of Various Vulnerable Populations*

Location	*General Population*	*Disabled Age > 5 y*	*Minority Groups*	*Age > 65 y*	*Below the Poverty Level*
Bradenton, FL	49,504	11,365	5,574 Hispanics 7,481 African American	12,589	6,572
Denton, TX	80,537	11,298	9,025 foreign born; 13,188 Hispanic, 14,081 speak a language other than English at home	6,364	11,776
San Francisco, CA	776,733	150,131	239,565 Asian 109,504 Hispanic 60,515 African American 3,844 Hawaiian/Pacific Islander 3,458 American Indian/Alaska Native	106,111	86,586

* The groups represented here may vary considerably in number across communities.

Source: U.S. Census, 2000.

Training and Education

It is not sufficient to read a single chapter on special needs issues. Continuing education is necessary, particularly as policies and procedures are rapidly evolving within the U.S. alone. To obtain more information, these resources may be useful.

- Universities and colleges have developed programs across the U.S. and in some other nations that include opportunities for stand-alone courses, certificates, or degrees. Many offer courses available on the Internet for distance learning. Links to programs can be found at the FEMA Higher Education Project website (http://www.training.fema.gov/EMIweb/edu/collegelist/, accessed January 12, 2009).
- FEMA offers an interactive course at their Independent Study (IS) website. IS197 concerns special needs (http://training.fema.gov/EMIWeb/IS/is197SP.asp, accessed January 12, 2009).
- Professional emergency management conferences, such as the National Hurricane Conference or the International Association of Emergency Managers, offer topical workshops and Continuing Education Unit credits for special needs courses. Specialized conferences appear on list serves for emergency management such as the 2008 conference on special needs held by FEMA Region II in New York City. Organizations such as the International Association of Emergency Managers, the National Emergency Management Association, or the Natural Hazards Center at the University of Colorado-Boulder provide list serves (the latter is available free at www.colorado.edu/hazards/).
- Scholarly journals are increasingly publishing special needs research. Top journals that should be scanned for recent articles include the *Natural Hazards Review,* the *International Journal of Mass Emergencies and Disasters, Environmental Hazards, Natural Hazards, Disaster Prevention and Management, Disasters,* and the *Journal of Emergency Management.*

Further sources of information and training stem from local, state, federal, and international emergency management agencies. Such entities routinely hold tabletop exercises and community drills. Participation is recommended. Training should include all personnel in a medical setting from those who dispose of biohazards or push wheelchairs to the top administrators.

Finally and perhaps most importantly, healthcare personnel should engage in cross-training with disaster organizations. The American Red Cross trains shelter managers and provides other disaster courses. For professionals in psychology and psychiatry, the Red Cross requires careful credentialing before assistance can be rendered.

Other organizations can benefit from cross training as well. For example, after the 1989 Loma Prieta earthquake in San Francisco, a Latino healthcare organization called Salud Para La Gente cross-trained with the American Red Cross. The benefits were significant. Salud Para La Gente developed an emergency response healthcare plan and the Red Cross expanded its network of providers for the Spanish-speaking community. This partnership likely paid other dividends as well across the community by demonstrating the value of cross-cultural and interorganizational linkages. The medical community can work with experienced disaster providers to offer training. Shelter managers can benefit from specialized instruction offered by the medical community to help identify evacuees who appear stable but could deteriorate due to unseen medical conditions, nutritional requirements, and other circumstances. Medical associations can partner with veterinary organizations to deliver joint assistance to people using service animals.

Public Education

One of the foremost tasks in the preparedness phase is educating those at risk about approaches to reduce their own vulnerabilities. Medical personnel can play an important role in this by extending information to their patients.

- Place informational brochures in waiting rooms. Free, disability-specific brochures can be downloaded from the National Organization on Disability (NOD) at www.nod.org (select Emergency Preparedness Initiative). Care should be taken to provide materials in multiple formats for various languages and literacy levels as well as for people with varying degrees of visual limitations. Offices may also consider purchasing communication boards that include specific languages, pictures, and situations (i.e., bleeding or pain).

- Include individual and household risk assessments during medical histories and annual examinations. Disaster checklists can be obtained at www.ready.gov, www.fema.gov, and www.preparenow.org. Histories can concentrate on the level of individual or household preparedness for an event such as an evacuation. Long-term psychological trauma tends to be more likely among those with previous trauma. By assessing for such trauma (e.g., war injuries, interpersonal violence, prior disaster or severe injuries) it may be possible to identify pre-event those at risk and offer advice and counseling resources to strengthen patients' ability to respond with resilience.[9,10]
- Advise patients that they should establish an emergency bag or "go kit" (Table 8.2). Materials that should be included are identified at www.ready.gov and www.redcross.org. Within this kit, it is particularly important that patients include medications, lists of medical routines, a medical history, communications information and preferences, nutritional needs, insurance and Medicaid/Medicare papers, and contact information for healthcare and pharmacy providers, family, guardians, or caretakers.
- Alert patients to opportunities for obtaining emergency bag items or other information, especially low-income patients and U.S. seniors on Medicare Part D (particularly those that are experiencing gap coverage). This might include assisting patients with pharmaceutical programs that provide free or reduced medications.
- Explain to patients how general populations and special needs shelters operate. Because individuals with disabilities may be reluctant to evacuate due to the belief that shelters will not be ready, it can be valuable to provide that information and encourage evacuation.[49]
- Send new parents home from the hospital with checklists for emergency procedures in a disaster context and/or fund emergency bags (formula, diapers, and other key items).
- Target people with disabilities and seniors for special attention and provide information through both direct contact and accessible-format materials. Medical personnel tend to have high levels of credibility when disseminating information, so these efforts can have considerable impact.
- Link with home healthcare agencies and encourage them to provide disaster information to patients, particularly those in transition from hospital to home. A family leaving the hospital with someone using an oxygen tank for the first time may need special training not only on the medical equipment but also on how to help the family member take appropriate protective actions in a disaster. For example, how can a family member move an individual with new mobility limitations without injury? Where can the family member obtain assistance in such a situation?
- Support domestic violence shelters with outreach to individuals experiencing intimate partner violence. Because it appears that domestic violence may increase after disasters, those known to be at risk require additional attention. Medical personnel can provide information and escape options and support the efforts of domestic violence prevention staff.[50]

Table 8.2: Suggested Items for a "Go Kit" to Use in an Emergency

General items (based in part on www.ready.gov)
- Radio and batteries for 3 days
- Water, 1 gallon per person per day for at least 3 days
- Flashlight and extra batteries
- Whistle to signal for help
- Cell phone or communication device with extra batteries
- Clothes and bedding in case of an overnight stay including in a vehicle
- First aid kit
- Medications and medical records
- Identification papers
- Dust mask or t-shirt to use as an air filter
- Toilet paper, paper towels
- Disinfectant, hand gel, antibacterial towelettes
- Appropriate food for each person for 3 days
- Can opener to open cans; plates, utensils, cups
- Communications plan to stay in touch with the family
- Maps

Additional items for senior citizens (based in part on www.redcross.org, www.ready.gov)
- Extra medications, medical records, prescriptions
- Assistive devices that may be needed
- Denture needs
- Pillows or other items that provide comfort or support

Additional items for people with disabilities (based in part on www.nod.org)
- Dark glasses for those sensitive to light
- Assistive devices; folding cane
- Paper to write notes
- Medical records
- Communications devices
- Extra battery packs for anything requiring power; recharging devices
- Patch kit for tire repair
- Heavy gloves to move debris or use with a wheelchair
- Whistle to signal for help

Additional items for parents of young children (based in part on http://www.ready.gov/kids/step1/index.html and www.redcross.org)
- A special and familiar toy or blanket
- Familiar food appropriate for medical and nutritional needs including infant formula; bottles; powdered milk
- Diapers
- A familiar pillow to aid the child in sleeping
- Activities to keep the child busy, especially those that do not need batteries
- Clothing and bedding appropriate for weather variations

Pets and Service Animals (see also www.hsus.org and www.nod.org)
- Veterinary records; first aid kit
- Food, medications, water; can opener
- Vests and identification for service animals
- Muzzles, leashes, collars, identification on the pet
- A crate to use in a shelter environment
- A toy
- Litter, pan, scoop; newspaper for bedding to litter
- Paper towels, plastic bags
- Stakes or tie downs

Registries

Special needs registries are often considered a useful preparedness strategy. Registries are lists of people who might require assistance in an emergency, such as a person who is blind or someone with limited transportation options. Such listings have been touted as a possible solution to identifying those at risk and providing adequate resources. Registries vary and might be extremely comprehensive, including everyone who lacks transportation. In comparison, others might focus on just those who require paratransit vehicles for people using wheelchairs. Registries have never been studied empirically, although it is clear that they do have benefits as well as limitations. After the 2003 wildfires in California, the Independent Living Council conducted an assessment. Although a registry existed identifying those needing assistance, problems occurred when emergency personnel could not access the confidential registry due to security measures.[51] Other challenges with registries include the possibility that registrants fear self-disclosure of personal information, costs associated with maintenance, physical location, and the means for storing and backing up the list (paper, database, or web based).

Typical groups who work together to maintain registries include emergency managers, home health and related social service agencies, aging organizations, disability organizations, disaster organizations such as the American Red Cross, fire departments, emergency transportation and medical units, paratransit resources, the health department, veterans affairs personnel, disability and rehabilitation services, and interpreters. Issues of confidentiality and access typically arise because of the myriad organizations and agencies that might participate. A single organization, such as the fire department or emergency telecommunications office, might manage the list. Each agency or organization may maintain their own respective list to facilitate contacting clients. Maintenance of registry lists appears to be particularly challenging. A well-funded effort in Alabama for a nearby chemical weapons facility faced annual challenges in updating registrant contact information.[52] Registries, although certainly a practical strategy, also represent a considerable challenge.

Evacuation

There are many reasons why evacuation is problematic. The main reason that so many people were stranded or died after Hurricane Katrina was due to lack of transportation. A study done on Hurricanes Floyd and Dennis discovered that people with disabilities might have assumed that shelters were not prepared for them and they would not evacuate.[49] When someone identified as an evacuation "buddy" is unavailable, escape is not possible. There is no standardized system in place to evacuate massive numbers of people from congregate facilities. Specific locations face particular challenges. As an example, a domestic violence shelter in New Orleans could not purchase bus tickets when officials closed the bus station during the Hurricane Katrina evacuation. The shelter director eventually found keys to a van and drove the residents to safety in Baton Rouge.[53] The last bus of evacuees to leave Plaquemines Parish below New Orleans was populated with Vietnamese-American men who were attempting to protect their economic livelihoods and family possessions until the last possible minute.

The large-scale evacuation of New Orleans revealed several issues. To move people quickly and without accessible transportation, those assisting people with disabilities left wheelchairs, assistive devices, and other necessary items behind. The Louisiana Department of Rehabilitation spent 6 months trying to retrieve items and return them to their owners. Some wheelchairs that cost up to $30,000 were irreplaceable. Paramedics in Texas, Oklahoma, and other locations reported serious problems when patients arrived at shelters. Buses had sometimes driven for 12 hours straight through, resulting in not only deteriorating conditions for medical patients on board but also a hazardous waste situation for first responders. The goal of evacuation is to conduct pre-event planning and activate appropriate resources for those at risk. Prior to the approach of Hurricane Ike on the Texas Coast in 2008, emergency management officials put such plans into place for congregate populations and special needs residents.

Because medical professionals represent trusted, credible individuals, it is valuable for them to become involved in evacuation and transportation planning and the issuing of warning messages. Medical personnel can also engage in the following activities.

- Participate in evacuation planning and provide insights on how to transport people with particular conditions in a safe and healthy manner. Ensure that medical records, medications, and support staff stay with those at risk. This includes those who may appear healthy but could deteriorate under conditions of stress, heat, or severe cold.
- Assist with training evacuation personnel in methods for transporting individuals with a specific condition, from someone relying on a ventilator to a patient with a bariatric disorder.
- Contact patients who might not receive warning, evacuation, and transportation messages, including the deaf, hearing impaired, blind, aged, and those with low levels of literacy or who are non-English speaking. Conducting outreach through health clinics and other facilities that serve low-income individuals and families can help to disseminate information through credible sources. Advocate for these groups by encouraging local officials to do the same.
- Advise patients and local authorities to develop plans for pet evacuation. Seniors seem more likely to evacuate if pets accompany them. Such planning also benefits service animals.
- Encourage local officials to search widely for accessible transportation resources. The best efforts to use nongovernmental resources require advance negotiation for liability and reimbursement.[44]
- Ensure that receiving personnel are well trained and organized to manage a variety of conditions when patients or vulnerable groups arrive. These range from medical problems and interpersonal violence to children separated from their parents.
- Join local officials in planning and advertising local general population and special needs shelters. Ensure that those in need of such facilities realize that arrangements have been made for their mobility, nutritional, and other needs as well as for their service animals.
- Request that local officials keep evacuees with their durable medical equipment, assistive devices, and service animals. Help patients and officials develop personal evacuation plans, protective actions, and communication strategies that keep families, guardians, and caretakers together. Suggest a buddy system, with multiple backups, for those in need of personal transportation assistance. A checklist to determine if someone needs a buddy can be found at www.preparenow.org.

Response

The emergency response phase focuses on saving lives and reducing damage from an impending or ongoing event. Efforts are made "to reduce casualties, damage and disruption and to respond to the immediate needs of disaster victims."[48] Response activities are likely to include: implementing an emergency response plan and requesting support personnel; initiating search and rescue activity; first aid and emergency medical intervention; opening special needs and medical shelters; and measures such as sandbagging, implementing a plan to operate generators, or opening a distribution center for medications.

Shelters

Two kinds of shelters begin operations after a disaster. The first is a general population or mass care shelter open to everyone. Traditionally, the American Red Cross operates this facility in the U.S., although in most disasters, others such as faith-based organizations may also open shelters. In developing nations, nongovernmental organizations may establish relief centers. General population shelters are supposed to accept people with disabilities and their service animals, but that is not always the case. During Hurricane Katrina, for example, some general population shelters turned away people with disabilities who could have remained independent. The massive evacuation also complicated the situation for people who lost or were forcibly separated from assistive devices and durable medical equipment. Children, people with acute medical needs, seniors, and people with disabilities were also separated from friends, family, guardians, and caretakers. This meant that these individuals were routed to the second type of shelter, usually referred to as a special needs or medical shelter.

Ideally, it is desirable to accommodate as many people as possible, given their condition, in a general population shelter to maintain independence and reduce impact on staff in both types of relief centers. Keeping evacuees with their own equipment (e.g., medical, communications), key social support systems, medical records, and medications during evacuation increases the probability they will actually leave the area. The U.S. Department of Justice offers an Americans with Disabilities toolkit for state and local governments on their website specific to shelters. Key recommendations for shelters include

- Plan ahead; "a person's health will be jeopardized without access to life-sustaining medication that must be refrigerated."
- Individuals with disabilities, including "those with disability related needs for some medical care, medication equipment, and supportive services" should use general population shelters with family, friends, and others.
- Provide trained staff to medical shelters and keep families together in such locations.
- Modify kitchens to allow people with medical conditions, such as diabetes, to have immediate access to food and medications.
- Provide a variety of means to communicate.
- Safeguard residents from further injury by assessing the environment, especially considering individuals with mobility or sensory disabilities such as low vision or blindness.
- Offer a "low-stress" location, which may be particularly valuable to children and adults with cognitive disabilities.
- Invite people with disabilities to specify their needs and participate in problem solving as they can provide relevant, useful insights.
- Stockpile durable medical equipment and medications for shelter use.

As another step toward proper facility use, general population shelters should establish intake procedures to identify specific needs and ascertain if an evacuee requires further support. Generally, shelters distinguish between those who require minor assistance and can remain in a general population center (e.g., those with asthma or require tube feeding) and those who require enhanced care such as a continuous intravenous infusion. Other issues to assess include mobility, language and communication preferences, literacy levels, presence and needs of service animals, and availability of a family member or translator. If most of these needs are met, the individual can remain in the general population shelter; however, the facility should remain cognizant of the continual needs of the evacuee. Other confidential questions might be asked in a private setting to encourage disclosure and to design appropriate support or intervention.[54] For example, a patient with HIV may fear disclosure; however, if that patient were separated from medications required to control the disease, the information regarding HIV infection would be crucial to obtain. A similar situation exists with a family member at risk for domestic violence. Intake staff should be trained to establish a trusting environment to secure crucial healthcare information. The intake process also allows for consideration of potential transfer to a special needs shelter.

Special needs shelters represent a last-resort outpatient facility where those with extensive medical requirements can receive care. Such locations are reserved for those not acutely ill and admission should be based solely on medical eligibility. Special needs shelters require extensive pre-event planning for staffing, supplies, facility selection, transportation, logistical support, intake, and discharge. Medical supervision is mandatory in a special needs shelter and should be coupled with adequate staffing and resources including reliable sources of power, water, heat, air conditioning, proper nutrition, and supplies. Where possible, it is far more desirable to place patients in an existing facility.

In both general populations and special needs shelters, discharge planning is required. Those in charge must consider whether the evacuee is able to travel home. Issues to consider include 1) debris removal from the roads and inside the home, 2) restoration of utilities to minimum levels, 3) transportation of the evacuee home and proper support to sustain basic needs while residing in the home, 4) the evacuee's needs to return home including transportation, medical care, family support, and power, 5) the evacuee's loss of critical resources that need replacement, including a wheelchair, and 6) the needs of the evacuee's service animal. By identifying the problems that must be addressed, a list of possible support organizations can be created including disability and aging organizations, veterans facilities, home health agencies, veterinarians, rehabilitation centers, medical supply companies, and others familiar with the transition from shelter or hospital to home.[54]

Continuity of Care

Disasters disrupt multiple community functions, including a wide range of medical services needed by vulnerable populations. Post-Hurricane Katrina reports indicate that not only did hospitals close, but other facilities including clinics, mobile outreach units, dental offices, dialysis centers, and cancer treatment facilities ceased operations. Vulnerable populations suffered significant disruptions in healthcare services, particularly seniors and people with disabilities. Although a situation as extensive as Hurricane Katrina occurs rarely in the U.S., it is clear that continuity of care to low-income households suffered. To ensure that vulnerable populations sustain continuity of medical care, it is necessary to

- Ensure that medical records can be easily transferred. This requires a system for protecting and duplicating medical records that can survive the disaster itself.
- Develop a crisis plan to expedite prescription refills, sometimes at significant distances.
- Store extra supplies including prescription medications in an easy-to-access location for distribution to low-income households, especially senior citizens on fixed incomes. When people must evacuate, it may be useful to help them reestablish contact with a pharmacy and/or pharmaceutical company assistance program.
- Establish and participate in networks among healthcare organizations, public health agencies, and community-based organizations that connect to vulnerable populations. These include groups who are non-English speaking, homeless, and newly arrived immigrants.
- Contact congregate or similar facilities that may need support due to staff reductions or disruption of supplies. Solicit volunteers (best done through pre-disaster memoranda of understanding or mutual aid agreements) to serve at veterans' centers, state schools, centers for people with cognitive disabilities, farm worker rest centers, domestic violence centers, adult daycare, senior centers, nursing homes, and similar locations. Offer free screening or testing for basic healthcare needs.
- If healthcare facilities are established during a disaster (including points of distribution for medications for patients exposed to bioterrorism agents or influenza prevention), be sure that locations are accessible to people with disabilities, seniors, and others. Offer childcare to encourage single parents to present for medical care.
- Work with and train shelter staff to identify and assist people experiencing a disruption in healthcare services, including those requiring dialysis, cancer treatment, or HIV management. Plan how to assist these shelter residents prior to the event, particularly those distant from their usual healthcare providers.
- Be aware that most donations and acts of volunteerism occur during the response period. The bulk of human needs occur through the extended recovery period.

Recovery

Recovery is a process that involves "putting a disaster-stricken community back together."[55] Activities that might occur during this period include: 1) discharging individuals from special needs or general population shelters, 2) ensuring that persons with disabilities can navigate their damaged living environment when they return home, 3) restoration of utilities and healthcare access, 4) debris removal with adequate safeguards for health risks, 5) major reconstruction of the built environment including roads, ports, bridges, transit, and paratransit systems, and 6) providing both temporary and permanent homes that are accessible. In this section, a few of the key areas are examined in which medical personnel can have a significant impact.

Recovery Planning

Although predisaster recovery planning is ideal, most locations fail to accomplish this task. Consequently, postdisaster recovery planning is the norm. Such planning typically sets out guidelines and goals for rebuilding the community. In many locations, a recovery planning task force is convened. The broader public may be periodically informed of progress or invited to actively participate. Regardless, medical professionals bring a special kind of asset, called structural social capital, to the planning process. This kind of social capital emanates from the status attributed to medical professionals.[56,57] They bring capital from this status into events such as a recovery planning process. The capital can include insights, ideas, suggestions, procedures, and perspectives that can impact the recovery plan. Because medical professionals also benefit from the respect of the broader community, they are viewed authoritatively and their opinions have a great deal of credibility. Their participation is important, in part because they can advocate for those lacking a presence on the recovery planning team. Seniors may be unable to travel to a recovery meeting. People with disabilities may be working to reestablish basic household, work and healthcare routines and not have time to attend. New immigrants may not even learn of the meeting or be unfamiliar with how such a process is conducted.

Medical personnel can thus be advocates for those lacking a voice though actions including the following.

- Emphasize a need for paratransit resources and accessible roads, curbs, bridges and neighborhoods during the rebuilding process.
- Encourage recovery planners to reach out to and include non-English speaking residents.
- Request that recovery meetings are accessible for a wide variety of participants.
- Suggest that recovery meetings be held in accessible locations including senior centers, homeless missions, farm worker labor camps, independent living centers, and public housing units.
- Discuss the value of integrating a holistic recovery design that connects people to the locations they need to visit such as the pharmacy, grocery store, and healthcare or fitness center. Ensure that environmental quality is included in the recovery plan so that future generations are not affected by debris management, pollution, or loss of habitat.[58]
- Advocate that a percentage of all new construction fall into the affordable range for the affected community.
- Help maintain a wide range of economic opportunities so that people can earn a living from home-based to small businesses to large-scale industries. Specify that rebuilt businesses must safeguard those at risk with appropriate mitigation strategies.

Debris

Disasters can generate massive amounts of debris that must be handled according to appropriate environmental controls. After Hurricane Hugo in 1989, North Carolina officials sought alternatives to burning massive amounts of green waste due to concern over air quality and ozone pollution, which could unduly affect those with chronic respiratory conditions.[59] Their solution was to convert the downed trees into mulch and firewood. The attacks on September 11, 2001, represented multiple and different kinds of challenges. Monitoring of both short and long-term health conditions continue due to inhalation of contaminated air at the World Trade Center.[21,60–62] Increased rates of asthma and a condition known as the "World Trade Center cough" have emerged as the key concerns, especially among specific groups such as firefighters, truck drivers, and other debris workers.

Vulnerable populations that bore increased potential risk included workers cleaning adjacent locations. A mobile medical screening project reached out to Hispanic workers who did not speak English and lacked health insurance. Furthermore, these workers did not receive personal protective equipment or training for hazardous waste contact. Medical staff found persistent symptoms that lingered after discontinuing the work that included irritated airways, fatigue, headaches, difficulty sleeping, and dizzy spells.[63] One study of expectant mothers found a possible incidence of lower birth rates and shorter pregnancies.[21] To support vulnerable populations in disasters that generate debris, the following are suggested.

- Question patients about their exposure to any element of debris including dust that settles inside a home, mold that grows from floodwaters, and exposure to hazardous household chemicals or more serious toxic waste. Monitor patients appropriately.
- Ask patients to identify their occupation and note any potential exposure to debris. Be sure to screen for temporary work assignments and volunteer activities.
- Identify specific work crews that handle debris and establish a procedure to follow their health and record symptoms for an appropriate duration of time. Pay particular attention to those who lack training and may be hired as day laborers.
- Demand protective equipment and training for all debris workers and contact state and federal authorities to provide oversight at work sites.
- Work with medical epidemiologists to gather and analyze debris effects. Include a census of people living, working, or traveling in or through the affected area. Identify populations that may bear disproportionate risk due to exposure and provide appropriate medical intervention.
- Support healthcare and other organizations that attend to those without routine access to medical care who may have been exposed to hazardous substances, including undocumented workers or the pre-disaster homeless.
- The World Trade Center Health Registry will continue to monitor 8,148 individuals exposed to the debris and other effects after the terrorist attacks for 20 years. Medical providers should remain informed about the longitudinal consequences of debris exposure. (See: http://nyc.gov/html/doh/wtc/html/registry/registry.shtml, accessed January 12, 2009).
- Provide healthcare information in relevant local languages and at varying literacy levels (Figure 8.3).

Figure 8.3. Biloxi, Mississippi, September 27, 2005 – Vietnamese residents of Biloxi, Mississippi are assisted by a FEMA community relations representative. Mark Wolfe/FEMA News Photo. See color plate.

Psychological

Although it may seem counterintuitive, most people fare well psychologically after disasters. In a massive meta-analysis of 60,000 disaster victims, the most commonly appearing symptoms were depression and anxiety.[9,10] Posttraumatic stress disorder, a form of anxiety, was relatively low. Nonetheless, it was also clear that certain conditions increased vulnerability to psychological symptoms. Prior trauma has been linked to the development of posttraumatic stress disorder. Some studies link sex, race, and ethnicity to higher rates, although it is also believed that severity of exposure exacerbates posttraumatic stress disorder. People living in inferior housing, which is more prevalent among some populations such as female-headed households, will experience higher levels of exposure to damage and injuries. Predisaster trauma can also increase the potential for postdisaster trauma, such as prior exposure to interpersonal violence. Massive collective loss is also associated with higher rates of trauma, such as when an entire community must relocate or suffers significant losses.[64]

More common psychological responses include trouble sleeping and the potential for increased use of alcohol, drugs, and smoking. Increase of the use of these substances tends to be associated with predisaster use. What may mediate these responses are strong interpersonal relationships, having obtained counseling for prior trauma, being embedded in a secure social network, and remaining optimistic about the situation. Medical personnel can screen patients for risk (alcohol and drug abuse, nicotine addiction, and domestic violence history) and offer information and referrals to local counseling and crisis intervention. In the U.S., FEMA funds crisis counseling for disaster survivors.

Reestablishing Medical Facilities

When the Indian Ocean tsunami struck the community of Nagapattinam in the State of Tamil Nadu in 2004, a local hospital with 56 buildings and 300 patients lay in its path. As local villagers raced into the compound with cries of “water, water,” staff and family scrambled to carry patients to higher floors. The waves burst through the neonatal unit, surged into most of the buildings above the height of patient beds, and destroyed valuable medical equipment. This represented a significant loss for an impoverished community. Yet not a single patient or staff member died. Medical staff then moved quickly to try and resuscitate the victims outside the facility. The futility of this effort, however, soon became clear. Victims either lived or died; there was little middle ground. Just a few months earlier, the staff had experienced disaster training albeit not for a tsunami. The training transferred to the new context.

As the waters receded, remaining mud and debris damaged the buildings further. Over the following year, medical staff worked with UNICEF and other nongovernmental organizations to secure funds and rebuild the hospital farther inland. The new hospital required water treatment facilities, a new kitchen, new beds, x-ray and surgical equipment, and offices. Restoration of services was urgent because the hospital was the only medical facility for hundreds of miles.

Hurricane Katrina caused similar damage to healthcare facilities including the loss of Charity Hospital in New Orleans, a facility for indigent patients that will not reopen. Although some hospital and treatment facilities have opened in the damaged areas, low-income healthcare remains disrupted. Reports of limited service to people with disabilities continued 4 years later. To maintain services to vulnerable populations, it is recommended to

- Develop business continuity plans for a medical facility or office.
- Determine the additional number of disaster survivors who can be added to a patient load (surge capacity) and the costs of those services. Consider a sliding fee or take a tax contribution for those services.
- Develop mutual aid agreements with comparable facilities, including cross credentialing of staff, so they may work at multiple hospitals.
- Prepare memoranda of understanding with area shelters, congregate facilities, and others to provide continuity of care to these locations.
- Plan medical mission teams with stored supplies and funds prior to the event.
- Develop a staff release plan to send medical personnel to affected areas.
- Join international and national efforts like the Disaster Medical Assistance Team program before disaster strikes; acquire training and plans for deployment.
- Support local emergency management efforts to reduce risks through mitigation planning and implementation of risk reduction measures.

Mitigation

Mitigation is defined as "sustained action taken to reduce or eliminate the risk to human life and property from hazards."[65] Mitigation can be divided into two main types, structural and nonstructural mitigation. Structural mitigation measures target the built environment and might include shatter-resistant glass in nursing homes, elevating homes above anticipated flood levels, securing bookcases and filing cabinets to the wall to avoid injuries during an earthquake, and safe rooms. Nonstructural mitigation measures include land-use management that disallows development in floodplains or building codes that increase roof resistance to high-velocity winds. Medical offices should create protective action plans for the range of local hazards that could affect patients and staff.

Medical facilities can be hardened to withstand local hazards and ensure continuity of care. By working with architects and engineers, additional strengthening can be added to secure roofs, retrofit walls for local risks, and prevent projectiles and debris from penetrating windows and doors. To reduce risks to life safety, FEMA recommends that facilities prevent loss of power through purchasing and locating generators in areas safe from hazards and by developing a generator operations plan. In short, by securing medical facilities, the possibilities for assisting vulnerable populations and preserving critical services increases. Nonstructural mitigation measures would include code compliance, purchasing hazard-specific insurance, and identifying alternate locations for continuing operations should a disaster affect offices and facilities. Avoiding downtime for the facility and reducing the costs of displacement can protect a medical business.

Medical professionals can also support local efforts to safeguard those at higher risk. Few trailer parks, which usually house low-income households, offer congregate safe room locations from tornados. Other congregate settings fare poorly as well, a situation that can be remedied through supporting new building codes and local land-use planning. In 2008, FEMA funded a grant to the Association for Retarded Citizens of Baldwin County (Georgia, U.S.) for construction of the first congregate safe room for people with special needs. The Hazard Mitigation Grant Program provided $3.2 million USD for the facility, which will shelter 430 people. In addition, the grant provides funds to retrofit the Laundry and Life Skills Training Center to increase the capacity of the roof to withstand 320-kph winds. This structural mitigation project will safeguard a previously at risk population and should be duplicated widely.

Other locations can benefit from mitigation measures that alert people to danger. Sirens, alarms, lighted strobes, vibrating devices, pagers, wireless devices, tactile signs, and evacuation devices can be installed in any workplace including a medical office, home health agency, dialysis center, hospital, or personal home. Physical barriers can be removed to allow for egress by those in wheelchairs and evacuation devices can be purchased and placed pre-event for use (an extensive list of disability-specific devices can be seen at the Job Accommodation Network, www.jan.wvu.edu, accessed October 15, 2008). Medical associations should consider partnering with civic organizations to secure funding for placement of such devices in private homes and congregate facilities.

Finally, the time period immediately after a disaster is usually referred to by emergency managers as the "window of opportunity." This phrase means that the opportunity exists to introduce measures that reduce further risk during this period. After the 2004 Indian Ocean tsunami, for example, many nations expressed concern about massive epidemics from the number of deceased. Although most researchers suggest that such outbreaks are extremely unlikely, the concern prompted an opportunity. Across the affected area within India, both governmental and nongovernmental organizations vaccinated tens of thousands of survivors against cholera, typhoid, hepatitis A, and dysentery.

Emerging Policies and Practices

Several policies and practices have emerged since Hurricane Katrina in the U.S., although some remain in draft status. The U.S. Department of Transportation will develop plans for highway evacuation. The Federal Highway Administration is producing guidance for transportation of people with disabilities that provides advice for evacuation of congregate facilities where such individuals reside. FEMA, following a lawsuit (Brou v. FEMA), is continuing to integrate people with disabilities and disability organizations into their policies and programs to make temporary housing accessible. The National Disaster Housing Strategy and Plan (in draft status in early 2009) acknowledges the valuable partnership that can occur with disability organizations, especially at the state level. The National Council on Disability in recent years has investigated emergency preparedness issues and reports through minutes of its quarterly meetings available on its website (www.ncd.gov, accessed October 15, 2008).

RECOMMENDATIONS FOR FURTHER RESEARCH

Extensive research remains necessary on vulnerable populations. More specifically, a number of research questions carry implications for medical professionals. Future research might focus on

- How various jurisdictions develop, use, and share registries, including the challenges of maintenance and confidentiality.
- Medical support during the evacuation of residents using general transportation resources including buses, paratransit vehicles, and caravans.
- The development of checklists and forms usable during life histories to assess risk and document disaster-related health issues.
- The most effective strategies for keeping families, guardians, and caretakers together during evacuation, sheltering, and return to the home.
- Loss of healthcare facilities for low-income households, how they regain access, and how communities restore such services.
- The type of medical outreach services most commonly needed for marginalized populations after a disaster and the duration of time those services must be provided (from routine procedures like annual examinations to more detailed care).
- Analysis of communication tools for a full range of vulnerable populations as used by medical professionals.
- The critical role of home health agencies in reaching the homebound with disaster information.
- The assessment of special needs and medical shelters, from intake procedures to discharge, and all dimensions of service from routine patient care to medical emergencies, staffing, and logistics.
- The most expedient routes for provision of healthcare access to immigrant populations after disasters, as well as the kinds of healthcare concerns that most commonly arise.
- Improving knowledge about some racial and ethnic groups in disasters, such as Native Americans. Within the Native American population, additional issues may surface such as how elders fare in disasters and whether the impact of proximity to hazardous wastes, newly appearing diseases such as the Hanta virus, or long-term exposure to occupational hazards has an effect.
- Comprehensive examinations that span the life cycle of disasters: preparedness, response, recovery and mitigation such as
    - Case studies of effective partnerships that span vulnerable populations, engage the broader community, and leverage resources to address unmet healthcare needs after disasters.
    - Examination of intake and discharge procedures from general populations and special needs shelters.
    - Psychological effects of disasters on medical personnel including secondary trauma or compassion fatigue that may result from working with survivors.
    - Mitigation success stories for a full range of medical facilities.

CONCLUSION

Whether interested in public education, emergency response, long-term recovery, or risk reduction, the medical community can support efforts to aid vulnerable populations. From a social vulnerability perspective, risk reduction requires more than healthcare, accessible shelters, or construction assistance. As international disaster humanitarian Fred Cuny[66] wrote, "Vulnerability reduction is ultimately a social problem that requires a lifetime commitment." Civic involvement is necessary to address continuing problems including a lack of affordable and safe housing, domestic violence, pollution and environmental degradation, access to jobs, language prejudice, racial discrimination, and exclusionary practices. Such involvement will ultimately reduce risks. By participating in efforts that address public housing issues, promote literacy, reduce partner abuse, increase healthcare access, conserve floodplains, retrofit low-income housing, and reach out to new immigrants, society can create more disaster-resilient communities. In the interim, those interested in special needs populations can educate patients and providers, secure important facilities, design outreach efforts, partner with other community and advocacy organizations, and be part of the cadre of people dedicated to increasing life safety for all.

Resources (all websites were accessed January 12, 2009)

- FEMA offers a variety of training materials, including free online courses (downloadable and interactive) and on-campus courses at its Emergency Management Institute (EMI) location. A list of courses can be obtained from www.fema.gov. From the independent study (IS) course list, select the FEMA IS197 course.
- The NOD offers downloadable resources at its Emergency Preparedness Initiative page at www.nod.gov.
- The National Council on Disability is currently generating a series of reviews on all phases of emergency management. The site at www.ncd.gov contains updates and copies of minutes from the quarterly meetings.
- The Gender and Disaster Network provides extensive materials including those that apply worldwide at www.gdnonline.org.
- FEMA and the Humane Society offer tips for protecting pets and service animals at www.fema.gov and www.hsus.org.
- FEMA for Kids provides games and downloadable materials. The American Red Cross offers a "Master of Disaster" curriculum that is tied to school content at www.redcross.org.
- Buddy assessments and emergency kit information can be secured in multiple languages at www.preparenow.org.
- A set of papers that include content on vulnerable populations is available at http://understandingkatrina.ssrc.org/.
- A large bibliography on social vulnerability can be found along with college course materials at the FEMA Higher Education Website available from http://www.training.fema.gov/EMIweb/edu/collegelist/. Once there, select the free college courses and the Social Vulnerability course. These materials will be produced in an edited book titled *Social Vulnerability to Disasters* (August 2009), edited by Brenda Phillips, Deborah Thomas, Alice Fothergill and Lynn Blinn-Pike.
- AHCA forms and checklists for Home Health Agencies (Florida) and Adult Daycare facilities, assisted living facilities, ambulatory surgical care centers, hospice centers, hospitals per Florida statute.
- Educational materials for seniors and people with disabilities can be viewed at www.eadassociates.com. These materials are in the form of "wheels" that can be dialed to reveal hazard-specific preparedness information.

- An extensive bibliography on Hurricane Katrina can be accessed at http://lamar.colostate.edu/~loripeek/KatrinaBibliography.pdf.

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Part II

Operational Issues

9

Public Health and Emergency Management Systems

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INTRODUCTION

Emergency management has always included a component that addresses the health of the public. The major concern during an emergency, whether in the form of a hazardous materials incident, terrorist event, disease outbreak, or other type of disaster, is its potential to harm the health and well-being of people. A formalized system that connects "emergency management" and "public health," however, did not begin to emerge until the latter part of the 20th century. At this time, healthcare leaders and policymakers began promoting standardized processes and assigning functional responsibilities to specific government agencies and entities, ensuring consistent inclusion of the public health component in the management of emergencies. The result has been the creation of programs and implementation of concepts that, when appropriately applied, ensure accomplishment of the ultimate goal of managing emergencies. The final outcome of these processes is the reduction of morbidity and mortality and return of circumstances to the preemergency state or better.

This chapter addresses concepts and issues that are essential for understanding how public health integrates with emergency management at all levels and in varying emergency circumstances. It focuses on the following

1) A general overview of public health and emergency management systems and how they interface
2) Comprehensive Emergency Management, including the all-hazards approach
3) The Incident Command (Management) System, including the adoption within the United States of the National Incident Management System (NIMS)
4) Interconnectivity of healthcare systems as it relates to public health and emergency management systems and activities
5) Management of volunteers who spontaneously volunteer or are assigned to public health (and healthcare) and deploy in support of emergencies
6) Communications (technical and procedural) among public health and emergency management systems

CURRENT STATE OF THE ART

Overview of Public Health and Emergency Management Systems

An analysis of U.S. systems provides insights into the challenges of coordinating medical, public health, and emergency management entities. Perhaps one of the greatest defining events that measured how the United States manages emergencies and their inherent health elements was Hurricane Katrina, which made landfall August 29, 2005, impacting coastal Louisiana, Mississippi, and Alabama. The immediate medical and health impact of this storm resulted in 1,800 deaths, thousands of injuries and illnesses, and hundreds of thousands of displaced persons. Hurricane Katrina prompted response and recovery actions by all levels of the U.S. government and offers of assistance from many foreign governments.[1] The number of dead continued to rise long after the event, as recovery personnel discovered bodies in previously submerged dwellings and other locations. The exact number of victims may never be known. Injuries and illnesses, including psychological and stress-related effects, also continued to emerge among the displaced thousands. Subsequent Hurricanes Rita and Wilma added to the number of victims, although not in significant numbers.[2]

Prior to the September 11, 2001 terrorist attacks on New York City's World Trade Center and the Washington, DC area–based Pentagon and Hurricane Katrina, the U.S. had neither experienced an emergency resulting in mass casualties from a single event nor one of a magnitude witnessed in foreign countries since the time of the 1918 influenza pandemic. From 1975 to 1994, natural hazards (earthquakes, hurricanes, floods, and tornadoes) in the United States and its territories resulted in more than 24,000 deaths and approximately 100,000 injuries.[3] This figure contributed to the U.S. government's focus on refinement of emergency management strategies. This, followed by the September 11 terrorist events, created an unprecedented emphasis on defining the country's direction on matters related to comprehensive management of emergencies.

Several key initiatives in the form of legislation, directives, and guidelines impacting public health and emergency management emerged during the latter part of the 20th century

Table 9.1: U.S. Pandemic and All-Hazards Preparedness Act (2006)*

Title I: National Preparedness and Response, Leadership, Organization & Planning

- Creates a U.S. (HHS) Office of Assistant Secretary for Preparedness and Response (ASPR) and combines federal public health and medical emergency activities under that office
- ASPR will appoint official to provide guidance to public health agencies for integration of needs of at-risk populations at federal, state, and local levels
- ASPR will submit National Health Security Strategy to Congress every 4 years

Title II: Public Health Security Preparedness

- Oversees cooperative agreements/grants to state/local public health entities for improvement of health security
- Requires nonfederal (state or consortium) contributions to public health preparedness programs
- Requires Secretary to collaborate with state, local, tribal, and private entities to develop measurable, evidence-based preparedness benchmarks
- Secretary may award grants on disease detection improvements to hospitals, universities, and laboratories
- Establish nationwide electronic public health situational awareness system
- Provides grants to states for tuition loan repayment programs for individuals who agree to 2-year service at state, local, or tribal health departments
- Secretary cooperates with private industry during a pandemic on tracking initial distribution of federally purchased influenza vaccine

Title III: All-hazards Medical Surge Capacity

- Transfers NDMS from DHS (back to) HHS
- Appoints Director for federal support of MRC
- Expands Epidemic Intelligence Service Program
- Awards grants to hospital and healthcare facilities to improve surge capacity

Title IV: Pandemic and Biodefense Vaccine and Drug Development

- Requires Strategic Plan for Countermeasure Research, Development, and Procurement
- Establishes Biomedical Advanced Research and Development Authority
- Establishes Biodefense Medical Countermeasure Development Fund
- Establishes National Biodefense Science Board
- Directs Food and Drug Administration to provide technical assistance to developers of medical countermeasures
- Establishes limited antitrust exemptions for biopharma companies for enhanced collaboration between companies and with government
- Reforms BioShield procurement program

* Commonly termed the "PAPA Legislation."

Adapted from *Passage of S.3678: The Pandemic and All-Hazards Preparedness Act.* Mair, M et al. Clinicians Biosecurity Network, University of Pittsburgh Medical Center. December, 2006.

and early years of the 21st century. Although U.S. philosophy is based on the premise that "disasters are local," most initiatives have been generated at the national level, resulting in a "top down" approach. The logical entity with primary responsibility for public health issues is the U.S. Department of Health and Human Services (HHS), so most initiatives connecting public health to emergency management include HHS in planning and implementation. A cabinet level department, HHS is the U.S. government's principal agency for protecting the health of all Americans and providing essential human services, especially for those least able to help themselves.[4] With the federal government's increasing emphasis on emergency management, the HHS's responsibilities in the areas of disaster and emergency management have become increasingly more pervasive and significant.

To understand the interconnectivity of public health and emergency management, it is helpful to have an awareness of key driving initiatives. A plethora of initiatives, derived from a sequence of reactions to unprecedented emergency events, have been introduced. Many of those initiatives in the public health realm, although under or influenced by HHS authority, became more closely aligned and consolidated when the U.S. President signed Senate Bill 3678: *The Pandemic and All-Hazards Preparedness Act* into law in December 2006.[5] This legislation directed that a newly formed HHS Office of Preparedness and Response be established and headed by an Assistant Secretary. The office serves as the umbrella organization for the various health-related emergency management programs that had previously been under various HHS administrations (Table 9.1). This resulted in more streamlining of functions and programs essential to management of public health emergencies. The Office of Preparedness and Response consolidates several functions under the Assistant Secretary, and more clearly delineates specific public health emergency management elements. The four Titles under the Act are: Title I: National Preparedness and Response, Leadership, Organization and Planning; Title II: All-Hazards Medical Surge Capacity; Title III: Public Health Security Preparedness; and Title IV: Pandemic and Biodefense Vaccine and Drug Development.[5] (Table 9.1 outlines details of each Title cited in the legislation.[6])

Descriptions of the derivation and components of specific programs included in the December 2006 legislation as well as other key initiatives linking public health and emergency management systems are described here and include the: National Disaster Medical System (NDMS), National Response Plan (NRP)/National Response Framework (NRF), Strategic National Stockpile, Metropolitan Medical Response System (MMRS), Weapons of Mass Destruction Act of 1996, Homeland Security Act of 2002, and various Homeland Security Presidential Directives (HSPDs) and bioterrorism focus and funding initiatives.

National Disaster Medical System

In 1984, the Reagan Administration expressed concern about the absence of an organized national approach to managing the human element (injury, illness, public health effects, and death) resulting from a disaster or other catastrophic event. Public health and emergency management leaders also expressed concern that local and state entities would be unable to manage the effects of large-scale events such as a catastrophic earthquake. The response to these concerns was the formation of the NDMS. The initial structure of NDMS was a partnership of federal agencies, including HHS, Department of Veterans Affairs (VA), Department of Defense (DoD), and Federal Emergency Management Agency (FEMA).[7] NDMS was later codified into law within the *Public Health Security and Bioterrorism Preparedness and Response Act* [PL 107–188] of 2002.[8] HHS was the original coordinating agency for NDMS. After September 11, 2001, FEMA was relocated to be within the Department of Homeland Security (DHS) and DHS became the NDMS partner agency in the place of FEMA. Oversight responsibility for NDMS was also transferred from HHS to DHS. In 2006, passage of the aforementioned *Pandemic and All-Hazards Preparedness Act* returned oversight and coordination of NDMS to HHS.

The three primary NDMS missions are field medical response, patient transport, and definitive care. Each mission is described herein.

1) NDMS *field medical response* is provided by Disaster Medical Assistance Teams (DMATs), Disaster Mortuary Operational Response Teams (DMORTs), and Veterinary Medical Assistance Teams (VMATs) deployed to the disaster site(s) in support of local and state resources engaged in response and recovery operations. Descriptions of these teams and their capabilities are addressed in the "volunteer" section of this chapter.
2) *Patient transport* includes the movement, distribution, and tracking of victims from the event site(s) to lesser-impacted areas of the United States. DoD manages the patient transport mission during federally declared disasters. Transport may be conducted by U.S. Air Force aircraft, in addition to commercial air, rail, bus, or other methods. The NDMS transport component is coordinated through memoranda of understanding (MOUs) between representatives of NDMS and those of airports, local emergency medical services (EMS), and civilian hospitals that receive and treat casualties.
3) *Definitive care* involves expansion of national patient care capacity through agreement by civilian community-based hospitals nationwide to provide staffed beds for victims of casualty-producing events. At the time of this writing, approximately 1,800 U.S. hospitals or healthcare systems ("NDMS-enrolled facilities") have signed MOUs that commit staffed beds for the definitive care component. Although it is clearly understood that beds do not take care of patients, use of the term "bed" in this context is meant to represent a surrogate marker of patient care capacity.[9] The MOUs outline how victims will be received, approximate numbers of available staffed beds by clinical categories/services, and the process for reimbursement of services. Most large, comprehensive hospitals in the U.S. are NDMS enrolled. Federal Coordinating Centers (FCCs) provide oversight of this definitive care component. FCCs are managed by the VA and DoD and are located at VA medical centers or DoD medical treatment facilities in approximately 70 locations throughout the U.S. (Table 9.2). VA and DoD FCC representatives remain prepared for potential activation through routinely conducted bed reporting exercises.[8] This allows FCC planners to remain abreast of approximate available staffed beds in the five DoD-designated categories of med-surg, critical care, burn, pediatric, and psychiatric. Bed reporting exercises are important planning tools for assessment of dynamic bed availability trends reflective of local and regional periodic impacts of seasonal influenza and other issues.[10]

Prior to the response and recovery efforts resulting from Hurricane Katrina, the three components of NDMS had never been fully activated. Instances of partial activation have included the deployment of DMATs in support of many presidentially declared disasters and high threat events and of DMORTs for the September 11, 2001 response/recovery, air crashes, and other high casualty–producing incidents. The Katrina event, however, overwhelmed local, state, and regional resources and resulted in full activation of all three NDMS components: field medical response, transport, and definitive care.

National Response Plan/National Response Framework

Within the U.S., when local and state resources are overwhelmed by disasters or other mass emergencies resulting in a Presidential disaster declaration, the National Response Plan (NRP) is usually activated. In 1992, the newly published *Federal Response Plan* (later renamed the NRP) was first implemented when Miami-Dade County, Florida was devastated by Hurricane Andrew. The Plan became the official formal guide and remains the federal blueprint for managing disasters and other emergencies in the U.S. Prior to development and implementation of the Federal Response Plan, response and recovery activities were less organized and there was a risk of misallocation of resources. The plan originally included 12 "Emergency Support Functions" (ESFs) assigned among 28 federal agencies and a single non-government agency, the American Red Cross, with FEMA as the lead federal agency. As part of the post–September 11, 2001 government reorganizations, in 2004, the NRP replaced the Federal Response Plan and expanded the number of ESFs from 12 to 15, assigned among 30 federal agencies and the American Red Cross. Each ESF is coordinated by a lead federal agency, with several supporting agencies.[12] Each ESF is concentrated on a specific function or service area. In September 2006, DHS announced that the NRP would be expanded and renamed the National Response Framework (NRF).[13] The NRF was later implemented in March 2008. The NRP/NRF appears to have vastly improved national response and recovery efficiency and effectiveness. States and many local entities have adopted or are in the process of adopting NRP/NRF guidelines and concepts.

Although all ESFs may potentially impact the direction of public health and healthcare aspects of an emergency, ESF #8 is of primary importance. The specific focus of ESF #8 is "public health and medical services." HHS is the lead federal agency for ESF #8, with support from many other agencies. During activation of the NRP/NRF (and specifically ESF #8), HHS and applicable support agencies coordinate and implement an array of functions with the goal to decrease morbidity and mortality associated with response and recovery. ESF #8 personnel manage issues such as health and direct medical services, mortuary care, epidemiology, and environmental health and safety concerns.

Table 9.2: VA and DoD FCC Sites

Responsible For	*Includes*
Veterans Affairs Managed	
VAMC Birmingham, AL	Birmingham/Montgomery
VAMC Tucson, AZ	Tucson
VAMC N. Little Rock, AK	Little Rock
VAMC Long Beach, CA	Long Beach/Greater Los Angeles
VA San Francisco, CA	Oakland/San Francisco
VAMC Bay Pines, FL	Tampa/Orlando
VAMC Miami, FL	Miami
VAMC Atlanta, GA	Atlanta
VAMC Indianapolis, IN	Indianapolis
VAMC Kansas City, MO	Wichita
VAMC Lexington, KY	Louisville/Lexington
VAMC New Orleans, LA	New Orleans/Baton Rouge
VAMC Jackson, MS	Shreveport
VAMC MA (VA New England Healthcare System) Leeds, MA	Boston/Eastern MA/Northampton
VAMC Detroit, MI	Detroit/Flint/Ann Arbor/Grand Rapids
VAMC Minneapolis, MN	Minneapolis/St. Paul
VAMC (VA New Jersey Medical Center) Lyons, NJ	Newark/Northern/Central
New Mexico VA Healthcare System, Albuquerque, NM	Albuquerque/Santa Fe
New York Harbor Healthcare System, NY, NY	NYC (minus Bronx) and Northport
VAMC Albany, NY	Albany/Buffalo/ Syracuse
VA Hudson Valley Healthcare System, Castle Point, NY	Bronx
VAMC Salisbury, NC	Charlotte, Raleigh, Durham, Richmond
VAMC Brecksville, OH	Cleveland/Akron
VAMC Oklahoma City, OK	Oklahoma City
VAMC Portland, OR	Portland/Vancouver
VAMC Philadelphia, PA	Philadelphia/S. New Jersey
VAMC Pittsburgh, PA	Western PA/Northern W. Virginia
VAMC San Juan, PR	Puerto Rico/Virgin Islands
VAMC Nashville, TN	Nashville/Knoxville
VAMC Dallas, TX	Dallas/Ft. Worth
VAMC Houston, TX	Houston
VAMC San Antonio, TX	San Antonio
VAMC Denver, CO	Salt Lake City
VAMC Hines, IL	Milwaukee, WI
DoD Managed	
Keesler Air Force Base, MS	Mobile/Pensacola/Gulfport
Luke Air Force Base, AZ	Phoenix
Naval Hospital Camp, Pendleton, CA	Orange County
Travis Air Force Base, CA	Sacramento/Travis
Naval Medical Center, San Diego, CA	San Diego
Evans Army Hospital, Ft. Carson, CO	Denver/Boulder
Naval Ambulatory Care Center, Groton, CT	New Haven/Hartford

Responsible For	*Includes*
Dover Air Force Base, DE	Wilmington/Dover
Jacksonville Naval Hospital, FL.	Jacksonville
Fort Gordon, GA	Augusta
Tripler Army Medical Command, Hawaii	Honolulu
POMI, Naval Hospital, Great Lakes, IL	Chicago/Gary/Hammond
Walter Reed Army Medical Center, Washington, DC	Baltimore
National Naval Medical Center, Bethesda, MD	DC/Maryland
Scott Air Force Base, O'Fallon, IL.	St. Louis
Offutt Air Force Base, NE	Omaha/Lincoln
Newport Naval Ambulatory Care Clinic, Newport, RI	Providence
Wright-Patterson Air Force Base, WP, OH	Cincinnati/Columbus/Dayton/Toledo
Charleston Naval Hospital, Charleston, SC	Charleston
Moncrief Army Command Hospital, Ft. Jackson, SC	Columbia/Greenville/Spartanburg
Wm. Beaumont Army Medical Center, El Paso, TX	El Paso/La Cruces
Marine Naval Medical Center, Portsmouth, VA	Norfolk/Virginia Beach
Andrews Air Force Base, MD	Northern Virginia Suburbs
Madigan Army Medical Center, Tacoma, WA	Seattle/Olympia/ Tacoma

These include food, water, and vector control and other key issues through deployed personnel, supplies, and equipment. The NRP/NRF also includes a series of annexes that contain incident-specific guidelines. For instance, in 1998, policymakers added a Terrorism Annex. With the formation of DHS (and its oversight of FEMA), the NRP/NRF has been revised to reflect these organizational changes and additional annexes.[8] The NRP/NRF is a dynamic document that will continue to be updated as new threats emerge and as processes are determined or refined.

Strategic National Stockpile

One critical strategy to maintain public health in health-related emergencies is containment and prevention of disease. The U.S. Strategic National Stockpile supports this strategy through provision of life-saving pharmaceuticals, vaccines, antidotes, and other medical supplies and equipment for use in prevention and treatment of effects from biological pathogens, toxins, chemical agents, or other emergency events (see Chapter 16). Managed by the U.S. Centers for Disease Control and Prevention (CDC) within HHS, the Strategic National Stockpile includes 12-hour "push packages," as well as vendor-managed inventory. These resources are stored in classified, strategic locations, ready for immediate delivery to impacted sites. The stockpile program includes comprehensive public health and medical support through epidemiology, medical treatment, prophylaxis, disease prevention and environmental decontamination. The U.S. CDC coordinates with states in developing processes for deployment of Strategic National Stockpile resources in an emergency.[14]

In the U.S., VA supports CDC in coordinating movement and delivery of stockpile assets. In addition, many VA medical centers throughout the country have their own on-site pharmaceutical caches. Although primarily for use in treating veterans, these caches may be requested for use in a civilian community-wide incident.[15]

Metropolitan Medical Response System

When national coordination and deployment of resources is needed, U.S. government officials may activate NDMS and the NRP. Examples of such events include Presidentially declared disasters and emergencies. A more locally based resource is the Metropolitan Medical Response System (MMRS). HHS developed the MMRS in 1996, as concern grew about potential public health crises associated with events involving weapons of mass destruction (WMD). Originally aligned under and funded by HHS, the MMRS was supported by direct funding to local governments in major metropolitan areas. The MMRS uses local volunteers for initial public health, emergency, and medical management until federal resources arrive (typically 24–48 hours). Although the initial MMRS focus was on WMD incidents, focus now includes all types of disasters and hazardous materials incidents.[16]

In 2004, the MMRS program was realigned under the U.S. DHS Office of State and Local Government Coordination and Preparedness, Office for Domestic Preparedness. Grant guidance and funding were transferred to the state administration agency in each state, which further provides oversight to and collaboration with local MMRS programs.[17]

Weapons of Mass Destruction Act of 1996

The U.S. federal government's emphasis on addressing the growing concern about terrorism and weapons of mass destruction (WMDs) began in the 1990s. The 1993 attack on the World Trade Center in New York City and 1995 sarin nerve agent attack on the Tokyo subway system fueled the preparedness efforts. U.S. Senators Nunn, Lugar, and Domenici were also worried about the instability of rogue nations and their potential access to WMD. This led to the 1996 Defense Authorization (WMD) Act, which resulted in the formation of the DoD's Domestic

Preparedness Program. This program provided funding for equipment and training for civilian first responders and healthcare providers in communities throughout the U.S. These activities served to strengthen partnerships and planning among public health, healthcare, and emergency management entities.[8]

Homeland Security Act of 2002 (Public Law 107-296)

This Act, which was signed into law in November 2002, called for the formation of the U.S. DHS. In the largest federal government reorganization in more than 50 years, DHS combined functions of other departments and agencies, including consolidation of responsibilities under a single department.[18] NDMS and other public health elements were among those functions realigned under DHS. The creation of DHS influenced the continuing necessity of public health and emergency management entities to work collaboratively at all levels.[8]

Homeland Security Presidential Directives

Several HSPDs have significantly influenced how public health and emergency management systems interface. Of particular relevance are HSPDs 5 and 8.

The President of the U.S. signed HSPD 5 in February 2003. HSPD 5

- Directed the development of a National Incident Management System
- Established a Unified Command System for national response
- Renamed the Federal Response Plan to the National Response Plan

HSPD 8, signed in December 2003, mandated a national domestic all-hazards preparedness goal, including measurable readiness priorities, targets, and metrics. The nationally mandated goals include involvement of state and local responders, and health, and medical entities.[19]

Bioterrorism Focus and Funding

A dramatic sequence of events continued to influence international direction involving public health and emergency management systems in the early years of the 21st century. Confirmed cases of severe acute respiratory syndrome, threat of avian influenza (and a possible pandemic), anthrax incidents following the September 11, 2001 terrorist attacks, and other global threats led to new funding and policy and procedures in many countries. Within the U.S., national leaders mandated programs that would strengthen focus on public health and emergency management programs. Several key initiatives emerged that would shape public health and emergency management systems integration at national, state and local levels.

The Public Health Security and Bioterrorism Preparedness and Response Act of 2002

This Act established the HHS Office of Public Health Preparedness, an effort to improve the ability of the U.S. to prevent, prepare for, and respond to bioterrorism and other public health emergencies. This initiative also improved coordination among entities responsible for the nation's emergency management.[8]

Health Resources and Services Administration National Bioterrorism Hospital Preparedness Program

In 2002, the U.S. HHS Health Resources and Services Administration (HRSA) assumed responsibility for guidance and grant funding to states (primarily public health departments) for the development of programs to prepare hospitals and other healthcare entities to manage bioterrorism or other events involving infectious disease and epidemics.[20] This initiative was a significant step in addressing needs and roles of healthcare resources at local levels. The grant awards have supported hospitals, emergency departments, community health centers, outpatient centers, EMS systems, rural health clinics, home healthcare, and other systems in building surge capacity and programs for mass prophylaxis, immunization, treatment, quarantine, isolation, and other essential measures. Although the program's focus was "bioterrorism," the processes it initiated have significantly enhanced the cooperation among healthcare, public health, and emergency management, resulting in improved all-hazards, comprehensive emergency management plans and systems. With passage of the 2006 *Pandemic and All-Hazards Preparedness Act*, Biohazard Hospital Preparedness Program functions transferred from HRSA to the Office of the Assistant Secretary for Preparedness and Response. With the alignment under the Assistant Secretary for Preparedness and Response, the aforementioned program is no longer limited to "bioterrorism preparedness," but is now termed the Hospital Preparedness Program. Although the program title implies a focus on "hospitals," in reality, the program includes more comprehensive support that comprises preparedness initiatives in nonhospital healthcare organizations as well.

CDC's Cooperative Agreement on Public Health Preparedness and Response for Bioterrorism

The intent of this grant-based program has been to enhance public health preparedness and response at local and state levels. Under this program, states receive funding and, in turn provide funding and guidance to local public health entities, enabling the development of statewide plans for improvement of response to bioterrorism and other infectious disease outbreaks. Targeted areas of improvement outlined under the agreement are planning and readiness assessment, surveillance and epidemiology, laboratory capacity/biological agents, health alert network/communications and information technology, communicating health risks and health information dissemination, and education and training.[21] (Table 9.3) As with the aforementioned Hospital Preparedness Program, that focuses on "bioterrorism," benefits of planning and processes extend well into the all-hazards arena. Also similar to the Hospital Preparedness Program, this initiative has been a catalyst for continued integration and partnerships between public health and emergency management systems.

The aforementioned initiatives and resulting programs have not only brought attention to the importance of public health in the management of emergencies, they have served to integrate local, regional, and state entities into comprehensive, nationally directed emergency planning. The concept of comprehensive emergency management, coupled with application of a process, such as the incident command (management) system, became the cornerstone for effective management of the vast number of entities with related, but distinct functions. The formalized approaches for managing emergencies are addressed herein.

Table 9.3: U.S. CDC Grant Programs to Improve Public Health Preparedness and Response for Bioterrorism

Planning and readiness assessment establishes strategic leadership, direction, assessment, and coordination of activities (including the Strategic National Stockpile response) to ensure statewide readiness; interagency collaboration; and local and regional preparedness (both intrastate and interstate) for bioterrorism, other outbreaks of infectious disease, and other public health threats and emergencies.

Surveillance and epidemiology capacity focuses on enabling state and local heath departments to enhance, design, and/or develop systems for rapid detection of unusual outbreaks of illness that may be the result of bioterrorism, other outbreaks of infectious disease, and other public health threats and emergencies.

Laboratory capacity – biological agents develops the capability and capacity at all state and major city/county public health laboratories to conduct rapid and accurate diagnostic and reference testing for select biological agents likely to be used in a terrorist attack.

Health Alert Network enables state and local public health agencies to link public health and private partners at all times through Internet capability. The program provides for rapid dissemination of public health advisories and ensures secure electronic data exchange.

Communication of health risks and dissemination of health information ensures timely information dissemination to citizens during a bioterrorist attack, other outbreak of infectious disease, or other public health threat or emergency.

Education and training assesses the training needs of key public health professionals, infectious disease specialists, emergency department personnel, and other healthcare providers related to preparedness for and response to bioterrorism, other outbreaks of infectious disease, and other public health threats and emergencies.

Sources: U.S. Centers for Disease Control and Prevention (CDC), 2003. "Continuation Guidance for Cooperative Agreement on Public Health Preparedness and Response for Bioterrorism – Budget Year Four." [Online article; retrieved 8/03] http://www.bt.cdc.gov/planning/continuationguidance/pdf/guidance_intro.pdf.

THE ALL-HAZARDS APPROACH – COMPREHENSIVE EMERGENCY MANAGEMENT

The context for today's U.S. all-hazards emergency management programs emanates from a subcommittee of the National Governors' Association chartered in 1977.[22] At the time, federal policy and funding were centered in two areas: civil defense and disaster assistance. The bulk of the funding was for civil defense activities such as preparedness for enemy attacks, population relocation planning, and radiological monitoring programs. No funding was available for preparing for any other type of hazard. When natural and technological hazards did strike, federal assistance to state and local governments was provided by a variety of up to 16 agencies. This assistance was not always well coordinated, leading some state directors to describe it as the "second disaster."

The National Governors Association formed the subcommittee to study the problems and make recommendations to the incoming President Jimmy Carter. One recommendation was to combine the various federal agencies with disaster relief missions into a single agency. This single agency became known as FEMA. Another recommendation was for "dual use" of civil defense funding to prepare for other hazards. This notion was tied to a

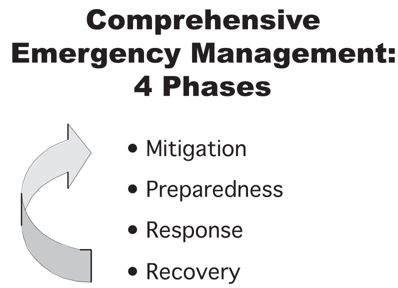

Figure 9.1. Phases of comprehensive emergency management.

third recommendation, which promoted a new vision of federal disaster policy.

Comprehensive Emergency Management is a conceptual framework that encompasses all hazards, all disciplines, and all levels of government (including the private, nonprofit, and volunteer sectors). It views disaster management activities as occurring across four phases that are cyclical: mitigation, preparedness, response, and recovery (Figure 9.1). *Mitigation* efforts are aimed at eliminating or reducing the effects of hazards, such as improving building codes, zoning, structural design, and construction. *Preparedness* activities (planning, training, resource identification, and exercises) are designed to build capabilities necessary to manage the effects of hazards. *Response* actions include those taken to stop the ongoing negative effects of the disaster, and *recovery* actions are those that restore services and rebuild infrastructure, housing, and the economy after a disaster. The recovery phase of a disaster can last for years. Reviews conducted in the recovery phase are intended to identify potential improvements to future mitigation, preparedness, response, and recovery efforts.[23]

To assist state and local government implementation of the comprehensive emergency management concept, FEMA developed what is referred to as the Integrated Emergency Management System. The Integrated Emergency Management System was developed with input from the disaster research community, which provided three principles that continue to remain significant guidelines in emergency management. The first was the recognition that disaster planning must be inclusive of the various groups that respond to disasters. Prior to this, government agencies were prone to engage in isolated planning processes, without including other government entities, business and industry, nonprofit, and faith-based organizations. Second, the Integrated Emergency Management System provided a framework that organized emergency management programs into multiyear development processes (Figure 9.2). The third key principle was that emergency operations plans should be organized around *functions*, not agencies or hazards. This was the beginning of the "all hazards" focus for emergency planning.[24] Planners had developed multiple, unique emergency plans for the variety of hazards that threatened a jurisdiction but researchers argued that a single, comprehensive all-hazards plan should be the standard because similar activities needed to be performed regardless of the cause of the disaster.

Agent-generated demands such as search and rescue, medical care, evacuation, and so forth represented only limited components of disaster operations. Quarantelli argued that there were two sets of demands that occur during disasters – agent-generated and response-generated demands[25] (Figure 9.3). The response-generated demands are the requirements for the exercise of

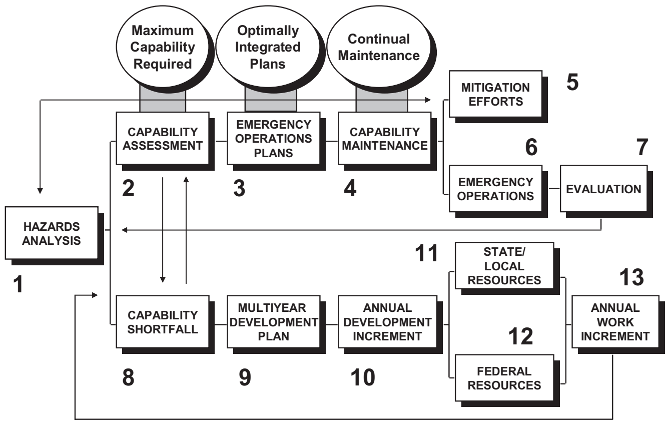

Figure 9.2. The Integrated Emergency Management System program development process flowchart.

authority, decision making, communications, and coordination that occur within an organization and between organizations as they attempt to provide assistance. The response-generated demands are those that are most often cited in after-action reviews of disaster responses. As a general rule, emergency plans do not address these needs, but the Incident Command System (ICS) does. This is one reason why it is so important to integrate ICS into emergency operations plans and to mandate ICS use by all agencies with roles in disaster response.[25]

THE INCIDENT COMMAND SYSTEM

In the 1970s, challenges with the on-scene coordination of wild land firefighting efforts in California resulted in a U.S. Congressional mandate to develop a solution. The Firefighting Resources of Southern California Operational Procedures task force was formed and produced the National Interagency Incident Management System in 1983.[23] The National Interagency Incident Management System consisted of the ICS and four subsystems: training, qualifications and certification, supporting publications, and related technologies.[26] (See Table 9.4 for a listing of the components of the ICS[27].) In 2003, after minor revisions, the National Interagency Incident Management System was renamed and became the NIMS. One significant change was the 2002 Presidential executive order that mandated the use of ICS by federal,

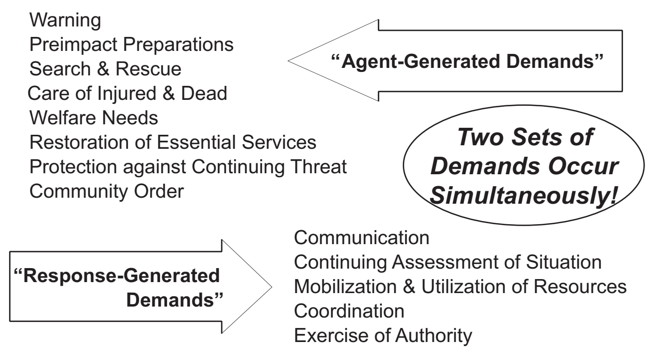

Figure 9.3. Agent-generated and response-generated demands in disaster management. *Source:* Quarantelli, Enrique, Major Criteria for Judging Disaster Planning and Managing and Their Applicability in Developing Societies. Disaster Research Center, University of Delaware, Newark, Delaware, 19716 USA. 1998.[25]

Table 9.4: Incident Command System Components

Components of the Incident Command System

- Common Terminology
- Integrated Communications
- Unified Command Structure
- Manageable Span of Control
- Consolidated Action Plans
- Comprehensive Resource Management
- Designated Incident Facilities

National Interagency Incident Management System, Washington, DC; 2003.[27]

state, local, and tribal governments and the private sector (HSPD 5, Management of Domestic Incidents). HSPD 5 also directed the revision of the former Federal Response Plan into the NRP. The NRP exemplified the functional approach to planning created under the Integrated Emergency Management System and the incorporation of ICS.

To ensure that the various federal, state, local, and tribal government agencies and private sector organizations (e.g., hospitals that accept federal grants such as those for bioterrorism preparedness) would begin to apply ICS, the DHS issued NIMS compliance requirements.[28] The NIMS requirements for hospitals, released in 2006, were modeled after those for local and tribal governments. An overview of the 17 NIMS requirements is found in Table 9.5.[29]

Various models exist for applying ICS to healthcare organizations. The Hospital Emergency Incident Command System gained popularity with hospitals in the 1990s and was revised in 2006 into the Hospital Incident Command System.[30] The U.S. Department of Veterans Affairs, Veterans Health Administration guidance sets forth a simplified ICS structure, explaining how ICS is integrated within the organization's emergency operations plan and overall emergency management program.[31] The Veterans Health Administration's guidance heavily influenced the outcomes of the Hospital Incident Command System revision process within the U.S.

One barrier that organizations have faced in incorporating ICS into their emergency operations plans has been a lack of useful guidance. Most ICS resources do not explain how the ICS structure relates to an organization and how ICS is implemented in response to emergencies. This has led staff having little knowledge or background in using ICS to inappropriately

Table 9.5: National Incident Management System Compliance Elements for U.S. Hospitals (2006)

- 17 Elements of Compliance
- 5 Categories:
  - Organizational Adoption
  - Command and Management
  - Preparedness Planning
  - Preparedness Training
  - Preparedness Exercises
  - Resource Management
  - Communications and Information Management

NIMS Integration Center, Washington DC; 2006.[29]

Table 9.6: Three ICS Management Elements

ICS Management Elements

- Agency Executive – Director/CEO at the hospital facility, regional, or national level
  - Set overall policies and priorities
- Policy Coordination Entity – Operating unit/department managers
  - Support the Agency Executive and the Incident Management Team with technical assistance and program coordination
- Incident Management Team – Staff trained to perform ICS command and general positions
  - Staff the Emergency Operations Center and Response Support Unit
  - Develop the Incident Action Plan
  - Provide the Situation Briefings and Operations Briefings

Emergency Management Strategic Healthcare Group, Department of Veterans Affairs, Martinsburg, West Virginia. 2002.[32]

design an organization-specific application that reflects a "blend" of ICS and the organization's day-to-day administrative structure and/or terminology. The result is often exactly what ICS was designed to avoid – inconsistent terminology and organizational structures between agencies responding to emergencies.

An ICS organization is separate and distinct from the day-to-day administrative structure. In particular, the diagram for an ICS is not simply the standard organization chart. There are three basic ICS elements that relate to any organization: the agency executive, the policy coordinating entity, and the incident management team (Table 9.6).[32] Staff members are assigned to agency executive and policy coordinating entity roles based on expertise gained from their day-to-day positions, but the assignment of staff to the incident management team is based on staff training and qualifications.

ICS implementation differs depending on whether the incident occurs with or without warning. If there is a warning period, such as with a slowly developing hurricane, the Incident Management Team would use the *incident action planning process* to initiate preimpact activities. If the incident occurs without warning, any employee who detects the emergency should initiate the response through activation of pre-event plans designed to defend and protect people and property, and a supervisor should provide initial command. The initial command role includes situation assessment, notifications, designation of staff into ICS positions, and actions designed to defend and protect people, property, records, and the environment. The pre-event designated Incident Management Team would be mobilized, be briefed, and assume responsibility for managing the event (from the initial command staff). The incident action planning process would be initiated to manage further response and recovery activities.

INTERCONNECTIVITY OF HEALTHCARE SYSTEMS, PUBLIC HEALTH, AND EMERGENCY MANAGEMENT

Various means of coordinating healthcare, public health, and emergency management have evolved over time. With some notable exceptions such as Israel, however, standardization at all levels of government did not exist in most countries, including the U.S., until recently. Within the U.S., in the mid-1980s, many local community entities coordinated their preparedness activities via regional or local planning groups. In 1986, Local Emergency Planning Committees began to emerge primarily as collaborative forums for private industry and the public that were concerned about hazardous materials production. Local Emergency Planning Committees were mandated by the *Emergency Planning and Community Right to Know Act* (Title III of the *Superfund Amendment and Reauthorization Act*).[33] Over time, committee membership expanded to include representatives of the public health and healthcare communities. Local Emergency Planning Committees continue to be active in many communities. In addition, many municipalities, particularly those with NDMS FCC sites, began to sponsor forums and planning meetings that included participation by representatives of public health, healthcare, first response, and emergency management entities. With the 2002 HRSA-sponsored Bioterrorism Hospital Preparedness Programs, states began to emphasize collaboration of healthcare, public health and emergency management through the formation of planning committees and other means. This collaboration is projected to continue or be enhanced following the 2006 Pandemic/All-hazards legislation.

At the national level in the U.S., integration of healthcare, public health, and mental health was first described in a system that became known as the NRP/NRF. This framework, first used for designing emergency operations plans, has been replicated at the state and local government levels. In these plans, a "primary" agency (usually the entity having legal authority and responsibility for a particular function) heads the ESF. This lead organization coordinates assistance to states and localities with the support of related agencies and organizations. (See Table 9.7 for a list of the types of assistance provided under ESF 8, Public Health and Medical Services of the NRP/NRF.)

Although various local, state, and federal initiatives sought to provide interconnectivity to the many layers and levels of healthcare, public health and emergency management were not formally connected in a standardized fashion. In the early 1980s, Quarantelli concluded that the principles that support effective disaster planning were not the same as those that support disaster management. A universal management framework was needed to operationalize the relationships and activities described in the

Table 9.7: Types of Assistance Provided under Emergency Support Function (ESF) 8, Public Health and Medical Services

- Assessment of public health and medical needs
- Health surveillance
- Medical care personnel
- Health/medical equipment and supplies
- Patient evacuation
- Patient care
- Safety and security of human drugs and biologics
- Blood and blood products
- Worker health and safety
- Food safety and security
- Agriculture safety and security
- Behavioral healthcare
- Public health and medical information
- Vector control
- Protection of animal health
- Technical assistance

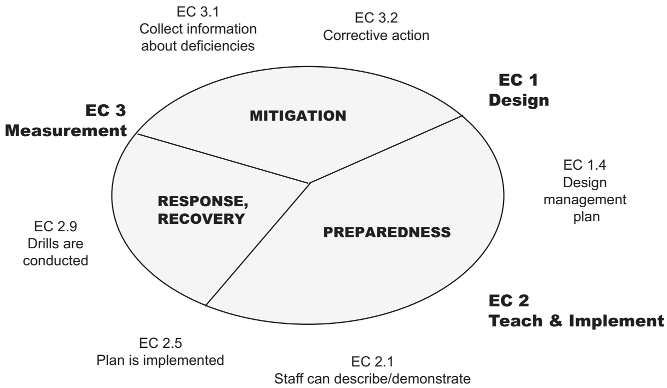

Figure 9.4. Relationship of EC to EM.

emergency operations plans. This framework was only embraced over a decade later by the medical and health communities to include such vital components as the use of ICS.

In January 2001, acting on an unsolicited recommendation from the National Director of Emergency Management Office at the Department of Veterans Affairs, the Joint Commission on the Accreditation of Healthcare Organizations (renamed the Joint Commission in 2007) promulgated landmark changes in their emergency management standards that required hospitals to use an IMS "consistent with that in use by the local community." In addition, the new standards required healthcare facilities to use an all-hazards approach and address the four phases of comprehensive emergency management (mitigation, preparedness, response, and recovery). Figure 9.4 shows the relationship between the Joint Commission Environment of Care standards and comprehensive emergency management. These new requirements have helped to ensure healthcare facilities coordinate with local public safety agencies. The Joint Commission further improved development of an operational system at the local level with its "cooperative planning" requirement, which calls for healthcare facilities to share names and contact information of staff assigned to ICS positions.[34]

Until 2002, no widely known published models existed that explained how healthcare systems integrated with public health, public safety, and emergency management at the local jurisdiction level. Barbera and Macintyre's Medical and Health Incident Management (MaHIM) System was developed to correct this critical deficiency. MaHIM provides a framework for integrating and organizing the various medical, public health, emergency management, and support disciplines at the jurisdictional or community level and describes the functional requirements for responding to a mass casualty incident (Figure 9.5).[35]

Despite the MaHIM system, clear guidance was still lacking that described how the medical and health system integrated with emergency management at all levels of government. Barbera and Macintyre's Medical Surge Capacity and Capability Model provides a management framework that serves as a foundation for current health system preparedness. The Model defined six tiers that interact during major incidents and affect the resiliency of a health system and/or require medical surge (Table 9.8).[36] Medical surge is defined as "the ability to provide adequate medical care under circumstances where demands resulting from a mass casualty or complex incident challenge or exceed the medical infrastructure." Two medical surge components are surge capacity and surge capability. Surge capacity is the ability to respond to a markedly increased number of patients, whereas surge capability is the ability to address unusual or very specialized medical needs.[35]

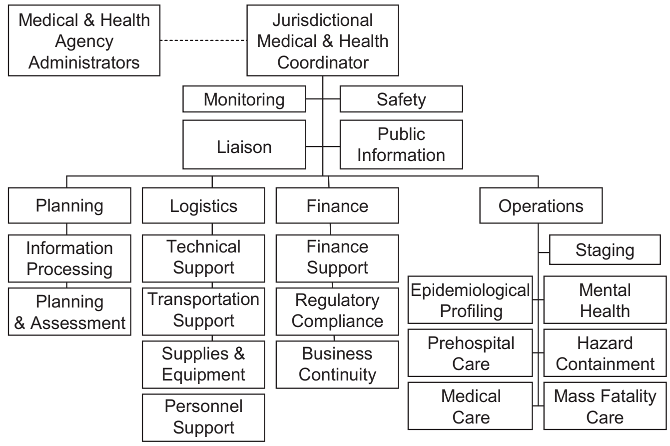

Figure 9.5. Medical and Health Incident Management (MaHIM) System (Barbera, JA and Macintyre, AG, Medical and Health Incident Management (MaHIM) System: A Comprehensive Functional System Description for Mass Casualty Medical and Health Incident Management, Institute of Crisis, Disaster and Risk Management, The George Washington University, Washington, D.C., October 2002. Supported by a grant from the Sloan Foundation.)[35]

A key concept that deserves emphasis is that the broader public health and healthcare system extends beyond first responders, disaster teams, and hospitals. Emergency planners should conduct prospective assessments of multiple systems whose missions address patient/victim care and integrate these systems into comprehensive public health and emergency management plans and programs. Although there are thousands of primary care practices throughout the U.S., there are also organized, formal representatives of other resources. Outpatient clinics and health centers are large assets that are often overlooked in comprehensive emergency management planning. Within the U.S., Community Health Centers (CHCs) are local, community-based facilities that serve low-income and medically underserved communities. CHCs can be health centers, migrant clinics, care to homeless clinics, and public housing–based clinics. The U.S. National Association of Community Health Centers reported that in 2006, more than 1,000 federally qualified health centers served more than 15 million people, many of whom were low income or other vulnerable populations.[37] In addition to federally funded CHCs, there are thousands of state and other-funded health centers, as well as Rural Health Clinics. Home and hospice care and nursing facilities are other critical entities that must be included in disaster planning, and represent a tremendous population of underserved and vulnerable patients, including the elderly, disabled, and chronically ill. Each year in the U.S., almost

Table 9.8: Tiers within the Medical Surge Capacity and Capability Management System

Six Tiers
■ Individual healthcare asset
■ Healthcare coalition
■ Local jurisdiction
■ State response and coordination of intrastate jurisdictions
■ Interstate regional management and coordination
■ Federal support to state and local jurisdictions

2 million adults are admitted to the nation's 16,800 nursing facilities. The literature cites multiple examples of consequences of failure to adequately include nursing facilities in emergency planning.[38] State departments of health maintain contact information for these entities. Public health and emergency management planners would be remiss to exclude CHCs, nursing facilities, and other cited critical resources when planning.

Management of Volunteers

In some systems, the success of public health and emergency management systems depends in large part on volunteers. In the U.S., volunteers have been essential; the only formal approach to managing public health crises was through the activation or deployment of uniformed personnel, such as the Armed Forces or Public Health Service Corps, and supportive services of civilian groups like the American Red Cross. Volunteerism and "neighbor helping neighbor" had long been the approach to managing local disasters and emergencies, until the late 20th century. The advent of NDMS and later, the NRP sparked the development or organization of volunteers to address public health and healthcare at the national level. Many specific disaster public health issues, for example epidemiology, infectious disease prevention and management, and surveillance had been addressed by paid staff of the CDC, uniformed Public Health Service personnel, other components of HHS, or state and local public health entities. The delivery of direct care services to disaster victims, however, required more specialized resources than the uniformed or paid-employee systems could provide. This led to the growth and expansion of nationwide systems of volunteers. This section highlights significant U.S. initiatives affecting the organization of volunteers used for disasters and other emergencies.

National Disaster Medical System Volunteers

Organized under NDMS, ESF 8, and ultimately, the NRP/NRF, NDMS volunteers represent the U.S. federal government's approach to providing organized teams of professionals who deploy to or near-by the disaster site to deliver direct healthcare services. Formed in the mid-1980s, the first type of NDMS team was the DMAT, composed of healthcare professionals and ancillary support personnel, who are locally based and sponsored. The "original" DMAT mission was to deploy to disasters and provide healthcare beyond their local areas or states. Over time, many local areas and states have emulated the DMAT model, forming teams that are also intended for use in local and state emergency events.[7,8] For example, in 2007, the State of California formed CAL-MATs and the County of Los Angeles has LAC-MATs. This approach is compatible with the U.S. approach of local-state-federal response to emergencies. DMAT personnel represent individuals who are usually employed in local hospitals, EMS, and other healthcare systems. In addition to performing their routine, daily roles, the individuals volunteer as members of DMATs in their geographical areas.

Although local resources, DMATs are "registered" with NDMS and may be activated as federal resources for declared disasters, terrorist incidents, or high-profile events where on-site medical care may be required. DMATs, located throughout the nation, bear the titles of their respective cites, states, or sponsoring organizations. Over the years, they have evolved to a level where each DMAT has characteristic uniforms, and DMATs routinely meet and train as teams and are equipped with medical supplies, as well as supplies and equipment to sustain life in austere conditions associated with disaster sites. If activated for disasters or emergency events, DMATs are "federalized," and members are sworn in as temporary federal employees. After authorization from their respective day to day employers, the NDMS arranges transportation and, if applicable, lodging for DMAT members at the deployment site. While performing duties under federalized status, DMAT members or their organizations are paid at "federal rates" and are provided malpractice insurance by the Federal Tort Claims Act. NDMS maintains a current database reflecting licenses and credentials of enrolled volunteers. The "normal" duration of deployment is 14 days, but this can vary according to each unique situation and its requirements.[39] As DMATs evolved since the 1980s, they have been deployed to hundreds of events and personnel have cared for thousands of victims. Specialized DMATs, defined by purpose (e.g., pediatrics) or composition (e.g., pharmacists) have also been created. NDMS leaders quickly identified additional needs for mass fatality management and expertise in pet and animal health issues. This resulted in the development of DMORTs and VMATs, respectively.[39] DMORTs, like DMATs, are locally formed teams of professional and support staff volunteers with expertise in managing human remains and associated activities. Members are commonly employed as funeral directors, morticians, and anthropologists, and the team is formed, trains, and deploys in a similar manner as a DMAT. DMORTs have been deployed in support of commercial air crashes; major floods, where cemetery integrity has been compromised; the U.S. Oklahoma City bombing and the September 11, 2001 terrorist attacks; and many hurricanes, tornadoes, earthquakes, and other events. More recently, VMATs, composed of veterinarians and support personnel, have been formed and have deployed to events where pets and other animals are affected. Hurricane Katrina was one notable example of VMAT deployment. Other NDMS-approved volunteer teams have emerged to meet evolving challenges. An example is the National Medical Response Teams, which are focused on events involving WMD.[39] Table 9.9 lists the types of NDMS volunteer teams.[40]

Medical Reserve Corps

During the 2002 U.S. State of the Union Address, President George W. Bush asked all Americans to volunteer in support of their country. Subsequently, the Medical Reserve Corps (MRC) was founded. A partner program with Citizens Corps and a national network of volunteers dedicated to ensuring homeland security, the MRC, along with the Citizens Corps, AmeriCorps, Senior Corps, and the Peace Corps, are part of the President's USA Freedom Corps. The basic premise of this initiative is to promote volunteerism and service nationwide.

The mission of the MRC is to establish teams or units of local public health and medical professionals who are willing to contribute time and skills both throughout the year and in times of emergencies. Whereas DMATS, DMORTs, and VMATs are organized nationally under NDMS, the MRC is organized under the Office of the U.S. Surgeon General. The Office of the Surgeon General issues direction on specific target areas that strengthen the public health infrastructure of communities. Much of the routine MRC focus is on improvement of health literacy, disease prevention, and eliminating health disparities. MRC volunteers include physicians, nurses, pharmacists, dentists, veterinarians, and epidemiologists. Support positions are filled by volunteer

Table 9.9: Types of NDMS Teams

Category	*Capability*	*Composition*
DMAT	Provide acute medical care	Physicians, nurses, and other medical support staff
DMORT	Provide fatality management	Funeral directors, medical examiners, and forensic experts
Specialized Disaster Medical Assistance Teams (e.g., burn, surgical, mental health)	Provide care specific to the disaster needs	Physicians, nurses, and other medical and support staff in specialization area
National Medical Response Team	Specially trained for response to events involving agents defined as WMD	Physicians, nurses, epidemiologists, chemists, and other medical and support staff
Management Support Team	Provide management support to deployed teams and interface with local medical disaster system	Leadership and administrative support staff
VMAT	Provide emergency support for rescued pets and other animals affected by disaster	Veterinarians and support staff
National Nursing Response Team	Activated for situations specifically requiring nurses and not full DMATs	Nurses
National Pharmacy Response Team	Activated for situations specially requiring pharmacists and not full DMATs	Pharmacists

Source: VHA Emergency Management Strategic Healthcare Group (EMSHG) 2002. *Emergency Management Program Guidebook*, Section 3. Department of Veterans Affairs, Martinsburg, West Virginia. (*Revised Jan-10–2008)

chaplains, legal advisors, interpreters, administrators, and other workers.[41]

Although the primary focus of the MRC is on local community public health and medical services, opportunity exists for volunteers to deploy outside their local jurisdictions, particularly in times of disaster or other emergencies. During the 2004 hurricane season, more than 30 MRC units supported hospitals and shelters around the country, assisting the Red Cross and FEMA in response and recovery. In 2005, hundreds of MRC volunteers assisted the Red Cross through support of shelters, special needs services, first aid, health, and mental health. Hundreds more deployed in support of HHS response and recovery operations following Hurricane Katrina and for other events. The Red Cross, HHS, public health, and other state agencies where MRC volunteers reside have coordinated deployments.

The MRC is headquartered at the Office of the Surgeon General, but is coordinated by this office in collaboration with local, regional, state, and national organizations that establish, implement, and maintain MRC units nationwide. The MRC maintains a website and sponsors an annual leadership conference, as well as serves as a clearinghouse to support this volunteer initiative.[41]

American Red Cross

Although Red Cross volunteerism is inherent in its role in ESF 6 (Mass Care) of the NRP, there is an array of Red Cross volunteer services affiliated with ESF 6 and beyond. The Red Cross is a vast private, nonprofit agency and the only nongovernment U.S. agency/department that has functioned as an NRP/NRF lead federal agency. In 2007, FEMA took over as the ESF 6 lead federal agency, with the Red Cross remaining as a significant ESF 6 support agency. In addition to the NRP mass care mission, the Red Cross, both through its national headquarters and local chapters throughout the country, delivers disaster recovery assistance through a 1905 Charter with the U.S. Congress. Each year, the Red Cross responds to more than 70,000 disasters/emergencies, including residential fires, which comprise the majority of its response activities. Thousands of healthcare and other types of volunteers, supported by national and chapter-based Red Cross paid staff, facilitate and deliver response and recovery missions for victims of fires, tornadoes, floods, winter storms, power outages, earthquakes, hurricanes, hazardous materials, technological incidents, and other types of events. Red Cross volunteers provide multiple services including shelter (and special needs shelters), food, first aid, health and disaster mental healthcare, disaster welfare inquires, and administration of blood and blood products. ("Special needs" is a term that FEMA and other response/recovery entities apply to individuals who require assistance for disabilities that are medical, mental, or psychological.)[42] The Red Cross also establishes and staffs mobile kitchens and feeds emergency workers at response and recovery sites. Throughout the year, the Red Cross provides many community-based courses, including programs on subjects such as disaster services, disaster mental health, cardiopulmonary resuscitation, automated external defibrillators and first aid, and shelter management. The U.S. Red Cross also offers many web-based and printed educational and support tools for disaster workers and victims, including those unique to persons with disabilities and non-English speaking individuals.[43] The Red Cross is therefore a significant volunteer resource in public health and emergency management.

Although the American Red Cross emphasizes disaster preparedness, response, and recovery initiatives, the International Committee of the Red Cross is more focused on issues involving armed conflict (war) and internal violence. The International

Committee, headquartered in Geneva, Switzerland, is an independent humanitarian organization whose operations are based on a mandate (the Geneva Conventions and International Committee of the Red Cross Statutes). As a neutral body, the International Committee supports prisoners and victims of war, and of internal violence and strife.[44] More aligned with the American Red Cross mission, but on an international scale, is the International Federation of Red Cross and Red Crescent Societies. This organization, funded by appeals for contributions and support, includes three components: health, disaster management, and promotion of humanitarian principles and values. The International Federation of Red Cross and Red Crescent Societies is composed of many partner organizations, including the Red Cross, the World Health Organization and other internationally based groups. Its disaster management component includes: an information system (e.g., tools, databases), relief fund, emergency response units (teams) and field assessment and coordination teams. The International Federation includes paid staff and volunteers situated around the globe.[45]

Community Emergency Response Team

The Community Emergency Response Team (CERT) concept was first developed and implemented by the Los Angeles City Fire Department in California in 1985. The department's purpose in implementing this concept was to strengthen local fire and hazardous materials response efforts through training and coordination of citizens and private and government employees. Over time, FEMA's Emergency Management Institute and National Fire Academy, both located in Emmitsburg, Maryland, adopted the CERT model and training on a national level, and expanded the emphasis to one of all-hazards.[46]

Since 1993, FEMA has provided CERT training nationally, and 28 states and Puerto Rico have formed teams, trained, and exercised as CERTs. Although CERTs are formed and based locally, they are supported (with training, exercise, and equipment) by their respective states and FEMA. CERTs are designed to supplement existing local resources and prepare under the axiom that disasters and response are local.[46]

Other Volunteer Initiatives

Even within the U.S., there are hundreds, if not thousands, of volunteers and volunteer cells or groups that are not cited in the aforementioned initiatives. Some are borne of local organizations whose philosophy is based on a neighbor-helping-neighbor mindset, whereas others are embodied in organizations that are nongovernmental and not reflected in the NRP/NRF or other formal government agency structures. Some of the nongovernment, nonprofit entities are focused on specific aspects of healthcare in response and recovery activities. An example of this is the distinct focus on stress management and mental health issues associated with disasters and other events.

Locally based stress management teams, whose primary missions are to support local, smaller scale incidents, but whose members, in many incidents, are willing to deploy in support of events that are external to their locations are present throughout the United States. The International Critical Incident Stress Foundation lists 682 locally based teams worldwide that include members who are trained and can apply principles of "Critical Incident Stress Management (CISM)" in support of victims of disasters and other events.[47] Many of these teams are composed of first responders who are certified in CISM. In many incidents, the team's focus is on "caring for its own," applying specific CISM concepts. Other mental health professionals are members of locally sponsored teams that may or may not endorse specific CISM principles and that are not affiliated with the International Critical Incident Stress Foundation.

Certain U.S. federal departments and agencies also list volunteerism in disasters and emergency events as components of their mission(s). In 1997, the U.S. Department of Veterans Affairs, Veterans Health Administration, a major participant in the external federal/national response, developed a volunteer program, the Disaster Emergency Medical Personnel System. The Disaster Emergency Medical Personnel System includes a database of Veterans Health Administration employees and retirees from throughout the U.S. who are willing to deploy in support of VA facilities or non-VA emergencies. Volunteers are registered and trained and may be deployed for up to 2 weeks. Volunteers include doctors, nurses, pharmacists, mental health, and other clinical and support personnel. Volunteers have deployed to several VA facilities and also nationally to Presidentially declared disasters. Veterans Health Administration Directive 2003–052 describes the scope, mission, and other formalized guidelines.[48]

Faith-based organizations are another emerging group with interest in volunteerism. Following a disaster or other emergency, it is not uncommon for churches and other faith-based institutions and groups to volunteer and contribute to response and recovery efforts, especially at the local grass roots level. In January, 2001, U.S. President George W. Bush signed Executive Order 13199, creating a formal White House Office of Faith-Based and Community Initiatives. Subsequently, offices began to emerge at the state level. Additional Executive Orders created several Centers for Faith-Based and Community Initiatives. Although the primary mission of then Office of Faith-Based and Community Initiatives extends well beyond "disaster volunteers," Faith-Based and Community Initiative entities have become increasingly engaged in collaboration with local faith-based and government groups in identifying, organizing, and training volunteers for victim support following disasters. In March 2006, U.S. Executive Order 13397 created a new Center for Faith-Based and Community Initiatives at DHS in Washington, DC.[49]

National Voluntary Organizations Active in Disaster

The National Voluntary Organizations Active in Disaster was formed in 1970 by representatives of seven U.S. voluntary organizations whose missions include "disaster response." The purpose of this nonprofit agency is to "improve effective service to those affected by disaster." By 1995, the organization's membership had grown to 28 members, including the Red Cross, and various public, nonprofit, and faith-based groups. The agency functions primarily by collaboration through annual meetings and other forums involving its elected officers and members, training, communication, and resources. The agency's principles are cited as cooperation, communication, education, mitigation, serving as a convening mechanism, and outreach. Although the agency does not directly provide or manage volunteers to disasters and other emergencies, it serves as an oversight and advisory body to its members and to those managing response and recovery. The agency also serves as a body that can assess, monitor, and advise on volunteer resource assignments, ensuring lack of redundancy and appropriate volunteer preparedness and use of resources. In 1993, FEMA Director James Lee Witt appointed the agency chairperson to a permanent seat on the FEMA Advisory Board.[50]

Convergent Volunteerism

Throughout the history of disaster response, there have been many anecdotal accounts of "convergent volunteerism." Convergent volunteerism is the arrival of unexpected or uninvited personnel, asking to render aid at the scene of large-scale emergency incidents.[51] Convergent volunteerism or "freelancing" by doctors, nurses, firefighters, and others can pose difficulties for those responsible for managing the response. Although many of these individuals may be legitimate professionals in their respective fields and well intentioned, specific areas of concern are worth noting.

1) Safety – Convergent volunteers often are not properly trained or equipped for the unique response environment, which can include hazardous materials or other threats. Safety of the volunteer, as well as of the victims, may be in jeopardy, and liability is a concern.
2) Accountability – A well-organized and managed response includes knowledge by the manager(s) of "who's who." Integrating those who are not "on the list" creates disruption of the team structure and can result in liability issues.
3) Training – It is axiomatic that those responding be appropriately trained in response principles and other areas unique to the specific event. The untrained "volunteer" interferes with response efficiency and effectiveness.
4) Skill levels – In addition to training in the general sense, specific training, education, and experience are key to how responders are selected and assigned. The convergent volunteer poses the problem of requiring supervision and assessment of skills on the spot, detracting from effective and efficient operations.
5) Security – Checking identification, reviewing credentials, providing access and other security processes are labor intensive and require resources. Staff time and effort is impacted when "undocumented" volunteers converge.[51]

Those charged with managing response, as well as planners and on-scene responders must be vigilant to the potential problem of convergent volunteerism and be prepared to implement steps to manage the issue.

Volunteer Credential and the U.S. Emergency System for Advance Registration of Volunteer Health Professionals

During and following a crisis, appropriately qualified volunteers are critical to successful health and medical outcomes. In the U.S., the terrorist attacks of September 11, 2001, the subsequent anthrax incidents, Hurricane Katrina, and other public health emergencies have resulted in the mobilization of significant healthcare and support resources. Assessments of these activities, along with focus on building surge of nationwide healthcare capabilities, prompted national leaders to propose a system to ensure readiness of potential volunteer healthcare professionals. Heretofore, a nationwide credentialing system for healthcare professionals has not existed and its absence has lessened the effectiveness and efficiency of providing qualified professionals for response to emergency events in a timely manner.[51,52] Recognizing the need for optimizing volunteer health personnel in emergencies, the U.S. Congress authorized the development of the Emergency System for Advance Registration of Volunteer Health Professionals (ESAR-VHP). HRSA was initially appointed to take responsibility for ESAR-VHP development and oversight, until the passage of S.3678, which transferred responsibility to the HHS Office of Preparedness and Response.[53,54]

Under ESAR-VHP, national guidelines were issued to U.S. states and territories to establish standardized, volunteer registration systems. Each state's system is to include readily available, verifiable, current information on each volunteer's identity, licensing, credentialing, and accreditation to hospitals and other healthcare facilities. The system will allow each state/territory the ability to identify and rapidly access healthcare professionals in an emergency or disaster. The goal is that eventually, states may share information across borders and even nationally.[53] States have progressed in establishing ESAR-VHP especially through use of existing databases managed by state and local health departments. Effective ESAR-VHP registration has occurred in some states through methods such as including registration as part of professional license renewal programs. The ESAR-VHP program is a collaborative effort among federal, state, and local entities, and accrediting and professional organizations.[53]

Volunteers with healthcare, public health, and related expertise are important resources for emergency events of all scopes, levels, and locations. Management of volunteers is crucial in ensuring appropriate use of resources, avoidance of redundancy, cost effectiveness, and ultimately, timely and quality support and care of those most affected by the event. Integration of volunteers into local, state, and national established and recognized systems is key goal. At the time of this writing, the development of ESAR-VHP is ongoing, and adequate evaluation of its success has not occurred. Experts in disaster medicine have voiced concerns about its process and progress.[52] Specific areas of apprehension include

1) The system requires active recruiting of professionals on the part of those involved in development and implementation. This is time-consuming and the process may hinder successful recruitment of all potential candidates.
2) There appears to be no standardization or uniformity in approach by states charged with administering the program. Some states are "attaching" credentialing to professional license renewal, others are recruiting through local health departments, yet others have not yet determined a formal approach.
3) The program is costly. Federal funding has been provided for initial program development, but there is concern that funding may not be sustained for the long-term. Funds will continue to be necessary for staff, information technology, record maintenance, and continued recruitment.
4) The program, for the most part, is targeting physicians, nurses, and mental health professionals. There are concerns in the response community, however, that pharmacists, licensed technicians, and other vital responders must be included to ensure an adequate pool of credentialed resources.[52]

COMMUNICATIONS

Following exercises and actual disasters, leaders routinely conduct after-action reviews to identify areas for improvement.

Communication – or lack thereof – is almost always cited as one of the greatest areas of failure during disasters and emergency events, particularly during the response and recovery phases. Communication applies to both *processes* of relating among individuals, agencies, and entities, and to physical *means* of communicating, that is radios, phones, recorded reports, and other tools used to convey information, direction, and issues.

Much of the content of this chapter has addressed efforts to improve communication processes through implementation of standards and systems, including the application of ICS. As cited, U.S. legislation and Presidential Directives, such as HSPD 5 (which directs the adoption of NIMS) have been issued with the goal to enhance effective communication and thereby provide more effective management of emergency events. The contents of two documents, the NRP/NRF and NIMS are the two primary texts for all engaged in roles inherent in public health and emergency management as applied to disasters and other emergencies. In a general sense, the content of both documents is designed to provide the framework for effective communication; both also include components that are specifically dedicated to communication.

U.S. National Response Plan/National Response Framework

Several components of the NRP/NRF specifically address communications.

- NRP ESF 2 is the "Communications Annex." The ESF Coordinator and Primary Agency for ESF 2 is the DHS/Information Analysis and Infrastructure Protection/National Communications System. The National Coordinating Center for Telecommunications is the ESF 2 operational component in a domestic incident. Support agencies include the Federal Communications Commission, General Services Administration, and the Departments of Agriculture, Commerce, Defense, Homeland Security, and Interior. ESF 2 coordinates federal actions that provide telecommunication resources and restore telecommunications infrastructure for a particular incident. When activated, ESF 2 coordinates and supports national security/emergency preparedness requirements. In an incident, ESF 2, if activated, works closely with the Regional Response Coordination Center and Joint Field Office of the activated NRP. A Federal Emergency Communications Coordinator represents ESF 2 at the incident area and coordinates closely with the affected state telecommunications officer, ensuring that federal requirements are compatible with state needs. As with all NRP/NRF ESFs, ESF 2 supports, not replaces, affected state and local assets and systems. ESF 2 applies uniform emergency telecommunications management and operational plans, procedures, and handbooks in the operating environment. [55]
- The NRP/NRF "Cyber Incident Annex" addresses communications when cyber security and systems are involved. The Annex is conjointly coordinated by DHS, DoD, and the Department of Justice, with several cooperating agencies. The Cyber Incident Annex addresses cyber-related incidents of all origins, such as an organized cyber attack, uncontrolled exploits such as a virus or worm, a disaster with significant cyber consequences, or other incidents that compromise infrastructure or key assets. The Annex is closely aligned with ESF 2 and functions as directed by the NRP-cited principals and processes. Because cyberspace is largely privately owned and operated, Cyber Incident Annex authorities must work closely with applicable nongovernment and private sector entities.[55]
- ESF 15 is the "External Affairs Annex." The primary agency is DHS/FEMA, and all agencies cited in the NRP/NRF are support agencies. ESF 15 coordinates federal actions to provide external affairs support to federal, state, local, and tribal incident management elements. ESF 15 collaborates closely with and issues guidance to the NRP/NRF "Public Affairs Support Annex." ESF 15 actions are pervasive throughout all other ESFs and Annexes and function in supportive roles. ESF 15 assists with providing accurate information on the incident and its effects, such as public health and safety. It also serves to support affected jurisdictions with information dissemination and coordination, enhancing a unified approach to information sharing and dissemination.[55]
- The NRP/NRF includes a "Public Affairs Support Annex." This Annex describes the interagency policies and procedures for incident communications with the public, whereas ESF 15 outlines resources and capabilities for the Public Affairs Annex. As with ESF15, DHS is the coordinating agency and all NRP/NRF agencies are cited as cooperating agencies. To ensure continuity and standardization for incident communications, policies and procedures are based on and flow through the NRP/NRF, NIMS, ICS, and the Joint Information Center. Integration among federal, state, local, and tribal entities is maintained throughout and following the incident, ensuring that uniformity and applicability of information to the public is synchronized. The NRP/NRF Public Information Annex contains a detailed description of entities and operations involved in the development, dissemination, and monitoring of information.[55]

The other principal document/guidance (in addition to the NRP/NRF) that is essential in effective communication management in an incident is the NIMS. Communication is addressed throughout specific NIMS components.

National Incident Management System

- Chapter I – *Command and Management* – includes a specific component on "Public Information Systems." The focus of this section is on systems and protocols for communicating timely and accurate information to the public during crisis or emergency situations. The section emphasizes a Joint Information System, as well as the Joint Information Center, cited in the NRP/NRF.[56]
- Chapter V is devoted exclusively to *Communications and Information*. The chapter describes common communications and data standards and emphasizes interoperability. Through policies and protocols outlined in this chapter, standards are applied to incident notification and situation reporting; status reporting; analytical data; geospatial information; wireless communications identification and authentication; and the national database of incident reports.[56]
- Under NIMS-TAB 4, *Logistics*, "Communications" is cited as a specific unit. This NIMS section describes that the Communications Unit develops the Communications Plan (in accordance with ICS) and ensures the most effective use of communications equipment and facilities assigned to the incident. In addition, the Unit installs and tests equipment; supervises and operates the incident communications

center; distributes and recovers communications equipment assigned to incident personnel; and maintains and repairs equipment on site.[56]

As state and local emergency management, public health, and other entities have adopted ICS and NRP/NRF-like systems and move toward NIMS compliance, those who have roles during disasters and other emergencies must also become aware and informed of these important guiding principles and practices. No event is too small for which to prepare and establish adequate communication. Many have adopted standard communication equipment and systems, such as 800-MHz radio networks, allowing timely and accurate information sharing surrounding an incident. In all settings, communications planning and dedicated personnel are critical to successful response and recovery.

RECOMMENDATIONS FOR FURTHER RESEARCH

This section of the chapter addresses several areas that continue to evolve and that will benefit from continuing assessment and deliberation. Areas for future research include the following.

National Response Framework Implementation

As noted, the U.S. NRP "evolved" into the NRF. Rationale for the "framework" (rather than "plan") approach is presumably to better align the document with its intended purpose, that is, written guidance for integration of community, state, tribal, and federal response efforts. The NRF is for use by senior leaders (e.g., governors, mayors) as well as practitioners and responders.[13] In essence, the NRF should enhance and improve comprehensive emergency management programs and activities in the United States. Deliberate review and evaluation of the NRF implementation process, by those at all levels, locations, and roles, is needed to provide information and validate the success of the NRF and its intended purpose. Evidence that the NRF is successful must be visible through actions, exercise, and response by all intended users.

Change in Population Focus

There is a trend toward increased numbers of uninsured and underserved populations, as well as in the numbers of elderly and chronically ill, associated with the aging of the "baby boomer" generation. The U.S. is also experiencing an increase in the number of non-English speaking residents. This explosion of vulnerable populations must be actively addressed if future response and recovery initiatives are to be successful. The six-tier paradigm, cited in the chapter's discussion on medical surge, aids in providing a framework for including the vast number of groups, as well as resources that extend beyond the "usual" first response and hospital-targeted groups. It is unclear whether this is sufficient and how success can be measured. How can health policy researchers design and implement better systems to address the needs of already vulnerable groups, rendered more vulnerable by disaster or other emergencies? The solution lies in part with inclusion of those who routinely serve the vulnerable and underserved, but more work remains to be done. The Assistant Secretary for Preparedness and Response Hospital Preparedness Program is evolving to include CHCs, nursing facilities, home and hospice care entities, and other nonhospital organizations, but this work is in the early stages, and inclusion must extend beyond a cursory "checking-the-box" if the needs of all potential victims are to be addressed.

Medical and Health Incident Management (and Other) System Changes

The chapter describes MaHIM, a paradigm and system that is designed to improve vastly, at the "ground level," how public health, healthcare, emergency management, and others across jurisdictional lines can best integrate and successfully respond to public health emergencies and other disasters. HHS and other national authorities have endorsed MaHIM, and many local and state authorities are adopting the model. Deliberate assessment and sharing of results of implementing MaHIM (and other models) should be fluid and ongoing to determine the best practice for working together during the most challenging circumstances.

Funding and Support

The sustainability of most public health and emergency management programs relies on government funding, in the form of grants, earmarked dollars, or other forms. Many in the public health/emergency management realm have been involved in programs that "lost" funding or experienced the concern that funding may not be renewed or may be drastically reduced. Recipients of MMRS funds, for example, have heard or believed that, every year is the last year for funding (only to eventually receive funding for the next cycle). Many resources are devoted to trying to "find money" to sustain existing programs rather than concentrating on developing future strategies to improve emergency management systems. Competitive grant recipients are almost always told that their programs and products are successful only if the grantee can demonstrate how the program will be sustained when funding expires. The future direction aspect of funding and support lies in a more aggressive collaboration with private enterprise, and exploration of other means of sustaining programs as a component of being a professional in public health and emergency management. This brief attention to funding is intended to highlight a vital issue of program success and to urge planners to include funding as a consistent and prevalent component in public health and emergency management programs.

Global Public Health and Emergency Management

The September 11, 2001 terrorist attacks on the U.S. were an awakening for public health and emergency management system leaders about the importance of international collaboration. Since that event, U.S. authorities have extended invitations to international experts and those with real-world experience, for example in preparing and managing such horrific events, to collaborate on preparedness activities. Beyond the common bond of fighting terrorism, however, is the threat of an avian influenza pandemic and similar large-scale public health emergencies. Through fear and concern often come partnerships. Because of terrorism and a possible pandemic, the U.S. is involved in many unprecedented initiatives. For example, the U.S. DoD and civilian (DHS and HHS) leaders have enhanced their relationships with the Israeli Home Front Command and Ministry of Health, focusing on training, consultation, and site visits for sharing of information on emergency management issues.[57]

One measure of commitment to programs is the amount of dedicated government expenditures. In May 2004, the U.S. Congress amended the *National Defense Authorization Act*, resulting in a shifting of significant funding from DHS to the Technical Support Working Group, a U.S. national forum focused on research and development for combating terrorism. An initial $25 million was earmarked for collaborative programs among the governments of the U.S. and those of Israel and the United Kingdom for the advancement of technology and equipment.[58]

Public health officials, emergency managers, basic scientists, and other key representatives of the U.S., Canada, and Mexico are closely collaborating on the North American Plan for Avian and Pandemic Influenza. The plan addresses a plethora of mutual concerns and actions, including the sharing of technology, information, surveillance, training and exercise, and vaccines and stockpiles. The plan is part of the Security and Prosperity Partnership of North America.[59]

Involvement, assessment, and implementation of international public health and emergency management initiatives are critical to global success in decreasing morbidity and mortality from public health crisis and other disasters.

CONCLUSION

The continuing threat of terrorism, along with real-world experiences with challenging disasters such as Hurricane Katrina; the 2001 terrorist attacks in New York and Washington, DC; the 2002 terrorist bombings in Bali, Indonesia; the 2004 Indian Ocean Tsunami and bombings in Madrid, Spain; the 2005 London subway attacks; the 2007 cyclone in Bangladesh; the 2008 terrorist attacks in Mumbai, India; ongoing terrorist events in Israel and other areas of the Middle East; and countless other events demand that public health and emergency management systems become better strategically and operationally aligned. An unprecedented number of laws and authorities, along with requirements of standards, are designed to improve incident outcomes at all levels. Those charged with the care of victims, as well as those responsible for management of healthcare and related systems are directly affected by public health and emergency management activities at all levels and will benefit most through remaining informed and contributing to evolving advancements.

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10

Legislative Authorities and Regulatory Issues

Ernest B. Abbott and Douglas P. Brosnan

OVERVIEW OF THE PROBLEM

Catastrophic disasters disrupt the health and medical system. Medical infrastructure (e.g., hospitals, clinics, doctors' offices, laboratories, pharmacies, and medical suppliers) may suffer physical damage, or lose electrical power or communications capabilities such as Internet and computer services. A disaster creates new requirements for medical care when large numbers of people suffer from serious injuries or infectious diseases or are exposed to chemical, radiological, or biological contamination. As demonstrated by the 2004 Indian Ocean tsunami and the 2005 Hurricane Katrina in the U.S., a disaster can generate evacuees in the hundreds of thousands that are separated from their regular medical care network (e.g., doctors, nurses, prescription medications, and medical records), yet continue to require baseline health and medical needs.

Catastrophic disasters also challenge the legal basis of the medical system. Compliance with some legal requirements becomes impossible and practitioners must be aware of current standards and legal mandates that exist in the disaster environment. For example, in the United States, federal rules require clinicians to perform a medical screening examination and stabilize any patient who arrives on hospital grounds requesting medical care. How does this regulation apply when there is a physical plant disruption such as a hospital flood or fire, or chemical or radiological contamination of the building? Another example is that virtually all sovereign governments ensure the competence of medical professionals by issuing licenses to those authorized to practice medicine within its borders – yet in a disaster, medical volunteers will cross state or national boundaries to treat disaster victims. Under what circumstances do their medical or other professional licenses allow them to treat casualties? Should they be concerned about violating geographic restrictions contained in their malpractice insurance policies? In many countries, government officials have broad emergency powers over healthcare and public health systems when there has been an official disaster or state of emergency declaration. Within the U.S., there is substantial variation among states on exactly what those powers are and who can exercise them.

This chapter will review disaster legal issues primarily from the perspective of a person or institution – including individual doctors or nurses, medical practices, laboratories, clinics, and hospitals, who collectively provide medical care to patients in the midst of catastrophic disaster or other public health emergency. This chapter summarizes the key changes in the legal environment under which disaster medicine is practiced. Medical providers are subject to requirements imposed by governments – federal, state and, in some cases, local governments and agencies. Providers must be familiar with duties of care created by the tort/malpractice system, which is enforced by courts through money judgments. They must be cognizant of requirements existing with third-party payers and private credentialing organizations and vendors. Despite what some may view as a minefield of legal risks – risks of criminal or civil penalties, revocation of critical licenses or credentials, and malpractice or breach of contract judgments – disaster medicine creates an extraordinary and rewarding opportunity to provide medical care to people when they need it most.

CURRENT STATE OF THE ART

Medical Malpractice and Disaster Medicine

Just as they do during nondisaster times, medical care providers must manage the liability risk (for improper or inadequate treatment) during catastrophic events. In litigious countries like the U.S., the tort liability system may have as much or more effect on how medicine is practiced than do regulatory standards imposed by the government. Under the tort liability system, liability attaches to any persons or institutions who participate in care provided to an individual patient who has suffered a significant injury or illness – ***if*** the injury or illness can be proven, in court after the fact, to be wholly or partially their "fault." Damages can run into the millions of dollars for individual patients, including both "compensatory damages" (such as current and future medical expenses, lost wages, projected future losses in wages, a monetary reward for pain and suffering), and, in egregious situations, "punitive damages." The liability system is intended to make "tortfeasors" (the label given to the persons whose improper actions or failure to act caused a patient's injuries and illness) pay money damages to make that patient (or the patient's estate) "whole," to the extent possible. The liability system is also intended to create a strong incentive to persons and institutions to act with appropriate care, that is, prudent and reasonable care in accordance with accepted medical practice in the circumstances in which that care is provided.

Medical care providers are generally familiar with the liability system (in various degrees of fear and loathing) as it applies to the day-to-day practice of medicine. The same principals also apply to the practice of medicine under disaster conditions. In fact, one of the main issues discussed by public health officials and emergency planners is how to assure medical providers that they can assist in the response to a catastrophic event without incurring debilitating liability judgments.[1] One can prepare medical providers to limit liability risk under disaster conditions if they have a basic understanding of key system characteristics. In the U.S. tort liability system, there are differences in legislation and case law in different jurisdictions. An individual or institution can be found "liable" for an injury to a person if the individual or institution owes a duty to provide treatment, fails to fulfill that duty, and thereby causes harm to that person. There is one major statutory exception for a sovereign government that supports many of the efforts to immunize medical providers from liability in disasters: the government cannot be liable if it does not give its consent.[2] Indeed, a sovereign government can limit not only the extent of its own liability, it can completely immunize other persons from liability.

The "duty" whose breach leads to liability can arise from several sources. These include: 1) an agreement (in which a medical provider promises to perform certain services in a particular manner), 2) statutes (in which the legislature has declared that a person has a duty, or responsibility, to act in a particular way), or 3) "common law" resulting from judgments of courts in individual cases determining or denying liability in particular situations and establishing legal precedents.

For medical malpractice liability, the most significant "duty" owed by a medical provider is a duty to diagnose and treat patients without negligence, in accordance with a standard of care. Normally this is the care which is reasonable for a qualified professional providing treatment in similar circumstances.[3] In "normal," nondisaster times, providers generally manage the risk that they might be found negligent by establishing and following standard procedures and protocols. Following these procedures minimizes the likelihood that their actions could, in hindsight, be characterized as "negligent." Providers also protect themselves by purchasing medical malpractice insurance.[4]

During a disaster, however, medical providers' ability to use nondisaster standard procedures and protocols is severely compromised, because

- Facilities are not fully functional due to infrastructure or operational damage
- Facilities are crowded
- Supplies and drugs are in short supply
- Staff is short-handed and fatigued
- Staff has been imported from other jurisdictions that use different procedures and protocols
- Medical records are missing or temporarily unavailable
- Volunteer medical providers are working in unfamiliar facilities and jurisdictions

The circumstances under which the conduct occurs determine whether it can be classified as "negligent" medical care. A doctor operating in a tent field hospital established by government officials or in an airport concourse may not have the equipment necessary for certain tests that in "normal times" would be standard medical procedure. It would not be "negligence" for a doctor to treat a patient requiring care during this emergency without using unavailable equipment, even if the patient experienced life-threatening complications that would have been avoided had that equipment been used. Rather, the care provided would be reasonable given the environment.

There are nonetheless significant liability risks that providers face in providing care during an emergency. For example, a patient's attorney may agree that a doctor did the best he or she could in the middle of a catastrophic event – but argue that the event became catastrophic because of negligence. For example, a medical facility could be found negligent in the development of its emergency plan which led to the loss of electrical power during a surgical procedure – and that *this* negligence, not the heroic efforts taken after disaster had struck – is what led to injury. Proper predisaster preparation might have ensured that necessary test equipment was available or training was provided on substitute tests that did not require the equipment. Moreover, whether the particular care provided was "negligent" even under emergency conditions will likely be a question that a court would decide after the fact. Most medical providers are, accordingly, concerned that actions taken in a catastrophic environment could lead to large malpractice judgments based not on true negligence, but rather on their inability to provide the care that would be considered appropriate under normal conditions due to lack of resources. Even though practitioners are only held to a standard that care must be reasonable given the circumstances in which it was provided, practitioners are keenly aware that, given the delay inherent in litigation, the memory of emergency conditions will fade long before they will be judged for possible negligence.

Malpractice insurance may not provide protection to providers in the disaster environment. To limit an insurer's malpractice exposure, malpractice insurance is typically written to cover a particular type of practice in a particular geographic location. Yet in a disaster, medical providers may be needed in other jurisdictions, perhaps even in another state or country. They may be asked to practice in temporary or substandard facilities, and may perform procedures that are not normally within their scope of practice. Standard malpractice insurance may not provide protection for any of these circumstances.

To address at least some of these concerns, in the U.S., most states and the federal government have enacted legislation that provides some immunity to medical professionals providing care during disasters. State Good Samaritan legislation and the Federal Volunteer Protection Act of 1997[5] provide significant immunity protection. For example, in California's Good Samaritan Law, there is "no liability where the licensee in good faith renders emergency care at the scene of an emergency."[6] In many states, liability protection is also extended to medical professionals who volunteer to help state or local public health or emergency management officials. California also has this type of provision: "health providers . . . who render services during any state of . . . emergency, at the express or implied request of any responsible state or local official or agency, shall have no liability for any injury sustained by reason of such services, regardless of how or under what circumstances or by what cause such injuries were sustained."[7] This immunity does not apply when the injury was intentional, or resulted from actions (or failures to act) that were clearly likely to cause harm, that is, where the injury results from a "willful" act or omission. Similarly, the Federal Volunteer Protection Act provides that "no volunteer of a nonprofit organization or governmental entity shall be liable for harm caused by an act or omission of the volunteer if . . . the harm was not caused by willful or criminal misconduct, gross negligence, reckless misconduct, or a conscious, flagrant indifference to the rights or safety of the individual harmed by the volunteer."[8] Note that protection under this law extends only to the actual volunteer – and not to any organization that dispatches or supports the work of volunteers (e.g., nongovernmental organizations such as the American Red Cross).

Furthermore, providers should be aware that the liability protection offered by Good Samaritan legislation and the Federal Volunteer Protection Act typically does not extend to those who receive compensation for their efforts. Is a physician who is part of a group medical practice, and who receives a fixed share of the profits from that practice even though much of the profits were earned while the practitioner was "volunteering" in a disaster, covered? Could the immunity provided by a Good Samaritan Act be challenged if a medical care provider receives an allowance for meals and living expenses while serving in a disaster field hospital? Is a pharmacist in the employ of a corporation a volunteer if the corporation allows the pharmacist, during his paid vacation, to travel to a disaster and serve as a pharmacist at a shelter? The answers to these questions are unclear and leave a significant liability risk exposure in many U.S. states.

Immunity is provided under the laws of some U.S. states to contractors providing emergency response services *in coordination with* or *under contract to* emergency response authorities.[9] Other statutes may provide immunity to responders in particular circumstances – such as in the administration of smallpox vaccine.[10]

There are often limitations on the scope of immunity. For example, no immunity extends to: 1) caregivers receiving compensation; 2) persons who are unlicensed; and 3) for-profit businesses (such as incorporated providers of medical care). Furthermore, the immunity from liability given to government contractors may also be limited. Although contractors are generally not liable for performing under a government contract that spells out precisely the work they are required to perform, contractors can be liable if they are able to use judgment in performing the contract.[11] This exception can be very significant, because the provision of medical services requires the application of judgment.

Although liability concerns of true volunteers practicing disaster medicine are low, there is uncertainty about the definition of "volunteer" and the scope of liability protection provided by existing immunity statutes. At the time of this writing, the Disaster Response Committee of the Board of the American Red Cross had such strong concerns about the potential scope of liability that it instructed the Red Cross' Response and Recovery Division not to deploy volunteers during a Pandemic Influenza event without assuring adequate liability protections. There are a number of legislative efforts underway to clarify and extend the scope of immunity for medical providers.[12] The accelerated pace of legislative changes and the variety of approaches adopted in states across the U.S. means solutions to many of these liability issues will be in a continuous state of flux.

Despite a lack of clarity under existing law, medical providers can take actions that will eliminate or significantly reduce their exposure to liability when providing volunteer medical services in an emergency. Within the U.S., virtually all of these solutions require that a medical provider be registered with an official governmental response organization and become a part of the government response. Government officials increasingly view the coordination of volunteer and private sector response efforts (public–private partnerships) to be a critical part of disaster preparedness and response efforts. In many U.S. states, statutes immunize actions taken at the direction of state emergency management officials.[13] In some state and federal government programs, volunteer individual practitioners are "hired" as temporary employees for minimal or no salary and the government extends its immunity protection to them and becomes the defendant to pay judgments arising from any remaining liability.[14] For example, if an individual is deployed to assist at a disaster site as part of a National Disaster Medical Assistance Team, the provider becomes "federalized" and is allowed to practice in any U.S. state or territory and has federal liability protections.

The liability protections available under current law and under a number of legislative proposals are primarily directed to individuals, and particularly to individual volunteers, rather than to the nonprofit organizations and private businesses that may participate in response efforts. Some of the organizations that will assist in medical care provision during disaster events are not traditionally part of the medical system. For example, during a pandemic influenza event, public health officials may request a major employer in a community to assist in the distribution of pharmaceuticals and administration of vaccines to its employees and their families. Current law may provide only limited protection to these businesses and they may refuse to participate in planning and actual response unless they can obtain liability protection or indemnity.

Registration with an official government response organization provides other important benefits, particularly where medical providers will be serving in facilities, communities, and states different from those in which their home practice is located. These benefits – discussed in greater detail later – include extending the provider's medical license in the new state, generation of identification documents and credentials that allow the provider entry into the disaster area, and logistical support.

LEGAL FRAMEWORK FOR DISASTER MEDICINE AND PUBLIC HEALTH EMERGENCIES: PUBLIC HEALTH POWERS

In the U.S., the foundation of both the "normal" and "disaster" legal system is the Constitution that created the federal system of government. In this system, it is state governments, and not the federal government, that have primary authority and responsibility to protect public welfare. In the Constitution, states enumerate powers to the federal government, specifically authority over interstate and foreign commerce, national defense, and the right to tax and spend for the public welfare. Yet the states retain their basic police power – the power to place restrictions on people and property and business to protect the public.

The U.S. system of federalism devised by the Founders is reflected throughout the medical system. Acting under its police power authority, states have created licensing and certification requirements for hospitals, physicians, nurses, pharmacists, and other medical professionals. State statutes specify rules for reporting of communicable diseases and other public health concerns (such as unsafe conditions in restaurants), and empower public health officials to take action (impose quarantine, or close restaurants) to protect the public. State law is also generally responsible for determining the standards of care applicable to the medical system and these standards are enforced through state court judgments in the medical malpractice system.

The federal government nonetheless also exerts extraordinary power over the medical care system. Communicable diseases can spread across state and international boundaries – allowing the federal government to exercise its power over international and interstate commerce and impose federal rules to prevent transmission of disease. For example, federal legislation authorizes federal quarantine within a state upon findings that a state's quarantine efforts are ineffective.[15] Similarly, because pharmaceuticals and medical supplies are sold in interstate commerce, the federal government has authority to regulate drug manufacture and use. Federal taxes fund the Medicare and Medicaid programs that pay for 20%[16] and 9%[17] of the medical care provided in the U.S., respectively. As a result, federal requirements placed on medical care providers who treat Medicare or Medicaid patients are enforced by federal civil and even criminal penalties. These requirements include protection of patient records and service obligations in addition to billing and reimbursement procedures.

In the U.S., officials at all levels of government have broadly worded authority to take action, in the face of "imminent threats," to "save lives, defend property, and protect the public health and safety." This authority can extend to actions that would normally be viewed as blatant violations of constitutionally protected rights to "life, property and the pursuit of happiness." These actions include seizure or destruction of property (including hospitals, medical supplies, or even animals); evacuation of people from (or detention of people in) a facility or geographic area; or even mandatory treatment of persons.[18] For some of these actions, the government may be required to provide compensation. For others, the government may provide discretionary disaster assistance, and for still others, individuals and businesses are not provided any additional resources.

PROVIDER OBLIGATION TO PROTECT PATIENT RIGHTS

Privacy

Medical care involves one of the most personal of relationships between patient and doctor, and medical files contain a great deal of highly personal information. These files contain data not just about the state of a patient's health, but about the patient's habits, family, finances, sexual practices, and sexual orientation. Proper sharing of patient information (with multiple medical specialists and with third-party payers) is critical to medical care and to the successful operation of a healthcare system. In the U.S., however, disclosure without patient consent in accordance with specific provisions is prohibited, frequently by multiple statutory and regulatory provisions. Most medical providers use well-developed procedures to assure that any exchange of patient information complies with law.

Disasters can overwhelm these procedures, force additional disclosures, and trigger exceptions to the "normal" disclosure requirements. For example, in the aftermath of a catastrophic disaster, governments and families face the challenge of locating missing persons. Medical providers face the challenge of finding relatives of family members to authorize treatment, and determining when to provide medical information to family members and the general public. Disaster conditions also require hospitals and medical personnel to operate in stressful, rapidly changing, and uncertain situations. Despite this environment, the need to share information and keep the public informed must be weighed against the privacy rights of patients and their families. Federal and state laws governing the release of patient information are generally unchanged in the setting of a disaster; however, there are provisions for information sharing in emergent settings. Typically, a provider should obtain patients' verbal permission for a disclosure of health information, and patients should be "informed in advance of the use of the disclosure," when possible.[19]

Federal Health Insurance Portability and Accountability Act Requirements and Protected Health Information in the United States

A principal objective of the *Health Insurance Portability and Accountability Act* (HIPAA) was to address difficulties experienced when employees with employer-provided health insurance changed jobs. There was a need to protect patient privacy when transferring health records to the new employer. Protecting privacy while addressing the portability of insurance led to a comprehensive federal regulation governing how participants in the medical care system – care providers, laboratories, and third-party payers such as insurance companies – maintain, protect, and disclose what is defined as protected health information (PHI) of patients only when authorized. To assure appropriate attention to the privacy interest of patients, HIPAA requires that medical care providers and payers have a documented privacy policy and appoint a Privacy Official and contact person responsible for training the workforce in the PHI privacy policy.[20]

HIPAA allows healthcare providers to share a patient's PHI as necessary to provide treatment, payment, or healthcare operations; this sharing of information applies during disaster events just as it does in "normal" times.[21] Treatment includes coordinating patient care with others such as emergency relief workers or personnel at potential referral receiving sites. Furthermore, where required or necessary to prevent or control disease, injury or disability, disclosure to a public health authority is expressly authorized by HIPAA.[22]

State legislation largely echoes the provisions of federal HIPAA regulations. Some states further delineate permissible activities for sharing PHI. For example, California legislation expressly permits the communication of PHI by radio transmission or other means between emergency medical personnel.[23]

Location/ Health Status

HIPAA generally permits providers to share very limited information concerning a patient's location and general condition or death as necessary to identify, locate, and notify family members or guardians.[24] Therefore, if necessary, a hospital may notify the police, press, or the public at large to the extent necessary to help locate, identify, or otherwise notify family members as to the location and general condition of the patient. Federal regulations also permit the sharing of basic information including the patient's identity, residence, age, sex, and condition to disaster relief organizations without patient consent if necessary to facilitate disaster response.[25] Even when disclosures are permitted by HIPAA, however, providers must be aware of any state statutes that might restrict disclosure of patient information. California law expressly permits disclosure of basic patient information to state or federally recognized disaster relief organizations,[26] and Arkansas has adopted basic HIPAA disclosure provisions[27] but other states have not done so and may have more stringent restrictions on disclosure. There is some confusion about whether HIPAA rules *permitting* disclosures preempt state laws.[28] In any event, under normal circumstances, when a patient incapable of communication arrives at a hospital, the facility must attempt to make contact with a family member or surrogate within 24 hours – a requirement that is suspended during periods of disaster.[29]

Hurricane Katrina forced the rapid evacuation of well over one million residents, and in the process of evacuation, many families were separated. Isolated individuals included parents and other caregivers, children, and grandparents. This disaster questioned the ability of the federal government to effectively track evacuees and reunite family members. As a result, in the post-Katrina *Emergency Management Reform Act* of 2006,[30] Congress enacted legislation requiring the Federal Emergency Management Agency Administrator to establish a: 1) National Emergency Child Locator Center (in cooperation with the U.S. Attorney General) within the National Center for Missing and Exploited Children, and 2) National Emergency Family Registry and Locator System. The former provides information about displaced children and serves as a resource for adults who have information about displaced children; the latter focuses on allowing displaced adults to register, furnish personal information to a database, and to make this personal information accessible to "those individuals named by displaced individuals." Implementation of this section will require negotiation of a memorandum of understanding with the Departments of Justice and Health and Human Services and with the American Red Cross and "other relevant private organizations." This system should help medical providers in their efforts to locate a patient's next of kin.

Public Health Officials

In the U.S., HIPAA allows disclosure of PHI to a "public health authority that is authorized by law to collect or receive such information for the purpose of preventing or controlling disease, injury, or disability, including, but not limited to, the reporting of disease, injury, vital events such as birth or death, and the conduct of public health surveillance, public health investigations, and public health interventions." This authorization also permits disclosures to "a person or entity other than a public health authority" if it can demonstrate that it is acting "to comply with requirements of a public health authority." PHI can also be disclosed to a person who may have been exposed to a communicable disease or is at risk of spreading a disease (for example, sexually transmitted disease), "and is authorized by (state) law to be notified as part of public health intervention or investigation." These specific provisions governing disclosure to public health officials that facilitate public health interventions are even more important during a public health emergency than during "normal" times. The provision in the HIPAA rule authorizing disclosure of PHI to law enforcement officials "to help identify or locate a suspect, fugitive, missing person," and "to provide information related to victim of crime" is even more critical during public health emergencies, particularly those that are triggered by criminal or terrorist activity.[31]

Immediate Danger

HIPAA further permits the disclosure of PHI without consent or prior notification when "necessary to prevent or lessen a serious and imminent threat to the health or safety of a person or the public; and is to a person or persons reasonably able to prevent or lessen the threat, including the target of the threat."[32] This exception is particularly important when communicable disease is involved; it allows disclosure of a patient's communicable disease status without the patient's consent to other persons (such as a patient's spouse or partner) to protect them from exposure.

Reporting and Recordkeeping Requirements

Even where disclosures of PHI are fully authorized, and even if those disclosures are in the midst of a public health emergency, HIPAA requires that the entity making the disclosure track when the disclosure was made, and to whom. Authorities must make this information available to the patient on request.[33] As a result, when developing their emergency plans, medical providers in the U.S. must pay special attention to ensuring that they will have systems to document the disclosures that they make, whether required or permitted, of a patient's PHI.

Media

A public health emergency or disaster will generate significant media attention. Despite media inquiries, hospitals must maintain confidentiality of PHI. A hospital reporter must have a patient's consent before releasing any personal information. A facility may, however, disclose general information about a disaster response such as the number of victims treated at the facility and the general types of injuries sustained so long as this information is not specifically identifiable to an individual. As mentioned previously, a hospital may disclose specific PHI to the media if this disclosure constitutes an effort to locate family members.

Data Storage and Security

The requirements of HIPAA include a stipulation that "covered entities" institute a data recovery plan insuring continuity of operations in the aftermath of a disaster.[34] A covered entity is a health plan, a healthcare clearinghouse, or a healthcare provider who transmits any health information in electronic form in connection with a HIPAA transaction.[35] Covered entities include doctors, hospitals, laboratories, and pharmacists, and also the insurance companies and other third-party payers that have access to a patient's PHI. This required system must include a data backup plan for the retrieval, and restoration of electronic PHI as well as an operations plan that enables the maintenance of privacy and security safeguards over PHI. State regulations may also require data protection and access in a disaster situation. For example, in California, hospital licensing regulations require hospitals to safeguard their medical records against loss or corruption.[36] California also details specific requirements for organizations maintaining only electronic records including off-site backup and retrieval systems.[37]

Although it is preferable to anticipate postdisaster challenges and proactively pass enabling legislation, in some situations the legal requirements can be modified postevent. For example, in the aftermath of Hurricane Katrina, the U.S. Secretary of the Department of Health and Human Services (DHHS) issued a waiver of penalties for violating certain HIPAA privacy provisions that proved impractical in the disaster setting including:

> *Sanctions and penalties arising from noncompliance with the following provisions of the HIPAA privacy regulations: (a) the requirements to obtain a patient's agreement to speak with family members or friends or to honor a patient's request to opt out of the facility directory (as set forth in 45 C.F.R. '164.510); (b) the requirement to distribute a notice of privacy practices (as set forth in 45 C.F.R. '164.520); or (c) the patient's right to request privacy restrictions or confidential communications (as set forth in 45 C.F.R. '164.522).*[38]

The U.S. DHHS provides a fact sheet confirming that HIPAA is not suspended and explaining what provisions may be waived during a national or public health emergency.[39]

Individual Liberty

Decisions on treatment of patients involving such issues as selection of diagnostic tests, therapeutic agents, surgical procedures, drugs, and diets are generally made by physicians and other care providers only with consent after appropriate disclosure of the risks, costs, benefits, and alternatives. This system reflects the privacy and liberty interests that patients have in their own bodies, and it is enforced not only by numerous regulatory requirements but also by judicial precedents. The provider may be liable after a patient suffers an adverse effect of treatment, if it was a known adverse effect of that treatment and it was not fully disclosed to the patient. The rules may change during a disaster. To protect the public health, the government is granted significant power to require testing or treatment of individuals, isolation of patients with a communicable disease, and quarantine of those with suspected or known exposure to communicable disease irrespective of the patients wishes. On a practical level, it is unclear whether the government would be able to exercise these authorities, particularly in a democratic society. For example, if patients who are thought to be a "threat to the public health" refuse to remain in quarantine because they want to leave to check on the safety of a loved one, would the government use force (potentially lethal force) to prevent this? Balancing the threat to the public with the risks to the individual and those enforcing the laws could be very challenging, especially in borderline cases.

Legal Basis of Mandatory Public Health Measures

Governments have a wide variety of legal tools that address communicable disease. Some, such as quarantine, have a history extending back centuries if not millennia. These public health powers may significantly limit individual patient rights, but as illustrated later, U.S. courts have generally provided wide latitude to public health authorities in adopting them.

A seminal case on restricting individual rights to protect the public health is *Jacobson v. Massachusetts*, 197 U.S. 11 (1905). In 1902, the City of Cambridge, Massachusetts, passed an ordinance finding that "smallpox [was] prevalent in the city and continues to increase." The city ordered vaccination of all its inhabitants, except children with a doctor's note saying that they were unfit subjects for vaccination. Henning Jacobson, a charismatic minister who had emigrated from Sweden, refused to be vaccinated. Reverend Jacobson viewed vaccination as unsafe and ungodly. Side effects of the cowpox vaccine used in vaccination were common. He refused to pay the $5 fine specified for violators, and he appealed his fine all the way to the U.S. Supreme Court.[40]

The court responded with a decision supporting the right of communities to use their police powers to protect the public welfare. In the words of Justice Harlan:

> Real liberty for all could not exist if each individual can use his own, whether in respect of his person or property, regardless of the injury that may be done to others. . . . *Upon the principle of self defense, of paramount necessity, a community has the right to protect itself against an epidemic of disease which threatens the safety of its members.*[41]

Justice Harlan also qualified the scope of the power to restrict liberty for public health:

> Police power of state must be held to embrace, at least, such *reasonable* regulations established directly by legislative enactment as will protect the public health and safety . . . *subject, of course, that . . . no rule . . . or regulation . . . shall contravene the Constitution of the United States, or with any right which that instrument gives or secures.*[42]

In other words, within the U.S., public authorities have the right to protect their communities from an epidemic of disease, but the actions taken to do so must be "reasonable," with some rational basis grounded in knowledge about treatment for the disease and its incubation period, virulence, and communicability. The requirement that public health measures – even those taken to protect the community from disease – cannot "contravene the Constitution" or any "right which that instrument gives or secures" is also extremely significant. The 5th and 14th amendments to the U.S. Constitution preclude a federal or state government from taking a person's liberty or property without "due process." Mandatory treatment, inoculation, quarantine, and isolation measures clearly restrict the liberty of individuals. Therefore, state and federal government use of these powers must be in accordance with due process, which includes both "procedural due process" (following appropriate *procedures*) and "substantive due process" (requiring that officials have a *substantive* reason and a rational basis for restraining individual liberty).

Procedural Due Process means that the state must provide notice, counsel, and an opportunity for a hearing to any person subjected to these mandatory public health measures. This is similar to the procedural rights offered in connection with involuntary commitment of a patient due to a mental disorder. "Substantive" Due Process requires that the state's proposed restriction of individual liberty be rational and reasonable.

The case of *Best v. Bellevue Hospital New York* is illustrative of these "due process" principles.[43] Mr. Best was diagnosed with tuberculosis but refused to complete his medication regimen and could have developed a drug-resistant strain. The Health Department issued an order detaining him and requiring completion of his treatment. Mr. Best filed suit against the health department and the hospital where he was confined. Mr. Best was granted a hearing and the courts assessed whether he was a danger to himself and the community. After a prolonged legal process that included four public hearings, significant attorneys' fees, and at least seven administrative, state court and federal court orders, the court found that the Health Department and other defendants had indeed provided the due process required by the Constitution. On procedural due process, the federal appeals court described the factors considered in determining constitutionality of detention procedures:

> First, the private interest that will be affected by the official action; second, the risk of an erroneous deprivation of such interest through the procedures used, and the probable value, if any, of additional or substitute procedural safeguards; and finally, the Government's interest, including the function involved and the fiscal and administrative burdens that the additional or substitute procedural requirement would entail.[44]

In general, quarantine and isolation procedures that provide notice, an opportunity for hearing (which can be held after an individual is detained) and access to counsel will satisfy procedural due process requirements. The hearing requirement does not preclude health officers from taking action immediately when there is a risk that the public will be exposed to a communicable disease if a person is not immediately placed in isolation or quarantine.

Courts must also determine whether a public health order violates a person's substantive due process rights; that is, it must review whether the government had a rational, reasonable basis for the order. This analysis involves a balancing of the collective right of self defense enunciated in *Jacobson* against individual rights to liberty and property. In these cases, courts have traditionally given great deference to the judgment of public health officers. One historical example is provided in an opinion by Judge Hydrick of South Carolina's Supreme Court in 1909:

> In dealing with such matters, a wide range of discretion must be allowed the local authorities, and they should not be interfered with, unless it is clearly made to appear that they have abused that discretion to the probable injury to health or life.[45]

There are relatively few recent cases defining the Constitutional requirements for mass quarantine; at the time of this writing, the United States has not had occasion to impose a mass quarantine for more than 50 years. In the U.S. legal system, two basic principles that have support in the case law can assist public health officials in understanding the legal approaches to control of communicable disease. First, the greater the restraint on individual liberty, the greater is the responsibility that government has to provide for those restrained. For example, when the state confines individuals in prison, or involuntarily commits individuals in a mental health facility, these individuals are no longer able to access their own food or medicines; courts have declared confinement without food or medicine, or in crowded and dilapidated prison conditions to be unconstitutional.[46] When individuals and families are deprived of the ability to meet their basic needs for food, shelter, and medical care by quarantine or other movement restrictions, the state becomes obligated to provide those basic needs.

Second, despite the great deference given public health officials, they cannot justify their orders simply by stating that the actions will prevent the transmission of disease. They must also show that they could not have controlled the spread of disease with alternative public health measures that would have had less impact on individual liberty. The U.S. Constitution provides that states cannot deprive persons of their "life, liberty, or property without due process." As in the *Best v. Bellevue* case, this language has been interpreted to mean that the public health objective should be achieved with the least restrictive measures possible for all cases, including patients with a communicable disease, suspected infections, and known or suspected exposures.[47]

By enforcing "restrictions of movement," the goal of public health officials is to increase the 'social distance' between potentially infected persons and uninfected persons. Effectiveness of different movement restrictions in increasing social distance and reducing transmission of disease is highly dependent on disease characteristics. These include incubation period, method of communicability, virulence, treatment options, and whether asymptomatic patients are contagious.

Some U.S. states have adopted statutes that include "the least restrictive means necessary test" (extrapolated from the *Model State Emergency Health Powers Act*).[48] At the time of this writing, other states and the federal government have not yet defined the minimum constitutional requirements for quarantine. In many cases, strict quarantine procedures are not necessary to reduce disease transmission. Other restrictions of movement, which increase social distance, such as school closings, restrictions on public meetings, work quarantine, and wearing of masks or respirators may be just as effective.[49] Because there are a number of less intrusive measures that may be equally or more effective than mandatory detention in a quarantine facility, a public health official may need to provide an affidavit with the quarantine order that explains why these less physically intrusive options were not selected.

Although there are a myriad of measures that reduce disease transmission, some are less intrusive on individual rights than others. For example, restricting public meetings or requiring use of face masks respects individual liberties much more than placing people in involuntary detention in a quarantine center. The decision about which measures to employ has important legal consequences.

Judge Hydrick's observation in *Kirk v. Wyman* is unusual in that he reversed a decision, thereby overturning a Board of Health quarantine order. In *Kirk v. Wyman*, an elderly "lady of culture and refinement," who had contracted leprosy while serving as a missionary in Brazil, was ordered released from a Board of Health operated quarantine facility because this "pest house" had previously been used to "detain Negroes with smallpox." The majority simply found it unfathomable for an upper class and presumably white lady to be so treated. The facts of this case illustrate the difficulty in balancing the "collective right of self-defense" against individual rights, for both health officers and the judicial system.

Legal preparation for a large-scale quarantine from a pandemic event extends beyond simply developing a notebook of standardized hearing notices and affidavits to be signed by public health officials. Attorneys must also enhance the procedural readiness of the judicial system, encouraging the courts to think through

- The systems to be used for handling a large number of hearing requests

- The measures that will be employed to protect the safety of hearing officers and participants
- Documentation/affidavits that will be required in a mass quarantine environment
- How the court and other officials will communicate to the public

Consent

Generally, rules for consent do not change in a disaster or public health emergency. The medical care system is accustomed to situations in which it is impossible to obtain consent from patients. For children, or those who are unconscious, mentally disabled, or otherwise unable to make an informed choice, consent is generally obtained from parents, or a spouse, or a guardian. In an emergency, whether the emergency involves an individual patient or a whole population during a catastrophic event, patient consent for management of an imminent medical crisis is implied. In this context, an "emergency" is a situation in which delay in immediate care would lead to serious disability or death, or immediate treatment is required to relieve severe pain. Frequently, within the U.S., state statutes provide specific requirements and definitions.

For example, in California, B&P § 2397 protects a medical care provider from liability when treatment is provided without consent, if the patient was unconscious, there was insufficient time to inform the patient, or the patient was without the legal capacity to provide consent and there was no time to find and obtain consent from the patient's legal representative. The term "capacity" is defined by statute as, "a person's ability to understand the nature and consequences of a decision and to make and communicate a decision." Minor patients lack capacity as a matter of law except when the minor has been given "emancipation" status (e.g., by court order, by military service, by marriage, or because the minor has been determined self-sufficient). In some jurisdictions, there are additional exceptions to the rule that minor patients lack decision-making capacity. For example, in California, a patient 12 years of age or older has the legal capacity to make informed consent decisions with respect to communicable reportable diseases, outpatient mental health, substance abuse, and pregnancy-related treatments.

The specific rules of consent can vary substantially in different states. For example, rules regarding pregnancy-related treatment are frequently controversial and there is no national consensus on the age at which a minor does not require parental consent. As a result, if volunteers in the U.S. from one state provide disaster medical services in another state, they should be aware of the specific consent laws that apply in that state.

AUTHORIZATION TO PROVIDE MEDICAL CARE

Licensing and Credentialing

Licensing

In the U.S., states regulate the practice of medicine. Thus, providers must be licensed in the state in which they are providing medical care. State licensing requirements generally extend not only to clinical care providers (e.g., physicians, nurses, pharmacists, veterinarians), but also to institutions (e.g., clinics, hospitals, and nursing homes). To obtain a state license, a provider or institution must demonstrate that they meet particular educational, training, and experience requirements. Medical practice is restricted to those skills and procedures commensurate to the training received and authorized under a professional license, a so-called "scope of practice."[50] Requirements are established by state laws and agencies; they vary by state, and licenses authorize professional activities only in the state in which the license is granted. States experiencing a disaster, however, frequently find that their existing resources of medical (and other) professionals are insufficient and that they must rapidly obtain assistance of professionals from other states. Medical professionals from other areas must be qualified to provide disaster relief services.

Upon declaration of a disaster or state of emergency, the governor of a state generally has the power to adjust the state's licensing requirements to allow practice by professionals from out of state. In some states the governor has the power to completely suspend the state's licensing scheme,[51] although in practice this power is not invoked except through procedures that assure professional qualifications. More commonly, a governor will exercise an emergency power that temporarily recognizes professional licenses issued in another state. For example, after declaring an emergency in California, the California Emergency Services Act bestows on the Governor broad emergency powers that include the ability to grant "any person holding a license issued by any state for professional skill permission to render aid involving such skill to meet the emergency as fully as if the license had been issued in California."[52] In the U.S., the Emergency Management Assistance Compact automatically provides for "cross licensing" to professionals who are deployed to a state as "state personnel" under this agreement. During Hurricane Katrina, existing laws allowing cross licensing of professionals did not work as quickly or as broadly as needed, and several efforts to broaden these rules were initiated. The Commission on Uniform State Laws adopted the *Uniform Volunteer Emergency Health Practitioners Act* in 2006 and 2007. This Uniform Law, which is only effective in a state after it is introduced to and enacted by the state, will provide automatic cross licensing of health professionals volunteering through a recognized credentialing system during emergencies.

Hospital Credentialing

The Joint Commission (formerly known as Joint Commission on the Accreditation of Healthcare Organizations) is an independent, not for profit U.S.-based organization nationally recognized for setting certain hospital performance standards and granting accreditation and certification to those hospitals meeting these standards. Joint Commission International, established in 1997, "extends The Joint Commission's mission worldwide by assisting international health care organizations, public health agencies, health ministries and others to improve the quality and safety of patient care in more than 80 countries" (http://www.jointcommission.org/AboutUs/Fact_Sheets/jci_facts.htm). The Joint Commission 2006 Hospital Accreditation Manual includes standards for administrators to grant disaster privileges, i.e. authorization for practitioners to work in their hospitals. When the healthcare facility emergency management plan has been activated and the hospital capacity is exceeded by the immediate surge in patients, "the CEO {Chief Executive Officer} or medical staff president or their designee(s) has the option to grant disaster privileges."[53] The official authorized to grant disaster privileges has broad discretion. To receive these privileges, however, the provider must present 1) a current picture hospital identification card, 2) a current license to practice issued by any state, federal, or regulatory agency, 3) identification indicating that the individual is a member of a federal Disaster Medical Assistance Team, or 4) a current hospital or medical staff member with personal knowledge regarding the practitioner's identity.[54] This standard requires that individuals authorized to grant hospital privileges be specifically identified and that there is a mechanism for managing personnel operating under temporary disaster privileges. The requirement further specifies that there must be a means for allowing staff to readily identify these personnel and that verification of credentials and privileges begins as soon as the immediate patient surge has resolved. This process is identical to the process established under Joint Commission standard M.S.4.100 for granting privileges to meet an important patient care need.[55] As an alternative to the Joint Commission process, the Executive Branch of state government may also have authority to grant hospital privileges in the setting of a declared emergency.

Financial and Reimbursement Issues

Regional disaster plans may include memoranda of understanding between healthcare facilities for staff sharing during emergencies. In some models, the facility requesting assistance provides reimbursement directly to temporary employees; in other systems the regular employer continues to pay salaries and receives reimbursement from the hospital that benefited from the shared services. For example, the District of Columbia Hospital Association in Washington, D.C. maintains an agreement among its members to assist hospitals in emergency management. This agreement addresses the logistics of personnel and equipment sharing and the transfer of patients. It also assigns credentialing responsibilities and legal liability to hospitals receiving assistance from others.[56]

Federal rules for reimbursement in the U.S. under Medicare, Medicaid, and state children's health insurance programs were relaxed in the aftermath of Hurricane Katrina. This was primarily because compliance with prior provider enrollment in these programs, recordkeeping, and licensure in the same state in which services were provided was both impractical and counter to public policy. Six days after the storm made landfall in the U.S., the DHHS issued a waiver of various requirements for participation in federally funded healthcare programs.

1) Certain conditions of participation, certification requirements, program participation or similar requirements, or pre-event approval requirements for individual healthcare providers or types of healthcare providers, including as applicable, a hospital or other provider of services, a physician or other healthcare practitioner or professional, a healthcare facility, or a supplier of healthcare items or services.
2) The requirement that physicians and other healthcare professionals hold licenses in the state in which they provide services, if they have a license from another state (and are not affirmatively barred from practice in that state or any state in the emergency area).[57]

Although a post hoc administrative response may not represent the most prudent of reactions, the government recognized the importance of encouraging flexibility in staffing to provide adequate healthcare delivery in the midst of a mass casualty incident. To accommodate an increasing patient surge, this waiver also extended to hospital bed classification requirements allowing "nonmedical beds" to be used for patients requiring medical services. The government reimbursed these services according to relaxed billing requirements. During the time of disaster relief, paper billing and substitute data were acceptable for those records that were destroyed or unrecoverable.

HEALTHCARE FACILITIES

The Joint Commission standards require hospitals, acute care facilities and acute care psychiatric facilities to maintain and regularly update disaster plans and to train and test staff preparedness.[58] Medicare in the U.S. also promulgates federal hospital emergency management plan accreditation requirements. Although Medicare conditions of participation for critical care facilities do not contain specific requirements for disaster management plans, the Interpretative Guidelines issued by Medicare to its state survey teams require the adoption of "emergency preparedness plans and capabilities."[59] The Medicare Interpretative Guidelines for hospitals and "critical access hospitals" (a safety network of hospitals identified by Medicare to ensure access to healthcare services in rural areas) require that the hospital formulate and implement a disaster plan to "ensure that the safety and well-being of patients are assured" during a disaster and that such plans include coordination among all levels of government emergency preparedness authorities with specific identification and response to likely risks in their general areas such as earthquakes, floods, and so forth.[60] The Interpretative Guidelines are detailed in their list of issues to be addressed in the disaster plan and include consideration for security of walk-in patients; security of supplies (including pharmaceuticals, water, and equipment); communications systems; provisions in the event of gas, power, and water disruptions; and mechanisms for the transfer of patients.

The U.S. Occupational Safety and Health Administration asserts authority to regulate "any reasonably anticipated disaster that could create a hazard for employees" at the workplace.[61] Such hazards include workplace injuries, fires, blood-borne pathogen exposure, and radiation and other hazardous materials exposures.

States within the U.S. also impose hospital disaster plan requirements. For example, California hospital licensing regulations require a "disaster and mass casualty program," which must be approved by the medical staff and administration, practiced by conducting at least two drills per year, and available for review by representatives of the California Department of Health Services.[62] California regulations require the plan to contain a hazards vulnerability analysis, community linkages with an "all-hazards" command structure, specific procedures during a disaster, a mechanism for plan activation, a process for reporting emergencies to external authorities, a command structure, and a means to notify and activate personnel.[63] Even though hospitals may fulfill these disaster regulations, they could be out of compliance with a multitude of requirements placed on them during non-disaster operational periods. For example, patient–nurse ratio requirements in the State of California (designed to provide individual patients with optimum nursing care) are unlikely to be practical in the setting of mass casualties and may actually be harmful to the affected population. Staffing ratios should not determine hospital capacity, as is often the case in nondisaster settings when nursing shortages frequently dictate the maximum number of patients that may be cared for at a facility. During a disaster, however, it would be difficult to obtain timely waivers of legislated nurse–patient ratios. Hospitals should be encouraged to prepare agreements with its nursing staffs and unions prior to and in anticipation of a patient surge during a disaster. Discussions between hospital administration and nursing should also explore means to increase staffing during emergencies.

EMERGENCY MEDICAL TREATMENT AND LABOR ACT

The U.S. *Emergency Medical Treatment and Labor Act* (EMTALA) was passed in 1986 in response to reports that hospitals were refusing to treat individuals with emergency conditions if they did not have insurance.[64] The EMTALA requires Medicare-participating hospitals to provide any individual presenting for care on hospital grounds with medical screening, stabilizing services, and appropriate transfer to a higher level of care if indicated. In addition, EMTALA sets forth civil monetary penalties on hospitals and physicians for:

1) Failing to properly screen an individual seeking medical care
2) Negligently failing to provide stabilizing treatment to an individual with an emergency medical condition
3) Negligently transferring or releasing from care an individual with an emergency medical condition (including active labor)[65]

Waivers to EMTALA mandates, even in the setting of a mass casualty event, have not been well developed. Project Bioshield legislation (enacted in the U.S. in 2004) provides some relief from EMTALA when the federal government declares an emergency.[66] This legislation allows the DHHS and the Centers for Medicare and Medicaid Services to waive temporarily EMTALA standards relating to

1) Transfer of unstabilized emergency patients if required by the circumstances of a declared emergency by a hospital in the emergency area during the period of the emergency; and
2) Directing or relocating patients for medical screening to alternate locations in accordance with the state emergency preparedness plan

The U.S. federal government issued an EMTALA waiver during Hurricane Katrina that suspended the requirement for hospitals in the designated disaster area to screen and stabilize patients if the disaster situation prevented it, provided that these patients were redirected to another facility for the medical screening examination and stabilization.[67] As the Agency for Healthcare Research and Quality notes, EMTALA requirements are not entirely clear, particularly with respect to transfer or "surge" facilities. The Agency for Healthcare Research and Quality recommends that elements of EMTALA "be reduced/waived for a temporary/limited service surge facility." For example, the benefits of transfer to a surge facility would be to make room for other patients needing tertiary hospital services, not necessarily for the benefit of the transferred patient; the patients would not necessarily be asked to consent to transfer to the surge facility.[68]

EMERGENCY MANAGEMENT AND PUBLIC HEALTH SYSTEMS

Through the end of the 20th century, there was relatively little effort to incorporate the public health and medical care systems with the emergency management system. Public health officials worked independently, operating under public health laws and authorities to protect public health and transmission of communicable diseases. Similarly, emergency management officials worked in isolation and were not prepared to assist in response to a major public health emergency such as an epidemic that had the potential to overwhelm the healthcare system. There was rarely coordination of disaster programs development between public health, medical, and emergency management officials.

In the U.S., there was a major philosophical shift after the terrorist attacks of September 11, 2001. The federal government mobilized massive resources to focus attention on preparing the nation for catastrophic events. Within a year of the attacks, Congress had enacted legislation creating a new federal department, the Department of Homeland Security (DHS), with the mission of protecting the nation from terrorist attacks and other threats. By Executive Order, President Bush directed the new DHS to establish a National Response Plan that would coordinate emergency response efforts of the entire federal government, in collaboration with states.[69] The President also required DHS to establish a National Incident Management System (NIMS) and directed that *every* federal agency (not just DHS) require state and local governments to be "NIMS compliant" as a condition for receipt of federal preparedness grants.[70] Meanwhile, Congress passed legislation adding new emergency healthcare authorities, with particular emphasis on preparation for a bioterrorism event.[71] Federal funding for state and local governments, first responders, and, to some extent, hospitals expanded dramatically to address the healthcare impact of potential terrorist attacks. Applicants for these billions of dollars in preparedness funding[72] had to demonstrate that they were "NIMS compliant."

THE U.S. NATIONAL INCIDENT MANAGEMENT SYSTEM

The goal of the National Incident Management System is to enable emergency responders from many different agencies, levels of government, and organizations to effectively coordinate disaster response activities. A key element of NIMS is its requirement that all entities involved in emergency response adopt the "Incident Command System (ICS)" to manage events. Under this system, "incident command" is established by the local or state government. Response resources arriving from outside the affected area establish contact within the incident command system. Although the emergency management system traditionally focused only on *government* actions, legislation passed after September 11, 2001, required that all first responders, including the private owners of critical infrastructure like hospitals and other medical facilities, be included in any emergency management plans and responses.[73]

People staffing an ICS in a major disaster may be from many different states and regions. Therefore, common terminology may be lacking. A request for a "nurse" does not communicate whether the need is for someone trained in triage or in administering immunizations or in caring for nonambulatory patients. Each medical organization involved in incident response should designate a staff member as liaison to local public health officials to determine how NIMS procedures and guidance apply to their group. The staff member should also review the developing guidance on NIMS applications to the healthcare sector.[74]

First responders (and first receivers) should negotiate mutual aid agreements with neighboring providers so that assistance can be delivered faster, and with fewer legal complications, when disaster strikes. Many of the issues addressed elsewhere in this chapter, for example, licensing, credentialing, reimbursement, and liability can be managed through mutual aid agreements. This can include the use of existing mutual aid agreements such as the Emergency Management Assistance Compact (an agreement approved by Congress and adopted by all 50 states and the principal territories of the U.S.).

U.S. FEDERAL DISASTER ASSISTANCE PROGRAMS

If a catastrophic event creates emergency or disaster conditions that exceed the response capacity of state and local governments, the governor of a state may request the President of the United States to declare a "major disaster" or emergency under the *Robert T. Stafford Disaster Relief and Emergency Assistance Act* (Stafford Act).[75] This declaration, once issued, triggers eligibility for a number of different federal assistance programs, including both grant assistance and direct federal assistance. Several of these programs are important for medical providers.

First, under the Stafford Act's Public Assistance Program, the federal government will provide a grant to "eligible applicants" of "not less than 75%" of the "eligible cost" of 1) performing certain emergency work to save lives, property, and the public health and safety; and 2) "repairing, restoring, replacing, or reconstructing" any damaged state or local government facilities, and eligible facilities of nonprofit organizations. The Stafford Act's public assistance program, administered by the Federal Emergency Management Agency (FEMA) within the DHS, can be critical to the financial survival of eligible entities affected by a declared disaster event. These include government and nonprofit healthcare providers, such as hospitals, clinics, ambulance services, and nursing homes.

Entities must meet certain requirements to be eligible for FEMA grant assistance. For example, the provision of emergency medical care is considered part of the normal business of a medical facility and the associated costs are not generally eligible for FEMA reimbursement, except in the most catastrophic of events.[76] The cost of creating additional facilities for emergency treatment may, however, be eligible during a catastrophic disaster.[77] Disaster assistance grants provided by FEMA are considered federal grants, subject to all of the boilerplate requirements of federal regulations,[78] including a requirement that all contracts for work be competitively bid.[79] Federal support will only be provided to supplement (not replace) assistance available from insurance, including employer-provided and individual policies, and Medicare/Medicaid.

U.S. GOVERNMENT EMERGENCY POWERS OVER HEALTHCARE FACILITIES

State emergency statutes are drafted extremely broadly and provide enormous power to governors and other designated state officials for emergency response. As previously discussed, the scope of these powers allows substantial restrictions on individual liberties by evoking quarantine, isolation, and mandatory treatment or inoculations. The governors' powers over private property are similarly expansive. For example, in Georgia (and in many other states) the governor may "Commandeer or utilize any private property if he finds this necessary to cope with the emergency or disaster."[80]

Although the power to commandeer property is clear, any exercise of this power is subject to two critical requirements identified in the Fifth Amendment to the U.S. Constitution: "a person shall not *be deprived of life, liberty, or property, without due process of law . . . nor shall private property be taken for public use, without just compensation.*" Thus, an owner can object to seizure of the property, and is entitled to due process to determine whether the seizure is justified. Similarly, the owner will be entitled to government compensation, measured by the value (as determined in court) of the property taken. In emergency circumstances, the due process and compensation hearings will occur after the government has taken possession of the property.

Although it may be authorized in law, commandeering of property in emergencies is highly disfavored. Effective catastrophic response by governments requires development of response plans, training of those who will implement them, and exercising those plans to ensure that they work. Governments recognize that the voluntary involvement of the private sector is fundamental to effective disaster response. In fact, the U.S. Congress has added a number of amendments to federal emergency management laws since Hurricane Katrina, directing FEMA and other agencies to include the private sector in emergency response plans and exercises. These statutory directives are repeated in several of the President's Homeland Security Presidential Directives.[81] Moreover, the emphasis in emergency planning is to identify emergency response needs in advance of the disaster and, if private sector response resources are required, to invite bids and proposals for contracts under which resources will be provided in an emergency. The cooperation from the private sector that is necessary for effective emergency planning and response is incompatible with any plan that relies upon commandeering of property except in the most unusual of events – where a need could not have been anticipated, and circumstances precluded negotiation of contractual arrangements.

EMERGENCY WAIVER OF U.S. STATE LAWS

In addition to commandeering property, many U.S. states also give their governors the power to temporarily suspend state laws and regulations that may interfere with the response or that become impossible to implement due to emergency conditions. California law states that "the Governor may suspend any regulatory statute . . . or the orders, rules, or regulations of any state agency . . . where he declares that compliance would . . . in any way prevent, hinder, or delay the mitigation of the effects of the emergency."[82] This provision can be applied to procedural and paperwork requirements of agencies, to medical staffing or other state regulatory requirements governing medical care, to substantive licensing provisions, or virtually any regulatory statute. For example, during the 2004 hurricane season (after Florida was struck by Hurricanes Charlie, Francis, Ivan, and Jean), Florida's State Coordinating Officer (with authority delegated from the governor) issued 61 Supplemental Orders that overrode statutory and regulatory requirements encompassing such varied subjects as property valuations for ad valorem taxes (taxes based on the value of real estate or personal property), the cancellation of homeowners' insurance policies, staffing requirements for home care services, and the reconstruction of facilities for cattle auctions.[83] Medical providers should be aware of this provision so that they can request waiver or suspension of requirements if necessary during a catastrophic event.

RECOMMENDATIONS FOR FURTHER RESEARCH

Legal issues encountered in catastrophic events are extremely dependent on who is the client and how that client may be affected by the event – either as a person or entity suffering loss, as a government seeking to protect the welfare of residents and businesses, or as a medical worker providing services on a contract or volunteer basis to assist those in need.

The kinds of legal issues encountered include "zero sum gain" situations where different individuals or entities seek to redistribute the cost or pain of the catastrophe by imposing liability so that negligent providers must pay the injured patient for the loss caused by their acts. This can include nonmonetary or regulatory issues, where those subject to regulatory requirements are simply trying to ensure that they do not run afoul of the law when their world has been disrupted by a catastrophic event.

To reduce ambiguity in the aftermath of a disaster, it is useful to clarify the rules prior to an event. It is harder to act confidently if liability is a concern. The knowledge that authorities will grant a waiver of a compliance rule when a disaster has rendered compliance much more difficult would improve a responder's ability to care for patients. A directive by the Uniform Law Commission to develop and then encourage legislative adoption of a Uniform Emergency Healthcare Practitioners Act is one example of a project that addresses these issues. Changing legislation may not be the most important challenge. The U.S. Centers for Disease Control and Prevention's Public Health Law Program convened a group of experts to develop a National Action Agenda for Public Health Legal Preparedness.[84] Although summit participants identified some areas in which new laws would be useful; they did not believe that developing new law was the first priority. Instead, they maintained that those who make, use, and are affected by law should become more familiar with the scope, substance, and application of existing laws.

Thus, in the United States and other nations, there may be adequate legal *authority* to grapple with public health emergencies. However, public health and medical personnel may have inadequate *understanding* of existing laws and how they can be applied in the unusual environment of a public health emergency. Furthermore, even in cases when providers do comprehend the statute, existing laws have not necessarily been enacted with the consideration for scenarios in which patient care needs massively exceed available medical and health resources, creating a scarce resource environment. Further work is needed to define an effective approach to these circumstances.[85,86]

Emergency managers strongly encourage the use of exercises, whether they are tabletop or full-scale drills. These simulations serve to test emergency plans, train emergency responders, and familiarize all organizations that will be involved in emergency response with the other organizations, governments, and businesses with whom they will work during a catastrophic event. In most of these exercises, relatively little attention is paid to the kind of legal issues that are important to the government response – let alone that by private and nonprofit organizations. Future research in the area of legal issues in disasters will be significantly advanced through the careful development of a Legal Issues Tabletop exercise.[87] Here, a potential public health emergency scenario is presented, and participants drawn from organizations that must respond determine what regulations and laws might interfere with providing medical care effectively. The result of the tabletop exercise would be the identification of legal obstacles that are as yet unresolved – and require further research.

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69. HSPD 5. Available at: http://www.whitehouse.gov/news/releases/2003/02/20030228–9.html.
70. HSPD 8. Available at: http://www.whitehouse.gov/news/releases/2003/12/20031217–6.html.
71. Public Health Security and Bioterrorism Preparedness and Response Act of 2002, Pub. L. No. 107–88, 116 Stat. 594; *see also* Pandemic Flu and All-Hazards Preparedness Act, Pub.L. No. 109–417.
72. FY 2007 budget allocates $3.393 billion state and local governments for disaster preparedness.
73. 42 USCA § 5122.
74. For example in FEMA Document 508–5, "Typed Resource Definitions, Health and Medical Resources (May 2005 – available

as of April 2007 at http://www.fema.gov/pdf/emergency/nims/508–5_health_medical_resources.pdf.)

75. P.L. 93–288, as amended, 42 USC §§ 5121–5206 and related authorities.

76. FEMA Recovery Policy 9524, available at http://www.fema.gov/government/grant/pa/9525_4.shtm.

77. Id.

78. 44 CFR Part 13, "Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments."

79. 44 CFR § 13.36.

80. Ga. Code Ann., § 38–3–51. In California the statute is even broader: it provides that the Governor may "commandeer or utilize any private property or *personnel* deemed by him necessary in carrying out his responsibilities and the state shall pay the reasonable value thereof." California Emergency Services Act, GC § 8572. The power granted to commandeer personnel is unusual in emergency management statutes, and the limitations on exercise of this authority are unclear.

81. E.g., HSPD 5, HSPD 8.

82. California Emergency Services Act, GC § 8571.

83. A. Bragg, "Experiencing the 2004 Florida Hurricanes: A Lawyers Perspective," in E. Abbott and O. Hetzel, A Legal Guide to Homeland Security and Emergency Management for State and Local Governments, (ABA Press 2005).

84. Journal of Law, Medicine, and Ethics, Supplement to Volume 36, available at http://www.aslme.org/cdc/.

85. Emile F. Chang MSC, Howard Backer MD, Tareg A. Bey MD, and Kristi L. Koenig MD (2008) "Maximizing Medical and Health Outcomes after a Catastrophic Disaster: Defining a New "Crisis Standard of Care," *Western Journal of Emergency Medicine*: Vol. 9: No. 3, Article 18. Available at: http://repositories.cdlib.org/uciem/westjem/vol9/iss3/art18. Accessed November 25, 2008.

86. "American Lawyers" Public Information Series; Community panflu preparedness: A checklist of key legal issues for healthcare providers; 2008 American Health Lawyers Association, pg. 20, footnote 45. Available at: www.healthlawyers.org/panfluchecklist. Accessed November 25, 2008.

87. A "Table Top" is so named because it does not try to recreate an emergency event by simulating the event and actually deploying response resources (ambulances, helicopters, doctors, nurses, and so forth), rather a scenario is presented to participants representing their organizations. These participants – perhaps while sitting around a table – think through and describe how they would respond to an event and interact with other organizations.

11

Syndromic Surveillance

Gary A. Roselle

OVERVIEW

Syndromic surveillance has been defined by the U.S. Centers for Disease Control and Prevention (CDC) as "the collection and analysis of health-related data that precede diagnoses or laboratory confirmation and signal with sufficient probability a case or an outbreak for further public health response." Based on its original definition, the purpose of syndromic surveillance would be to prevent morbidity and mortality by early identification of case clusters in which mitigation would affect the outcome of the disease's natural course. This original definition was designed for early event detection and became prominent in the public domain after the September 11, 2001 terrorist attacks in the United States and the subsequent anthrax illnesses and deaths.

With a heightened sense of urgency related to the so-called "war on terror," many systems were put into place within the United States for the protection of the public health. These included such diverse programs as vaccine initiatives (BioShield), static detectors located throughout large cities to identify specific organisms of interest in the air (BioWatch), and the beginning of a national syndromic surveillance system for early detection of outbreaks (BioSense). These three initiatives were designed for the following reasons, respectively: 1) prevention of disease if a terrorist attack occurred; 2) early identification of airborne pathogens during the asymptomatic phase of such disease; and 3) early identification of illness prior to definitive diagnosis that would be confirmed either by culture or laboratory tests. These government initiatives were complemented by independent, nonfederal syndromic surveillance systems that were designed primarily for early identification of naturally occurring illnesses but were adaptable for use in bioterrorism surveillance. Other countries, such as the United Kingdom,[1] Canada,[2] and Australia,[3] have also heightened the evaluation of syndromic surveillance systems for response to early detection of bioterrorism events. In addition, there are other syndromic surveillance initiatives in Europe[4–6] and Asia (e.g., Japan[7] and Taiwan[8]). These systems are largely based on surveillance of existing data, such as help line calls and emergency department visits. For such population-based reporting, several factors must be defined if the surveillance system is to be useful. The system must provide initial detection such as finding an event as early as possible. It must quantify the event by defining the number of people who are potentially ill and identifying the location for the source of infection with enough granularity to allow for specific intervention. In addition, it would be useful if the surveillance system incorporated other supportive data such as provider and laboratory testing, and permitted early, computer-based investigation of possible case clusters by using such items as patient demographics. At least in theory, this should allow for initial outbreak management, such as confirming existing cases and tracking new ones, and timely countermeasure administration such as isolation, antimicrobial prophylaxis, or vaccination. In addition, if maximal utilization of data is the goal, then bioterrorism surveillance systems should also identify naturally occurring outbreaks and case clusters, because this will be the most frequent use of the data on an ongoing basis.[9–17] For such data usage, there are multiple components of a surveillance system that should be defined prior to its implementation (Figure 11.1). Such questions as, "what is the population under surveillance?" "what is the time period for data collection?" and "what data will be collected and who provides it?" are essential components that should be decided in the planning phase. For personal data security purposes, the issue of information transfer and storage is absolutely critical. Some assortment of personal identifiers are mandatory even if only zip code, age, and sex are used. The issue of data analysis is also critical, particularly who will analyze the data, what methodology will be used and how often, and finally, how will the reports be disseminated, to whom, and by what method. Although all of these factors may appear to be self-evident, there are no accepted and universally available standards for syndromic surveillance that would make the answer to these questions simple. Added to these complexities would be the need for data validation, which may or may not be possible based on the need for reporting timeliness.

With an increased emphasis on surveillance for nonintentional events to augment the usefulness of expensive bioterrorism surveillance systems, the term "situational awareness" has moved from the military to the public health community. Thus,

SURVEILLANCE SYSTEMS
Components

- What is the population under surveillance?
- What is the time period of data collection?
- What information is collected?
- Who provides the surveillance information?
- How is the information transferred?
- How is the information stored?
- Who analyzes the data?
- How are the data analyzed and how often?
- How often are reports disseminated?
- To whom are reports distributed?
- How are the reports distributed?

Figure 11.1. Components of a surveillance system to be defined prior to use.

for a system to be fully operational, it should go beyond the possibility of early event detection and define the location, extent, and progression of disease clusters and outbreaks of many different types and at many different times. For this mission, it may be important to deal with a greater variety of data sources than traditional symptom syndromes. It may require more well-defined geographic locations for individuals (for example, a five-number zip code vs. a three-number zip code in the U.S.). More timely reporting that would approach real time may be necessary, meaning instantaneous transmission of any data point as soon as it is available with instantaneous analytic processing and report generation and distribution.

Last, the traditional use of symptoms for syndromic surveillance may not be adequate to accomplish all of these missions, including early event detection and situational awareness. A variety of other data sources have been suggested and investigated. Examples include over-the-counter medication sales, prescription drug purchases, number of phone calls to pediatricians' offices, absenteeism from schools or work, and ambulance emergency runs. This so-called "augmented syndromic surveillance" could allow for greater specificity of signals that define true clusters or outbreaks versus statistical anomalies that would otherwise require large increments of time by the public health authorities for investigation.[18–24]

CURRENT STATE OF THE ART

The concept of syndromic surveillance is relatively straightforward, although the proof of concept and/or value is yet to be shown. In its simplest terms, data that can be immediately obtained prior to definitive diagnostic testing (e.g., microbiology culture or laboratory serology) are transferred to a central repository. Examples of this type of data include healthcare diagnostic or procedural coding, such as International Classification of Diseases (ICD-10) or CPT5 codes, or chief complaints. After receipt at the repository, the data are parsed into groupings related to established syndromes, such as respiratory, neurological, or gastrointestinal. The philosophy of syndrome grouping such as this rests on the assumption that, although errors may be made in specific diagnostic or procedural codes or chief complaints, the general group of the codes should be correct and allows early analysis of data. In addition, even if ICD-10 or CPT-5 coding is not possible, natural language interpretation of chief complaints can be used with specific trigger words to allow assignment of a syndromic grouping. For identification of the possible spread of avian influenza, syndromic surveillance is considered an important component for early detection of avian flu infecting humans, primarily based on the use of the category of "influenza-like illness" or "respiratory" syndrome using the syndromic surveillance model.

Additional data can be added such as blood pressure or temperature to improve the predictive value of any signal derived from statistical analysis of the syndrome groupings. For instance, if evaluating traditional respiratory syndromes, the blood pressure of most patients arriving at a healthcare facility would be reasonably normal, even during cold and flu season. On the other hand, if an airborne anthrax attack were to occur, there may be a significant increase in patients with a respiratory syndrome, high fever, and very low blood pressure. A more robust response by the public health community may be required when confronting such a severe syndrome as defined by augmented syndromic surveillance.

There are multiple syndromic surveillance systems in use around the globe and even across the U.S. Often more than one is visible to regional public health entities for use as a stand-alone system or in conjunction with other local alerting systems, such as ambulance runs, to determine priorities for public health investigation and intervention. Syndromic surveillance contrasts with the "knowledgeable intermediary," the single clinician who, recognizing that a patient or group of patients arriving for care display an unusual set of signs or symptoms, activates public health authorities. Such knowledgeable intermediaries have been evident in the anthrax attack in the United States and the sarin gas attack in Tokyo. Syndromic surveillance is also different from standard reporting of notifiable diseases in that such disease reporting is often made after a diagnosis is confirmed such as hepatitis B, meningococcal meningitis, or tuberculosis. Although such reporting is important, it generally lacks the timeliness necessary for mitigation in the case of an intentional biological event. Syndromic surveillance, therefore, is a methodology designed to gain the advantage of earlier detection (by days) of a biological attack or other infectious illness. This may allow for earlier intervention to stop the spread of disease, rapid initiation of appropriate treatment for individuals affected, and, perhaps, by increasing such timeliness, increase the probability of apprehending the perpetrators of an intentional biological event.

Current state of the art in syndromic surveillance is a rapidly moving target. There are a multitude of surveillance systems available. One review of the literature identified 36 systems[25] and U.S. health departments alone have implemented syndromic surveillance systems in more than 100 sites since 2003.[15] This, coupled with the shift from early event detection to situational awareness, the development of large city systems individualized for specific geographic areas, and the creation of new technologies, necessitates using exemplar systems of syndromic surveillance in this discussion. In fact, for public health entities that are better resourced, multiple systems are often used simultaneously to differentiate true case clusters or outbreaks compared with anomalies identified by the syndromic surveillance system. Improving this signal-to-noise ratio allows for optimum use of public health resources for investigation and mitigation as

U. S. SURVEILLANCE SYSTEMS
Examples of

- National Electronic Disease Surveillance System (NEDSS)
  Centers for Disease Control and Prevention (CDC) and partners
- Epidemic Information Exchange (Epi-X)
  CDC, state/local health departments, federal agencies, military
- Rapid Syndromic Validation Project (RSVP)
  Some local, public and private institutions in New Mexico
- Real-time Outbreak and Disease Surveillance (RODS)
  Western Pennsylvania (13 counties, 14 hospitals, 10 emergency Departments)
- Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE)
  Department of Defense (DoD)
- BioSense
  CDC, state/local health departments, DoD, Department of Veterans Affairs (VA)

Figure 11.2. Selected surveillance systems from the United States.

needed. Figure 11.2 gives a brief listing of several U.S. surveillance systems, past and present, using a variety of methodologies to achieve the previously stated goals.

Surveillance Systems

National Electronic Disease Surveillance System

Although not a true syndromic surveillance system, National Electronic Disease Surveillance System is a U.S. CDC initiative designed to create standards to ensure uniform data utilization. This includes: data architecture; the user interface; information systems software architecture; tools for interpretation, analysis and dissemination of data; and secure data transfer. In fact, there are many surveillance systems in place in U.S. state health departments and the CDC using varied tools that are not interoperable. The plan is to establish standards and apply them to all the surveillance systems. This would allow electronic transfer of appropriate information from clinical information systems in the healthcare industry to public health entities. This would reduce provider burden in the provision of information, and enhance both the timeliness and quality of data delivery. It would also allow better integration of current datasets by those responsible for public health. This is an extremely complex operation, but, such interoperability will be critical as surveillance systems expand. Gathering information from single or multiple sources for interpretation will be critical because the large volume of information may facilitate statistical analysis and provide better data for the end user.

Global Outbreak and Alert Response Network

The World Health Organization (WHO) is in a unique position to manage international outbreaks of all sorts. Although this may not be syndromic surveillance, sources of data supervised by the WHO do include a variety of information systems from countries all over the world, each of which uses different surveillance systems, different reporting methodologies, and different degrees of voluntary reporting. All of this reporting is influenced by global resources, government oversight and political considerations, and includes differences in endemic diseases that may influence the data input into surveillance systems. Although there are multiple networks and institutions around the world, the WHO infrastructure is designed to provide an operational framework to link the expertise and skills needed to keep the international community constantly alert to the threat of outbreaks. Based on a management system in Geneva and regional hubs around the world, this so-called system of systems allows for general monitoring of outbreaks internationally. As a result of the global economy and the dramatic increase in international travel, outbreaks in Asia or South America can rapidly spread around the world. Therefore, timely data are important for national security and local health department information needs. In the absence of data uniformity, however, any information from such a network of networks must be analyzed carefully for validity and value.

Rapid Syndromic Validation Project

The Rapid Syndromic Validation Project was developed and tested by several organizations within the United States, including Sandia National Laboratories, the University of New Mexico Department of Emergency Medicine, and the New Mexico Department of Health. This system is a model that depends on information from practitioners on specific syndromes of interest. Clinicians enter data into a stand-alone, dedicated system. This provides two-way communication between clinicians and public health authorities. There are advantages and disadvantages. The main advantage of the system is that for syndromes of specific interest, the data should be valid and useful. The provider has defined the patient's illness to be of sufficient importance that the time required to transmit data to a computer repository is worth the effort. This should dramatically increase the signal-to-noise ratio and provide important data on specified syndromes. On the other hand, the workload in providing this information is a disincentive to reporting, and bias from uneven data collection and underreporting may be seen. Also, only syndromes of interest will be reported, rather than use of a statistical methodology to define what syndromes are occurring at greater than expected frequency. Such a system can be very responsive, however, to the need for situational awareness involving a single syndrome that requires reporting by clinicians in a timely manner.

Real-time Outbreak and Disease Surveillance

The Center for Biomedical Informatics at the University of Pittsburgh developed a system known as Real-time Outbreak and Disease Surveillance (RODS). It originated as a syndromic surveillance system that included several symptom groups based on chief complaints. RODS developed the use of natural language processing techniques to define syndromes from free text chief complaints because of delays in coding emergency department or outpatient visits. In addition, RODS has been augmented using such information as laboratory test results, radiology tests ordered, and nontraditional data sources such as over-the-counter drug sales, call centers, and absenteeism. Emergency managers used this system for the Winter Olympics in Salt Lake City, Utah, and it has many advocates. Of interest is the use of augmented data in addition to symptom data. Particularly during the 1999 influenza season, public health authorities noted that the earliest predictor of the increase in influenza was elevated over-the-counter sales of cough and cold medicines. This, at the very least, showed the concept that augmented syndromic surveillance might be an improvement over the more traditional symptom-based methodology alone. Extensive work has been done on the use of the natural language processor with good validity testing, although opportunities for further improvement exist.[26,27] This may not be necessary if appropriate coding is done contemporaneous with patient visits for transmission to the central data repository.

Epi-X

Epi-X is a U.S. CDC program that is a secure, web-based communication network for public health investigation and response. It provides timely information, reports, alerts, and discussions about terrorist events, toxic exposures, disease outbreaks, and other public health events. When U. S. public health officials post reports to Epi-X (or when cross-border surveillance information is received from Canadian or Mexican officials), the information is shared rapidly with public health officials across many U.S. states and jurisdictions. Information is encrypted and secured, an important aspect to maintain data security. Access is limited to specific public health officials. This is a data entry information system with limited access that can be very useful for early reporting of real and suspected clusters and outbreaks of disease across the country. It does involve provider labor in that it requires information be sent in a nonautomated manner to a web-based system. It has the advantage of being a secure system to public health officials. However, this limited access is also a disadvantage in that the information is not widely available in the public domain.

Electronic Surveillance System for the Early Notification of Community-based Epidemics

The Electronic Surveillance System for the Early Notification of Community-based Epidemics is a component of the Defense Global Emerging Infections System with programming from the Johns Hopkins Applied Physics Laboratory.[28,29] This was initially a fairly pure syndromic surveillance system generally defined by ICD-9-CM coding with collapse of symptom groups into syndromes such as gastrointestinal, respiratory, neurological, coma, and others. This is in use by the U.S. military services, and also is available at the Infectious Diseases Program Office of the Veterans Health Administration. This system uses a defined set of mathematical algorithms and a "stop light" methodology with red, yellow and white alert levels for individual facilities. It also allows for multiple onionlike layers of data that can be linked to the individual provider. Such linkage can be important if a group of diagnoses suddenly becomes identified as "red" based on single provider information. It is possible that these data may not define a cluster of true cases but rather coding variability by a single individual. In fact, the goal of such data layering is to allow review of a putative cluster of cases electronically to determine whether further action is required. As with most syndromic surveillance algorithms, the use of multiple statistical testing of the dataset generally assures some positive results by chance alone.

Neural Network

A neural network is designed as a system that is trainable to "understand" mathematically data input over time. It uses complex mathematical formulations to define aberrations based on previous complex and apparently erratic behavior. The computer reviews all historical data and defines any aberration based on previous "learning." It looks at increased numbers based on a statistical model without an a priori definition. Although the user selects numerous attributes of a dataset that might help characterize the behavior of interest, the automated detection processor trains on the specific data to look for anomalies. A major advantage of the system is the definition of items such as days of the week, seasons of the year, weekends, and other selected datasets that may have influence on anomaly detection. This is particularly important in healthcare where seasonal variation and weekday variation may be prominent. Such processing also allows channeling of very large datasets into smaller streams of digestible information. Although there is valid proof of concept for this type of data analysis when examining such items as harbor or motor vehicle traffic, medical proof of concept is sparse.

Using information from a Department of Veterans Affairs dataset, a proprietary neural network system tabulated infectious diseases data involving 10 pathogens and 10 variables in greater than 187,000 records. Specific spikes in data were found for hepatitis C antibody when the Veterans Health Administration was conducting a Hepatitis C Surveillance Day. Seasonal variation in diagnosis of *Escherichia coli* O157 was also determined. This methodology has not been adequately validity-tested but is another example of mathematical modeling for large datasets that involve organisms and other computerized data.

BioSense

BioSense was initially designed as an early event detection methodology assessing and analyzing existing diagnostic health data. It has been extended to ongoing situation awareness, and the U.S. CDC uses BioSense as the designated agency to oversee national biosurveillance data related to human illness. In its initial phase, BioSense data reported to the CDC were primarily ICD-9-CM and CPT-4 codes for outpatient and emergency department encounters. Most of these data were received from the Department of Veterans Affairs and the Department of Defense. In addition, demographic information was also transmitted, particularly related to geography, age, sex, and other items as available. For each patient there was a unique identifier assigned, although this was translatable back to an individual patient only by the sending agency and not by the CDC. This maintained patient privacy while allowing for the CDC to perform appropriate sorting and analysis. Once received, the diagnostic and procedure codes were collapsed into as set of syndromes (such as gastrointestinal, respiratory, or neurological) for analysis. Both statistical analysis and geographic mapping were available. As time progressed, increased timeliness of data transmission as well as expansion to more complete datasets became a major initiative at the CDC. Specifically, such items as vital signs and laboratory tests gained higher interest in order to provide added value to the basic datasets.

Data Integration

To add further value to any syndromic surveillance system, the addition of nonhuman data might also be useful. For instance, data on water systems nationally or internationally, data on unusual illness or deaths in animals,[30] or data from unusual occurrences regarding plants or food crops might also increase the positive predictive value of any clusters of human cases found by syndromic surveillance.

The complexity, however, of integrating systems that are dramatically diverse, such as those involving plants, animals, BioWatch sensors, and human data is daunting. In addition to the different types of data noted, there is also the question of differences in information technology architecture among the variety of datasets or between countries. Although there is variable architecture in human datasets,[31–33] this is highlighted when automated data systems are in place regarding plants, animals, or other more technical datasets such as BioWatch sensors. The information technology architecture of the originating datasets will be important if such large amounts of diverse data are to be electronically delivered, sorted, initially analyzed, and outliers defined. Developing a specific platform architecture that has been clearly defined for all of these diverse datasets remains a challenge.

At the time of this writing, the U.S. government is developing the National Biosurveillance Integration System that is designed to track and integrate data it will receive electronically from multiple agencies. Such agencies include the CDC, the Environmental Protection Agency, the Department of Agriculture, and many other national and international sources. It will use these data to generate reports on the state of risk to the public health. In addition to the difficult task of electronic data interpretation, the National Biosurveillance Integration System will also require human analysts to integrate the algorithmic quantifiable data and the more "fuzzy" threat data obtained from a variety of intelligence sources, such as that from U.S. Embassies and other electronic surveillance traffic. Although this is ground breaking technology, it will take significant time to fully implement and an even longer period to determine whether it is effective.

Data Analysis

There are a variety of mathematical data analysis formulae in place in the extant syndromic surveillance systems.[34–48] These include everything from cumulative sum scores, smart scores, and anomaly detection algorithms to trends, proportions, expected to observe frequency, standard deviations, and other more descriptive statistics. At this time, system designers have not demonstrated that any of the statistical methodologies are definitively and clearly superior to any of the others, or that they define specifically which outliers are critical for investigation.

With limited resources provided to the public health community, the critical element in a syndromic surveillance system is the ability to define which outliers are sufficiently important to generate an on-the-ground investigation and determine whether a biological event has occurred. This so-called signal-to-noise ratio is one manner of defining the validity of the syndromic surveillance system. If alerts are generated very frequently with little or no outcomes from laborious investigation, the system will go unused and thus have little value. If, on the other hand, the surveillance system is correct every time it defines an abnormal signal, then it is likely that such extreme specificity will not allow for sufficient sensitivity. It may allow other critical signals to go undetected at some unknown rate. Although mathematicians, statisticians and modelers are critical to the process of syndromic surveillance analysis, the most essential element will be in the hands of the public health and epidemiologic community where the signal-to-noise ratio will truly be defined.

Value

While inconclusive, there has been some evidence validating syndromic surveillance, implying these systems have value. This includes early surveillance of infectious syndromes and trauma after the September 11, 2001 attack in New York City. Such investigations yielded positive findings for certain defined infectious syndromes of interest such as exacerbation of underlying respiratory conditions and diarrhea/gastroenteritis.[49,50] Automated syndromic surveillance was also in place for the 2002 Winter Olympics in Salt Lake City, Utah. Although over 100,000 acute care encounters were monitored, no outbreaks of public health significance were detected. This effort does show, however, that an automated syndromic surveillance system can be implemented in a setting where thousands of persons gather for a specific event.[51] At a large public gathering of more than 40,000 persons in the U.S. state of Virginia, public health authorities conducted surveillance for early detection of disease outbreaks.[52] Groups of persons with gastrointestinal disease were found; the system also detected noninfectious events such as those related to heat and physical injury. At the Rugby World Cup in Sydney, Australia, an automated public health surveillance system was also used.[53] Although no outbreaks were identified, the system provided situational awareness without an increase in workload for clinicians. All of these efforts underscore the utility of public health screening and surveillance at mass gatherings where definitive diagnoses may be delayed. In New York City, diarrheal illness was detected through syndrome surveillance after the power outage of August 2003.[54] With regard to influenza-like illness, syndromic surveillance has been used in both eastern Virginia and Connecticut. It appears that the syndromic surveillance data were in alignment with the influenza season in both settings.[55,56]

These are promising examples, but the value of data obtained from any syndromic surveillance system compared to that obtained from a knowledgeable intermediary or the standard public health reporting systems has not been clearly elucidated. Many scholarly articles address this issue, but it is not clear that any have defined a specific, documentable role in early event detection for syndromic surveillance. This should not be construed to mean that early event detection is unimportant. Rather, it means it has not as of yet definitively proven itself to be effective. This may be related to inadequate data sources, lack of proper specific items for data transmission, the need for improvement of mathematical algorithms, or the fact that public health authorities lack awareness of the case clusters that may be found by such surveillance systems.

Difficulties in proving effectiveness of syndromic surveillance must be examined in the context of the system's initial development challenges. For instance, it is not clear, based on scientific research, which variables are necessary in an expanded syndromic surveillance system to identify abnormal signals and increase the signal-to-noise ratio. A second issue is the accuracy of the data provided to the analysts. It is well known that ICD-9-CM coding is extraordinarily variable. However, this may not be critical based on the large number of cases that would be submitted for analysis and the fact that groups of ICD-9-CM codes are collapsed into syndromes rather than as stand alone diagnoses. Another issue is the population for which syndromic surveillance data are provided. Are the patients for whom data are transmitted to the repository appropriate for surveillance? For instance, if most of the risk is generated in large metropolitan areas, are all such groups reporting into a national biosurveillance system such as BioSense? Do the data include information from the immunosuppressed populations because they may be the first to become ill if a biological event occurs? Does the system for data transmission, analysis, and feedback reporting provide an adequate timeframe to allow mitigation if an unusual occurrence is found?

These issues, as well as others, are unresolved at the time of this writing, likely based on the short timeframe during which national biological surveillance has been emphasized. In addition, because intentional biological events are extremely rare, proof of value for the system will likely be made from naturally occurring events such as influenza epidemics or gastrointestinal illness. Although these are important public health issues, they may lend themselves more to the knowledgeable intermediary reporting system than syndromic surveillance or standard public health reporting related to specific diagnoses.

It is, therefore, logical to assume that the syndromic surveillance community is in its knowledge acquisition phase to determine the methodology, value, and optimal use of syndromic surveillance data. Although data integration and analytic systems are being developed, it is critical that program evaluation proceed with sufficient vigor to answer these difficult questions in a quantifiable, scientific manner.[57–64]

RECOMMENDATIONS FOR FURTHER RESEARCH

The future of syndromic surveillance will rest entirely on evidence of value over time. Although enthusiasm will remain high for some indeterminate period, only a system with proven value will justify the effort and expense needed for long term, syndromic surveillance. Thus, the need for carefully constructed research on a variety of fronts is necessary. These should include, but are not limited to, assessing which variables are most critical for optimizing signal-to-noise ratios. In fact, weighted variables may be necessary because some data points may be more critical than others to identify true clusters or outbreaks. Currently, most of the variables used in syndromic surveillance are chosen based on the convenience of electronic reporting for those inputting data. For example, electronic emergency department chief complaints may be immediately available, but discharge diagnoses may be more accurate in determining the appropriate syndrome category. Future systems may need to integrate both types of data for timely and accurate analysis.[65] Although this may be necessary in the short term, sustainability is questionable without evidence of efficacy. Another issue that requires careful investigation is the validity of transmitted data, particularly because electronic transmission typically proceeds without human involvement to determine accuracy. Furthermore, it is not only important to know the accuracy of the data on an objective level, but also to know if the expected inaccuracies of certain electronic data such as ICD-10-CM coding will have an effect on outcome. Although inaccuracies may exist in ICD-10-CM coding, the ability to collapse codes into syndrome groups may obviate the added expense of improving accuracy at the individual patient level.

In addition to questions regarding system efficacy and validity, the technology that supports mathematical data analysis remains unproven as well. Approaches such as cumulative sums, smart scores, standard deviations, rolling averages, and anomaly detection algorithms are just a few of the methodologies that have been used for syndromic surveillance. However, there are currently insufficient data to define which of these systems provides the best information to protect the public health, provide early event detection, or enhance situational awareness. Clearly, this will be an iterative process requiring a collaborative effort by those in the mathematical, clinical, infectious diseases, and public health communities. These groups must perform the necessary applied and theoretical research that will allow the best use of data gathered by these systems.

Although most of the design and funding for syndromic surveillance is currently based upon early event detection and situational awareness for intentional biological events, proof of value for detection of nonbioterrorism related outbreaks will be necessary. This is particularly true when globalization increases the number of diseases moving from continent to continent and newly identified emerging infectious diseases (EIDs) appear in human populations (see Chapter 6). The number of EIDs per year is difficult to discern, however the emergence of the severe acute respiratory syndrome virus in 2002 exemplifies the speed with which global spread of a new pathogen can occur. The ultimate value of syndromic surveillance rests on its ability to define illness prior to a definitive diagnosis. This is particularly important in the case of EIDs, when diagnosis of disease may be delayed by uncharacterized etiologies. Syndromic surveillance used during the severe acute respiratory syndrome pandemic has revealed challenges in the implementation of these systems, including data acquisition and integration,[66] and indicates that major research efforts are needed.

Syndromic surveillance is necessary because of difficulty establishing a diagnosis in a timely manner for human infectious diseases. Although these systems can presumably be useful for inhibiting the global spread of new pathogens, this lack of rapid diagnosis certainly is not ideal. It is therefore critical that a major research effort be sustained to develop systems for rapid diagnosis of infectious diseases.[67] At best, syndromic surveillance is a temporizing measure that uses surrogate information in place of diagnostic data because such data are not available in a timely manner. This affects both the public's health as well as an individual's health because treatment is often based on poor information prior to a definitive diagnosis.

There are at least three types of tests that show promise for rapid diagnoses. The first is the specific test for a single entity. This is exemplified by rapid diagnostic testing for influenza and rapid polymerase chain reaction testing for methicillin-resistant *Staphylococcus aureus*. Although there may be issues regarding the sensitivity and specificity of the rapid diagnostic test for influenza, it does represent a point-of-care test that will identify a specific disease that can spread quickly through the population. It is important both for the individual patient with regard to therapy, and for the public health, because public health authorities may need to implement broader mitigation strategies for an influenza outbreak. Rapid polymerase chain reaction testing for single organisms, such as methicillin-resistant *S. aureus*, can be important for individual patients as well as for identification of case clusters. Although methicillin-resistant *S. aureus* may not be the most critical organism in screening for an intentional biological event, this technology represents an important tool for detecting a variety of organisms. Intense research is needed to define such testing methodologies, to validate the results, and to define clearly the sensitivity and specificity of the tests for individual patients and public health use.

A second essential area for research is rapid diagnostic testing for clinical syndromes. For instance, if patients have a set of symptoms indicating a respiratory syndrome, it might be more useful for surveillance purposes to rapidly establish a diagnosis of each person's illness. Optimally this would require a single sample from the patient (such as sputum or swab) that could be immediately tested for a large array of pathogens including viruses, bacteria and fungi. These microarray tests would be based on components of the organisms themselves. Advantages of this type of analysis include 1) the large number of microbes (thousands) that could be detected by a single assay, 2) the ability to use various patient samples for testing (e.g., blood, urine, stool, and tissue samples), 3) providing an unbiased disease assessment independent of provider variability, and 4) establishing a disease diagnosis independent of detecting the host response, such as antibody production. However, arrays that include both microbial and host–response probes can also be used to identify disease etiologies. With widespread use, such assays could be relatively inexpensive, developed for a variety of syndrome types, and be of immediate benefit to the patient as well as to public health for surveillance purposes. Further advances in sample preparation and analytic detection can potentially lead to point-of-care testing using microarrays for the rapid diagnosis of infectious diseases outside the hospital or laboratory setting. Research into the feasibility, usability, and validity of diagnostic microarray testing is also critical. Based on the results of such studies, further rapid testing could be developed to determine the presence of clinically and epidemiologically important markers related to specific organisms, such as antibiotic resistance genes, thereby improving both individual and public health. This approach may not always allow for diagnosis of newly emerging pathogens, but it would highlight a group of patients with a specific syndrome for which an array of diseases has been ruled out, and therefore, may require attention by public health entities.

A third critical area for future research is diagnostic testing to detect cases in the postexposure, presymptomatic stage of an infectious disease (i.e., the incubation period). Generally, this utilizes a single diagnostic array to examine thousands of host markers such as proteins, peptides, or nucleic acids, usually from a blood or tissue sample. This can be used to define specific results primarily based on the presence or absence of individual markers that identify a specific illness by using population-based information or previous samples from a single patient. Anomalies may represent divergence from a normal state of health or a specific illness. Such a finding could lead to a diagnosis or to specific testing that would establish a definitive diagnosis. These tests may be of particular value if there is evidence of disease spread in the population, a positive finding from a sensor such as a Biowatch monitor, or evidence of unusual plant or animal illness. Although this technology may seem futuristic and less well defined, it is a critical area for research, particularly as new microbes are discovered and advanced biotechnology becomes available to the bioterrorist community.

With all of these research endeavors, the key element for success will not be cost, workload, or political intent. The key element will be value at the individual, public health, or national and international security levels. Sustainability will be dependent on the value of any of these technologies, to prevent and mitigate disease or improve individual and public health. For existing systems, it is often unclear what public health actions should be taken when the technology suggests an emerging infectious disease or bioterrorism event. Detection must be coupled with the initiation of appropriate behaviors that reduce morbidity and mortality. Research and program evaluation will be the hallmarks of this effort.

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12

Triage

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OVERVIEW

Introduction

One of the hallmarks of a disaster is that the immediate needs of the affected population exceed currently available resources. Intuitively, this leads to the question of how limited resources can be used to optimize patient outcomes. Triage is the allocation of limited resources during a disaster. Although the concept of triage is applicable to all resources, the most commonly discussed and most studied application is to patient care. In this context triage is the rapid evaluation of patients to determine the most appropriate level of care and treatment, given the limited resources at hand. For the remainder of this chapter, triage shall refer specifically to identifying the appropriate level of care for patients during a mass casualty incident.

Although researchers have investigated this type of triage more extensively than the triage of equipment or other resources, even patient triage is not well studied. As with many topics encompassed by disaster medical sciences, it is extremely difficult to conduct randomized, controlled trials during an actual event; the use of other comparative study designs is also challenging. As a consequence, there is no high-quality evidence indicating which triage systems provide optimal resource utilization or maximal outcomes, or even whether existing triage systems are of any value in managing the scene, optimizing resource allocation among patients, or ensuring optimum outcomes. The majority of studies on disaster triage focus on how well triage systems can be applied, how well they work in drills, or how they can be modified for specific scenarios. These studies are usually conducted with simulated scenarios, and often performed on paper rather than using real or simulated victims.[1–3] Studies and reports describing the performance of triage systems during actual disasters are scarce and anecdotal; comparative and outcomes studies are lacking, although a few retrospective analyses have been conducted on individual patients comparing outcomes using different triage systems.[4,5] Even some of the basic assumptions underlying the use of triage in mass casualty situations have not been tested. For example, there is no solid evidence to support the claim that triage systems provide improved outcomes related to morbidity or mortality when compared with randomly assigned or "first come, first served" methods. Furthermore, it is not clear that various triage levels closely correlate with severity of illness or injury. These assumptions are, however, commonly accepted a priori, and provide a base from which a closer evaluation of triage systems can begin. Accordingly, this chapter will describe the existing triage systems but will be unable to recommend one system be used over the others due to the lack of scientific data.

History of Mass Casualty Triage

It is generally accepted that triage was invented during the Napoleonic Wars by Dominique Jean Larrey, surgeon-in-chief of Napoleon's army from 1797–1815. Although the concept of "inventing" resource allocation is dubious, Larrey can be credited with codifying a system for sorting battle casualties into categories based on urgency of evaluation. The word triage is derived from the French verb *trier*, meaning "to sort."

Following this initial development of a casualty-sorting system, triage continued to evolve as a consequence of wartime experience for over a century. The first civilian triage systems were developed in the latter half of the twentieth century. In modern times, approximately 200 years after Larrey's initial work in the field, several dozen systems exist worldwide, using more than 120 different types of triage labels and tools.

STATE OF THE ART

Vignette

On December 6, 2006 a manufacturing plant in Milwaukee, Wisconsin exploded due to a propane leak. Approximately 100 people worked in the affected building, which had begun evacuation just prior to the explosion. In the end, three workers died and dozens required emergency care. This industrial site had a large oxygen tank on the scene, making secondary explosion a concern. Furthermore, the plant used a significant number of chemicals, making the possibility of chemical contamination and the need for patient decontamination an additional consideration.

> "When I arrived at the scene of the explosion there were a couple of hundred people walking towards us looking

shocked and dismayed over what had happened. The best analogy I can give is that it was like a scene from a zombie movie as these people moved towards us. We were standing at the only exit from the factory compound and people were coming from all over the facility – narrowing into a single stream as they moved through the gate. While the majority were not injured, we could visually identify many with obvious injuries within the group of evacuees. Our first goal was to immediately separate the injured from the group so that we could triage them to transport units and receiving facilities. The most unexpected aspect of this event was that unlike many of the MCI drills I have witnessed, all of our patients were ambulatory with the challenge being not to miss any patients as they were self-evacuating. The final patient count was 44, with two ending up in intensive care. None of the victims were lying on the ground waiting for us to assess them like they are during training. They moved towards us in a wave, asking for directions and aid." – Battalion Chief Pepie Du De Voire, Milwaukee Fire Department –EMS Operations Chief

The preceding example illustrates several difficulties with the implementation and evaluation of mass casualty triage systems. First, actual disasters and mass casualty events are often quite different from simulations and training exercises. Protocols developed without field testing may be difficult to apply or seem less relevant in a field situation. Second, the possibility of secondary events (such as additional explosions) or contamination may complicate a triage situation. Third, the need to rapidly evaluate a large number of persons to promptly identify those most in need of immediate care almost certainly leads to a baseline level of inaccuracy in triage; there is no evidence to define an "acceptable miss rate," which is likely both situation and agency dependent. Even the outcomes that would define accurate triage have not been identified. With these caveats in mind, individual triage systems are examined in more detail.

Triage Systems

Despite the large number of triage systems extant throughout the world, most have several features in common. A majority of these systems use a "walking filter" to identify quickly less severely injured patients and remove them from the immediate disaster zone; these patients are usually tagged "minor" or "green." Patients not expected to survive are usually tagged "expectant," "morgue," or "black." Residual patients are then categorized into the remaining triage levels. The use of color codes, generally black, red, yellow, and green to identify differing severity levels, is common. The primary differences between systems rest in how patients are triaged to each level. Additionally, some systems use additional levels, colors, or classifications to further stratify victims. To date, no system has been shown conclusively to be better than any other in terms of patient outcomes, scene management, or resource allocation. Little information is publicly available about some triage systems known to be in use worldwide, particularly in Europe. What follows is a description of the triage systems that had sufficient available information to describe and discuss. These systems include START (Simple Triage and Rapid Treatment), Homebush Triage Standard, CareFlight Triage, Triage Sieve, the Sacco Triage Method, the CESIRA Protocol, MASS Triage, and Military/NATO Triage. Included is also a brief discussion of the SALT system, which has not been widely adopted at the time of this writing. A separate discussion of the secondary triage systems SAVE and Triage Sort, as well as the pediatric-specific systems, JumpSTART and the Pediatric Triage Tape is then provided.

START

Simple Triage and Rapid Treatment (START) is the most commonly used triage system for handling multicasualty emergencies in the United States and has been adopted by components of the federal government.[6] START is also used in Canada, Saudi Arabia, and parts of Australia and Israel. The START system was developed by the Newport Beach Fire and Marine Department and Hoag Hospital in Orange County, California in the early 1980s and is based on the NATO triage classification system.

START uses physiological parameters and is designed so that the healthcare provide can complete a patient assessment within 60 seconds or less and identify patients with immediate medical needs. Each patient is assessed and assigned to one of four color categories depending on the injuries (Table 12.1). A visible triage tag or ribbon is placed on each victim identifying the patient's category for rescuers who will collect, treat, and/or transport. START is based on the ability to obey commands, respiratory rate, and capillary refill (or radial pulse in the modified version as described by Schultz and Koenig[11,20]).

Following a mass casualty incident, START triage begins with directing victims who are ambulatory to move to a safe area. These patients are tagged as "minor" by using a green label and, typically, are not more thoroughly assessed until the remaining, more seriously injured patients have been treated. Triage continues in a systematic manner for the remaining victims. Triage categorization is based on three observations: respiration, perfusion (or pulse in the modified system), and mental status. The mnemonic, "RPM," has been created as a memory aid. Patients with no spontaneous respirations receive airway repositioning; if they remain apneic, they are tagged "deceased" by using a black label and receive no further interventions. Patients with respirations greater than 30 breaths per minute, capillary refill longer than 2 seconds (or lack of a radial pulse in the modified system), or unable to follow simple commands are tagged "immediate"

Table 12.1

START Triage

RED IMMEDIATE Priority I	Any of the following: Respirations >30 breaths/min No palpable radial pulse (or, in some systems, capillary refill time >2 s) Not able to follow commands
YELLOW DELAYED Priority II	Nonambulatory patients who do not meet black or red criteria
GREEN MINOR Priority III	Able to walk to a designated safe area for further assessment
BLACK DECEASED Priority IV	Not breathing despite one attempt to open the airway

by using a red label. The remaining patients are tagged "delayed" by using a yellow label.

Some areas use variations of the START triage system. For example, the Israeli triage system uses two additional categories and colors: blue for children, and gray for combined injuries such as chemical contamination and physical trauma.[7] Additionally, most agencies use a "no radial pulse" (modified system) criterion rather than "capillary refill time more than 2 seconds" to compensate for difficulties in determining capillary refill time in cold or dark conditions; few agencies continue to use capillary refill for determination of circulatory status.

START only allows for two interventions to be made during the triage process: direct pressure for bleeding control (preferably applied by a bystander or another victim to keep the rescuer free for further triage), and basic airway opening maneuvers. It is also recommended that repeated assessments are made as often as possible since patient conditions may change.

Use of START triage has been described for two terrorist incidents: the attack on the World Trade Center in New York in 2001, and the bombing of the Alfred P. Murrah Federal Building in Oklahoma City in 1995.[8–10] Use of START for two U.S. disasters, Hurricane Andrew in 1992 and the Northridge earthquake in 1994, has also been described.[11] There are, however, no data in these descriptive papers regarding whether the system was used correctly or improved outcomes for patients in any of these events; a description of the 2001 World Trade Center attacks notes limitations of START due to concerns regarding personnel and structural safety, but does not detail triage accuracy for the few rescued patients.[8]

Homebush Triage Standard

The Homebush Triage Standard methodology was developed in Australia in 1999 as an attempt to unify varying triage protocols across the country.[12] It is based on the START and SAVE[20] (Secondary Assessment of Victim Endpoint) triage systems. It includes a fifth triage category called "dying," which is given a white label. This category is meant to separate the dead (labeled black) from the dying, so that comfort care can be provided to those patients who are dying in an area where they are not surrounded by the deceased. The red category is assigned to patients who have no palpable radial pulse, are unable to follow commands, or have respirations more than 30 breaths per minute. Nonurgent and urgent patients are determined identically to START's minor and delayed patients, respectively. This system also uses geographical location rather than triage tags to indicate the patients' conditions. In other words, patients are physically moved to the "level white" area, rather than placing a tag on their bodies to indicate their triage assignments. In addition to a color, each category has a designated standard phonetic alphabet code (e.g., alpha, bravo, charlie, delta, and echo) to facilitate radio communications (Table 12.2). Finally, in addition to primary triage, this system includes a secondary patient assessment to evaluate the extent of injuries and consider them in light of the available resources. This secondary system is used to prioritize order of transport to the hospital.

Use of the Homebush triage system was documented in the Bali bombing on October 12, 2002, but again, only descriptive information is provided, with no data regarding triage accuracy or effects on any particular outcomes.[13]

Table 12.2

Homebush Triage Standard

RED Immediate	ALPHA	Any of the following: Respirations > 30 breaths/min No palpable radial pulse Not able to follow commands
YELLOW Urgent	BRAVO	Nonambulatory patients who do not meet black, white, or red criteria
GREEN Nonurgent	CHARLIE	Able to walk to a designated safe area for further assessment.
WHITE Dying	DELTA	Dying patients; may have a pulse, but no spontaneous respirations
BLACK Dead	ECHO	Not breathing despite one attempt to open the airway

CareFlight Triage

The CareFlight system is a triage tool used in parts of Australia. Presence of breathing, level of consciousness, and presence of radial pulse determine the triage priority. This system is similar to START, with the notable exceptions that respiratory rate is not evaluated in CareFlight and that assessment of mental status (ability to follow commands) is done prior to assessment of circulation. CareFlight also uses a four-color system to identify patients who should be triaged as unsalvageable, immediate, urgent, and delayed (Table 12.3). A retrospective 2001 study by Garner et al., compared START, modified START, and Triage Sieve with CareFlight and determined CareFlight to be more specific for critical injury (as defined by the modified Baxt criteria) and faster to administer.[5] This difference was minimal, however; the difference between the upper limit of the 95% CI for specificity of the modified START system (using radial pulse) and the lower limit of that for the CareFlight being only 1%. Although the Triage Sieve was significantly less sensitive (with roughly equivalent specificity) for critical injury in this study, some have noted that failure to include the Triage Sort (the secondary triage system that is meant to follow the Triage Sieve) as part of this algorithm may limit the applicability of these results to actual disasters.

Triage Sieve

Triage Sieve has been widely adopted in the United Kingdom, parts of Europe, and parts of Australia, and is accepted by NATO.

Table 12.3

CareFlight Triage

RED Immediate	Any of the following: Not able to follow commands No palpable radial pulse
YELLOW Urgent	Nonambulatory patients who do not meet black or red criteria
GREEN Delayed	Able to walk to a designated safe area for further assessment
BLACK Unsalvageable	Not breathing despite one attempt to open the airway

Courtesy of NRMA CareFlight.

Table 12.4

Triage Sieve

Priority I Immediate	Any of the following: Respirations <10 or >29 breaths/min Capillary refill time >2 s OR pulse >120 beats/min
Priority II Urgent	Nonambulatory patients who do not meet dead or immediate criteria
Priority III Delayed	Able to walk to a designated safe area for further assessment
Priority IV Dead	Not breathing despite one attempt to open the airway

Table 12.5

CESIRA Protocol

Red	Coscienza	Unconscious
	Emorragie	Hemorrhaging
	Shock	Shock
	Insufficienza respiratia	Insufficient respiration
Yellow	Rotture ossee	Broken bones
	Altro	Other injuries
Green		Walking

Triage Sieve is similar to START in that a preliminary walking filter is followed by the use of respiratory rate and capillary refill or heart rate to classify patients into triage categories. Patients able to walk are classified as "delayed" priority III; patients who do not breathe following an attempt to open the airway are classified "dead" priority IV; and patients with a respiratory rate of less than 10 or more than 29 breaths per minute, capillary refill time of more than 2 seconds, or heart rate of more than 120 beats per minute are classified "immediate" priority I. All other patients are considered "urgent" priority II. Triage Sieve does not measure level of consciousness (Table 12.4).

Use of the Triage Sieve was documented in the London bombings of July 7, 2005.[14] In general, Triage Sieve is used as a primary "triage-to-treatment" algorithm and is followed by a secondary "triage-to-transportation" algorithm, the Triage Sort.

Sacco Triage Method

The Sacco Triage Method was developed in the United States, using a novel development method. The Delphi technique was used to estimate the chances of victim deterioration by obtaining consensus among a group of experts based on changes in physiological parameters of the patient.[15] This triage system is intended to account for both the patient's physiological parameters and the available resources.

The Sacco Triage Method uses a computer program to collect available resources in a database. A physiological score is then computed mathematically for each patient. This score considers the patient's respiratory rate, pulse rate, and best motor response, assigns a coded value, and then sums these values to calculate the Sacco score.[16] The developers report that this score can be calculated and a triage category assigned within 45 seconds once all data have been entered.

The victims are tagged and organized into three groups according to the score. Triage tags have a large clock face with numbers representing the score and can be easily seen by emergency medical services providers. The triage officer contacts a central dispatcher and provides information on number of victims, the Sacco scores, ambulance-processing rate at the scene, and number of landing sites for helicopters. These data are entered into incident command software, which then produces the optimal triage strategy. This strategy defines the order in which victims are transported and treated and to which hospitals they are sent. The system also alerts the hospitals to the number, severity, and scheduled arrival of patients. The Sacco Triage Method is proprietary, and accordingly, the specific details of how triage categories are determined are not publicly available for review, research, or independent confirmation. Reliable information on current deployment and field success is not available, although implementation of this method in parts of Florida has been reported.[17] The developers report that the Sacco score accurately predicts a patient's survivability from trauma, although this has not been prospectively validated.[17]

CESIRA Protocol

The CESIRA Protocol, developed in 1990, has three basic categories: red, which includes patients who are unconscious, hemorrhaging, in shock, or having respiratory insufficiency; yellow for patients with broken bones and other injuries; and green for victims able to walk. CESIRA is the Italian acronym for the words describing these injuries (Table 12.5). CESIRA does not contain a dead category; nonphysicians are not legally authorized to declare death in Italy, and the system is designed for prehospital use when physicians are not present.

MASS Triage

MASS (Move, Assess, Sort, Send) is a disaster triage system that utilizes the U.S. military triage categories with a simple system to triage large numbers of casualties quickly in a mass casualty incident. It was developed and is now taught by participants in the National Disaster Life Support Foundation. Although MASS is based on START, it sorts patients into a triage category before individual assessments are done. The first, or "Move" stage directs victims who are able to walk to go to a designated area; these victims are marked "minimal"/green. The victims who cannot walk are asked to move an arm or leg; those able to follow the command and move an extremity are "delayed"/yellow. If victims cannot move when asked, they are assessed and assigned to either the "immediate" or "expectant" groups. The Assess stage of MASS is compatible with other triage systems, such as START. Additionally, the Assess stage may include a subjective component directing persons with an expected fatal injury (regardless of expected duration of survival, such as fatal doses of radiation or 100% total body surface area burns) to the expectant category. The "Sort" stage is a further, subjective categorization. "Send" is the transport phase. Transport may be conducted according to priorities determined in the Sort phase.

Military Triage/NATO Triage

The main objective of military triage is to treat and return injured soldiers to the front lines as soon as possible. For those who

Table 12.6

Military Triage

P1	T1	IMMEDIATE: Life-threatening injuries must be treated within first hour. Good chance of survival
P2	T2	DELAYED: Delay in treatment, can wait a few hours. Stabilization
P3	T3	MINIMAL: Walking, treatment may be delayed for several hours.
P1 – Hold	T4	EXPECTANT: Significant resources needed to treat patient. Signs of impending death
Dead	Dead	Dead

cannot return to duty, medical focus is on wound debridement, limb salvage, and preservation of life. Military triage is based on the North American Treaty Organization (NATO) triage classification, a subjective categorization based on expected survival and resource utilization. All NATO member countries follow a standardized triage system for their military operations providing consistency for multinational operations.

Military triage begins with the immediate sorting of patients according to type and severity of injury and likelihood of survival, and the establishment of priorities for treatment and evacuation to ensure medical care of the greatest benefit to the largest number. Most military triage systems use the "T" (treatment) system, T1, T2, T3, T4, and dead. Others such as the British Military system use the "P" (priority) system – P1, P2, P3 and P1-hold.[18] Holding areas are developed for victims according to their injuries following initial evaluation. Patients are treated and stabilized until they can be transported to a medical facility. The classification scheme is subjective, based on the experience of the triage provider rather than specified physiological criteria (see Table 12.6).

SALT Triage

A more recent U.S. federally funded project to examine existing triage systems has resulted in the development of the SALT (Sort, Assess, Lifesaving measures, Treat/Transport) system. After determining that no existing system has sufficient scientific support to recommend its use, a workgroup used the limited existing data and expert opinion to craft the SALT system, attempting to incorporate the best features of the existing systems. SALT is intended to serve as a national all-hazard mass casualty initial triage standard for all patients (e.g., adults, children, special populations).[19]

SALT begins with a global sorting of patients to prioritize them for individual assessment. Patients who are able to walk are instructed to walk to a designated area, and are assigned last priority for individual assessment. Those who remain are asked to wave or are observed for purposeful movement. Those who do not move (i.e., are still) and those with obvious life threats are assessed first because they are the most likely to need life-saving interventions.

The individual assessment begins with limited rapid life-saving interventions (LSIs). These are only performed if the intervention is within the responder's scope of practice, and only if the necessary equipment is immediately available.

The recommended LSIs include: controlling major hemorrhage, opening the airway, providing chest decompression, or using autoinjector antidotes. If the patient is a child and not breathing, the provider can consider giving two rescue breaths.

After any needed LSIs are provided, patients are prioritized for treatment and/or transport by assigning them to one of five categories. Patients who are not breathing even after LSIs are attempted are triaged as dead. Patients who have mild injuries that are self-limited if not treated and can tolerate a delay in care without increasing their risk of mortality are triaged as minimal. Patients who do not obey commands, do not have a peripheral pulse, are in respiratory distress, or have uncontrolled major hemorrhage are triaged as immediate. Within this group of immediate patients providers should also determine whether a patient has injuries that are likely to be incompatible with life given the currently available resources. If so, then the provider triages that patient as expectant rather than immediate. The remaining patients are triaged as delayed (Figure 12.1). To assist with identification of patients SALT recommends that dead be symbolized by the color black, expectant by gray, immediate by red, delayed by yellow, and minimal by green.

Secondary Triage Systems

In situations where projected out-of-hospital time is extensive, secondary triage systems may be used to further categorize victims for prioritization of transport. In severely resource-constrained environments, these systems are designed to consider likelihood of a positive outcome in addition to the urgency of treatment and the amount of projected resources that are needed. Consequently, the resulting priority decisions for transport (should an opportunity become available) and other resource utilization may not be in complete concordance with the primary triage.

SAVE Triage

SAVE, or Secondary Assessment of Victim Endpoint, is used with the START triage algorithm. This system uses objective and subjective individualized considerations for likelihood of survival and resource utilization to direct limited treatment options in the field and prioritize transport of victims who are most likely to benefit from advanced care. SAVE is designed to limit use of medical resources by defining those victims with poor prognoses and those whose outcomes are unlikely to improve with immediate care. Also, consideration is given to healthcare workers and other special categories of victims who, with minimal treatment (e.g., splinting of a sprained ankle), can assist in the disaster response by increasing the available resources (i.e., skilled personnel) supporting medical care. Treatment is prioritized toward victims whose likelihood of survival (if given medical care) is more than 50% and who would benefit from immediate intervention. These likelihoods are calculated based on prognostic tools including a limb salvage score, the Glasgow Coma Scale (GCS), and data on survivability after burns. The full details of this system are too extensive to present here but can be found in the original 1996 manuscript.[20]

Triage Sort

Often paired with the Triage Sieve, the Triage Sort is a secondary triage system that uses the Revised Trauma Score (RTS) to categorize patients into immediate, urgent, and delayed categories. The RTS is derived from the GCS, blood pressure, and respiratory

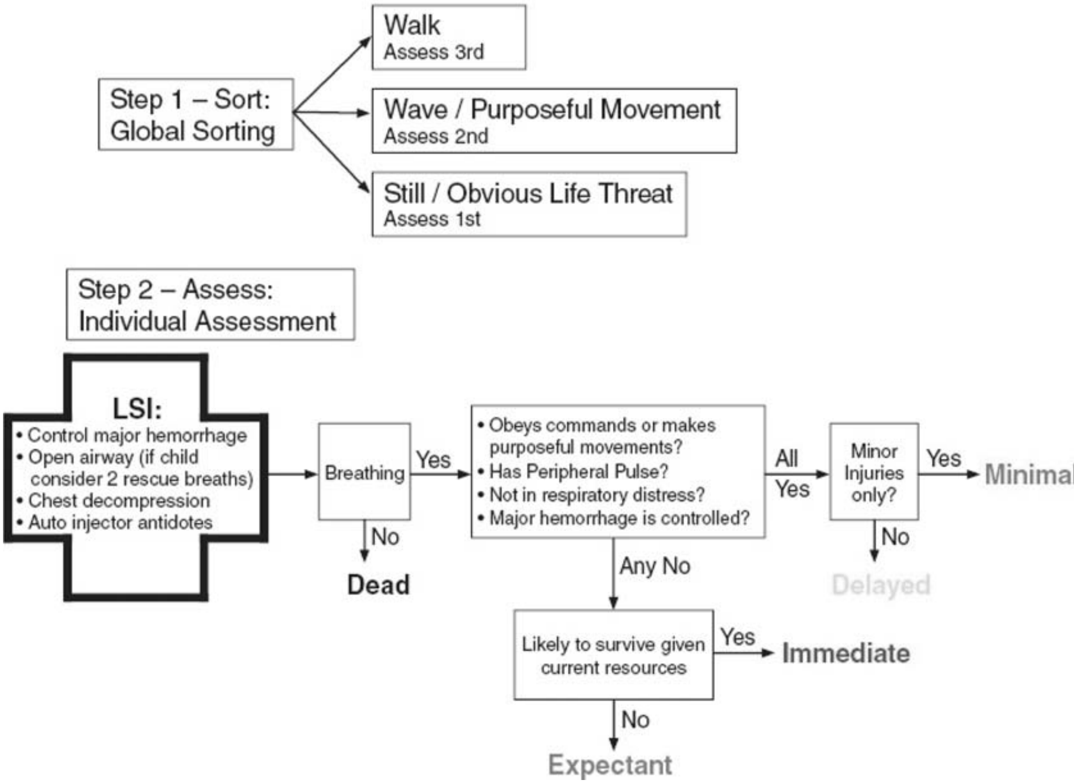

Figure 12.1. SALT Mass Casualty Triage.

rate. This system is generally first applied to patients initially "sieved" into the immediate category to further stratify them when transportation is limited. Attention is then given to urgent and finally delayed patients.

Pediatric Triage Systems

The physiological and anatomical differences between children and adults are significant. Children are more prone to head injuries, airway obstruction, and hypothermia. They have proportionally less blood volume than adults, and very young children may be unable to walk, communicate verbally, or cooperate with instructions. Care providers may have difficulty obtaining blood pressure readings on children, and the act of triaging children may cause emotional challenges to rescuers beyond the already stressful scenario of disaster triage. With these differences in mind, several triage systems have been developed specifically for use with pediatric patients; however, like the general triage systems discussed previously, there are presently no validated pediatric triage tools.

JumpSTART

JumpSTART is designed to be an objective, physiologically appropriate tool for triaging children younger than 8 years of age. JumpSTART was developed by Romig in 1995 and modified in 2001, and is a modification of the START triage system.[21] Three key changes were made to the START system based on children being more likely to suffer respiratory arrest than adults, having different respiratory rates, and young children being unable to follow commands.

In the JumpSTART system, when a child is identified as having a pulse but not breathing, the rescuer is instructed to reposition the airway and give five rescue breaths (called "jump-start" breaths). A child who is still not breathing after the rescue breaths would be labeled black, whereas a child whose breathing is present at this point would be labeled red.

When deciding whether a child should be triaged into a red or yellow category, responders must recognize the different values for age-adjusted normal and abnormal respiratory rates and the limited ability to follow commands in the pediatric population. For children, a respiratory rate less than 15 or greater than 45 indicates that a red label should be assigned. If the respiratory rate is between 15 and 45, a yellow label is applied. Although normal respiratory rates in children vary by age, this simplified rule was chosen to minimize confusion and maximize utility. For assessing mental status, young children may lack the capability of responding to commands. Therefore, JumpSTART uses the AVPU (Alert/Verbal/Painful/Unresponsive) tool rather than response to commands for the mental status component of the algorithm.

Pediatric Triage Tape

The Pediatric Triage Tape (PTT) is derived from Triage Sieve. It is used throughout the United Kingdom and parts of Europe, India, Australia, and South Africa. The PTT is designed to complement any existing triage labeling system. If the child is walking or an infant is alert and moving all limbs, the tape is not necessary, and the patient is labeled "delayed" (green). If a child is not walking or moving appropriately, the tape is used to measure the length of the child, similar to the Broselow Tape or other length-based algorithms. The PTT is divided into five length blocks; each block contains the algorithm for Triage Sieve, modified for age-appropriate respiratory and heart rate parameters.[22,23]

Table 12.7

JumpSTART Triage

RED IMMEDIATE	Any of the following: Respirations <15 or >45 breaths/min No palpable radial pulse Inappropriate response to pain, posturing, or unresponsive to stimuli
YELLOW DELAYED	Nonambulatory patients who do not meet black or red criteria
GREEN MINOR	Able to walk to a designated safe area for further assessment. This includes children who are developmentally unable to walk; however, these children must be the first to be assessed when the green patients are reevaluated
BLACK DECEASED	Not breathing despite one attempt to open the airway and, in patients with a palpable pulse, after provision of five rescue breaths

Courtesy of Dr. Lou E. Romig.

Comparison of Pediatric Triage Systems

CareFlight triage can be used in both children and adults. In a study by Wallis et al., CareFlight, PTT, START, and JumpSTART were compared in 3,461 injured children presenting to the Trauma Unit of the Red Cross Children's Hospital in Cape Town, South Africa.[4] The same modified Baxt criteria used in the Garner comparative study were used to define critical injury. Overall, CareFlight showed the best performance in sensitivity and specificity; 95% confidence intervals for sensitivity overlapped for PTT, CareFlight, and START, whereas specificity 95% confidence intervals overlapped only for PTT and CareFlight, with JumpSTART very slightly lower. Sensitivity was very poor (approximately 1%) for JumpSTART, compared with approximately 39%–46% for the other algorithms. This is the only published report that could be identified in which pediatric triage systems were compared. Therefore, it is currently not possible to recommend any of the pediatric triage systems as superior to any of the others.

Use of Common Scales for Triage

One might ask whether any of the individual assessment items contained in some of the aforementioned triage systems might provide comparable sensitivity and specificity in identifying the more seriously injured patients. It seems plausible that assessment of a single "score" or feature may prove as accurate as assessment of several parameters within a multifeature triage system. If validated, the use of a single value would be simpler and more rapid, and thus preferable. The most studied of these is the motor component of the GCS. A 1998 investigation demonstrated that the major discriminatory power of the GCS lies in the motor component. In this retrospective study correlating mortality with the first GCS score obtained in the field in approximately 1,200 patients, the motor score alone performed slightly better than the summed three-part GCS.[24] Several large studies have subsequently supported this finding.[25–28] A retrospective study of almost 30,000 patients from a state trauma registry suggests that separating patients into those who can follow simple commands (Glasgow motor score = 6) from those who cannot (Glasgow motor score from 1 to 5) provides the best discriminatory capability, perhaps providing a simple and elegant alternative to a multistep triage algorithm.[26] Research has demonstrated that a GCS motor component score of 5 or less is correlated with worse outcomes in trauma patients.[27]

Respiratory rate is another commonly used trauma triage criteria. There is limited evidence to support its use in the trauma setting. The frequently used cutoff of 30 breaths per minute as the respiratory criterion is arbitrary and not supported in current literature; it appears that lowering this cutoff to the mid-20s may improve overall triage performance.[29]

Outcome Measures for Triage Research

Although a large number of mass casualty triage systems exist worldwide, many with similar features, there are no currently accepted reference standards that define key outcome measures. There are essentially two categories of outcomes that could be used in assessing how triage affects patient outcome: patient-based scoring systems, such as Injury Severity Score (ISS), (e.g., does triage system "x" appropriately assign all patients with an ISS greater than "y" to the "red" category?) and resource-based systems (e.g., were all patients who required surgery or a blood transfusion in the first 2 hours after arrival at the hospital correctly assigned to the "red" category?). In 1990, Baxt et al., defined a set of criteria based on resource utilization within 2 days of arrival at the hospital to define a patients' level of serious injury, in an attempt to correlate resource utilization to ISS.[30] This was refined by Garner et al., in 2001 to reflect more accurately which patients in the prehospital setting were truly in need of immediate care. Although this landmark study retrospectively examined individual trauma patients to see how each of four systems (CareFlight, START, modified START, and Triage Sieve) performed, at the time of this writing, only one study has been published that examines the real-time performance of any mass casualty triage system with reference to these a priori criteria. The article discusses the performance of START triage at a train collision involving approximately 150 victims; the authors found that the "walking filter" appeared to function well in defining less severely injured patients.[31]

Some researchers suggest that scored scales, such as the ISS and RTS, could be used as reference criteria (gold standards) to assess the accuracy of triage instruments. It remains unclear which of these scores, if any, accurately predict outcomes or the need for resource utilization in a mass casualty setting. Furthermore, there is no agreement within specific scores as to which cutoffs should be used to define "correct" use of a triage instrument (e.g., what would "y" be in the previous example using ISS?). Although the reproducibility and applicability to a wide range of trauma patients makes tools such as ISS and RTS attractive, their validity in assessing outcomes in the mass casualty setting is unknown.

Measures other than clinical patient outcome may be important in judging and comparing trauma systems. How efficiently scarce field resources are used, how quickly patients are transported to hospitals, and costs of training, program implementation, and competency maintenance for personnel in a given system may be of tremendous importance. Essentially no work has been done to examine or define these nonclinical outcomes.

At this time, no specific recommendation based on strong evidence can be made to support any one triage system over another. Although not studied, it seems likely that use of a single standard system across an entire region is likely to improve

Table 12.8

Incident Type	*Triage Goal*	*Difference*
Single patient incident	Optimize individual patient outcome by providing all resources required to meet the patient's needs	No consideration of other patients
Multiple casualties	Prioritize patients for appropriate treatment/transport so they receive needed resources in sufficient time to reduce morbidity and mortality	Resources are devoted to patients according to priority, but patients receive all the care they need
Disaster	Prioritize patients for appropriate treatment/transport so they receive needed resources in sufficient time to reduce morbidity and mortality, but also ensure that scarce resources are utilized to provide the best outcome at a population level	Resources are devoted to patients according to priority, but patients who are unlikely to survive, given the available resources, are given a low priority for treatment/transport

interoperability during mass casualty responses. In the absence of additional evidence to recommend a particular methodology, choice of this system will likely be based on existing resources, the need for retraining, and flexibility in the face of various disaster scenarios. Specific attention to chemical, biological, and radiological/nuclear (CBRN) events is a critical component of state-of-the-art triage systems and must be considered when choosing a triage methodology. Although proposed, no CBRN-capable mass casualty triage system has been adequately studied.[32]

Other Triage Considerations

Differentiation of Disaster Triage from Other Triage Modalities

It is important to distinguish disaster triage from other types of triage, including daily emergency department triage, single-patient trauma triage, and multicasualty incident triage when resources are not exceeded and transportation and communication infrastructures are intact. Single-patient trauma triage (the process of determining whether a given single trauma patient, such as a motor vehicle crash victim, needs to be transported to a trauma center or not, often using the National Consensus Field Triage developed by the CDC) attempts to match the patient's clinical needs with the correct resources (trauma center vs. a hospital that is not a trauma center).[33] Unlike the mass casualty setting, however, this type of triage does not weigh the relative needs of several patients to determine who will get a relatively scarce resource, but instead helps determine whether a single patient might need the resources of the trauma center.

When personnel in the prehospital setting or emergency department are confronted with multiple patients, these providers prioritize care for individuals based on acuity. In these multicasualty situations, as well as in daily emergency department triage, the goal is to determine which patients can wait for treatment without increasing their risk of morbidity and mortality and which need immediate attention.

In disaster situations when resources are exceeded, the need to prioritize patients must include a rationing of supplies, shifting the focus from ensuring that each individual receives the best possible care to ensuring the population as a whole experiences the best possible outcome. In other words, the focus is on providing the most efficient care for the greatest number of people (Table 12.8). In some cases, this will include identifying patients who are not expected to survive and making the decision that no resources beyond comfort measures will be used for these individuals.

Context-Specific Triage

Although the majority of disasters to date have resulted in traumatic injuries from explosions, collisions, collapses, and other releases of kinetic energy, other scenarios that involve CBRN agents, or a combination of agents, are also possible; responders must be prepared to manage any type of event. Most of the triage systems described previously focus on triage of trauma victims in which kinetic or thermal energy is the only cause of their injury. It is possible that applying these triage systems to other types of events may not be feasible and may not improve patient outcomes. Developing an all-hazard triage algorithm may be difficult because it must be scientifically valid for all types of threats while remaining simple to use, accurate, reproducible, and rapid. Cone and Koenig proposed a basic triage algorithm, based on START triage, with simple modifications made for each category of CBRN event. These modifications address the need for further triage to maximize patient outcomes while protecting response personnel.[33] The SALT triage system is also intended to be an all-hazard triage method. In addition, timing of decontamination versus transport may be of critical importance in balancing patient care needs with personnel protection and is an important component of mass casualty triage protocols for CBRN events.

Biological mass casualty triage is likely to present the most radical departure from "routine" mass casualty trauma triage. Rather than a single, large peak of acutely injured individuals, response personnel may be faced with a prolonged presentation of victims in addition to the baseline number of patients already in the system. Victims are likely to have no trauma and there may not be a specific disaster scene. Rather than triage by acuity, a system that groups patients by exposure status may be necessary. Such a strategy has been proposed by Burkle and advocates triaging patients into five groups: susceptible but not exposed, exposed but not yet infectious, infectious, removed by death or recovery, and protected by vaccination or prophylactic medication.[34] Triage tools for biological events require development in concert with infectious disease, public health, and other experts in epidemiology and mass patient care. These tools may eventually take the form of telephone screening or broadcast messages for self-evaluation in affected areas. It is possible that referral to hospitals for triage evaluation may not be prudent due to risk of spreading the contagion. Given the broad uncertainty in biological mass casualty triage and the substantial differences between triage tools useful for trauma and those useful for purely biological events, a further discussion of these tools is deferred.

RECOMMENDATIONS FOR FURTHER RESEARCH

Current triage systems suffer from significant limitations.

- Lack of scientific validation
- Lack of standardization and interoperability
- Absence of flexibility in addressing nontraumatic disaster scenarios

It is vital that methodologically sound, outcomes-based research be conducted to address these limitations. In particular, specific questions that should be addressed within the field of disaster triage include

- What is the appropriate outcome measure for studying triage systems?
- Using this measure, which system (if any) is superior?
- What is the best way to rapidly sort large numbers of nontraumatic victims, such as victims of chemical, biological, or radiological attacks, for prioritization of treatment and transport?
- Is it possible, or even desirable, to have a "one size fits all" algorithm that would cover all of these possibilities, or are the differences between event types too pronounced?

In the meantime communities should select the triage system that is most appropriate for their circumstances, keeping in mind that interoperability within a region will be enhanced by using a standardized triage system. Furthermore, whichever triage system is selected, it should be used and practiced regularly, and whatever tools are needed for implementation should be readily accessible and familiar to the providers.

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13

Personal Protective Equipment

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OVERVIEW

Following terrorist attacks such as the September 11, 2001 events in the United States, governments around the world at local, state, and federal levels placed increased emphasis on preparedness efforts. Vendors capitalized on this heightened attention by embarking on aggressive marketing campaigns flooding marketplaces with advertisements for disaster survival kits, survival manuals, evacuation plans, instruction manuals on protecting families during a terrorist attack, and information on "the very best" personal protective equipment (PPE). However, as the time interval since the latest disaster increases, both public and government interest in being prepared tend to fade. For example, in the United States, at the time of this writing, there is no federal law requiring state and local officials to plan for the evacuation of the sick, elderly, disabled, or impoverished. Ironically, pets are more protected as both houses of the U.S. Congress passed bills that require local governments to plan for the evacuation of pets.[1] Nonetheless, some progress is being made in the area of PPE.

PPE is being considered by many organizations and agencies. These agencies are purchasing and supplying equipment for the protection of the workforce from possible attacks and threats uncovered through a hazards vulnerability analysis. Numerous pitfalls, obstacles, and confusing directions exist regarding equipment selection and indications for use in protecting individuals from a possible unknown hazard. The goal of this chapter is to provide the most complete, up to date, comprehensive information so an informed decision can be rendered for each unique work environment and potential threat.

STATE OF THE ART

PPE as a means to protect human beings from hazardous materials has been an evolving science throughout history. Much of what is now used in the civilian sector has been developed by the military as a result of warring factions using whatever protective means they could develop to counter hazardous materials used by opposing forces to gain an advantage. Therefore, any discussion on PPE requires a brief historical review of biological, chemical, and nuclear warfare.

The History – Biological Warfare

As early as the fifth century BC, Herodotus, a Greek historian, described how Scythian archers of the Black Sea used arrows with tips coated by a substance containing biological material.[2] The widespread use of bacteriological agents in an armed conflict can be dated back to 1346, at Kaffa (now Feodossia) where the bodies of Tartar soldiers who died of plague were catapulted over the city walls.[3] During the French and Indian War, fought in North America between France and England from 1754 to 1767, Sir Jeffery Amherst, an English General, clandestinely provided the Indians loyal to the French with blankets infected with the smallpox virus. As planned, the resultant epidemic devastated the Indian allies.

The most significant and ambitious known biological warfare program to date was started by Japan in 1937. The Manchurian laboratory complex was code named "Unit 731".[3] The Japanese subjected thousands of allied prisoners of war to experiments with biological agents until 1945. An additional offensive biological warfare program was discovered in Russia. In April of 1979, there was a tremendous blast in the city of Sverdlovsk. Residents of the city identified the blast as originating from Military Compound 19. Over the next several weeks, more than 40 people died of inhalational anthrax. U.S. government intelligence sources maintained that for many years a massive accident had occurred at a biological weapons production facility and released anthrax spores into the atmosphere. U.S. suspicions were confirmed when President Boris Yeltsin acknowledged at a 1992 press conference that the Sverdlovsk incident was in fact a massive biological weapons accident involving aerosolized anthrax spores.[3] In the fall of 2001, two employees from the Brentwood mail facility in Northeast Washington, DC, died after inhaling spores form an anthrax-contaminated letter sent to lawmakers on Capitol Hill.

The History – Chemical Warfare

There is debate as to what culture should be credited with the initial development of chemicals for military use during conflicts. If not the actual originators of chemical warfare, the Chinese were clearly early masters of using chemicals on the battlefield.[4] Early Chinese planners, strategists, and military leaders were aware of the tactical value of chemical weapons. Chinese writings detail the early use of riot control agents to suppress peasant revolts and the military delivery systems used by the conquering Chinese army.

An early recorded use of gas warfare dates back to the fifth century BC, during the Peloponnesian War between Athens and Sparta. Spartan forces attacking an Athenian city placed a lighted mixture of wood, pitch, and sulfur under the walls hoping that the noxious smoke would incapacitate the Athenians.[5]

In 1915, the first chemical war agent was used by the German military forces during World War I. In Ypes, Belgium, they released approximately 168 metric tons of chlorine gas, killing as many as 5,000 Allied troops.[6] The accidental discovery of tabun and sarin by German industrial chemistry scientists during pesticide research and testing in 1938 lead to the later widespread reproduction and stockpiling of these agents by the then Nazi regime. [6]

The History – Nuclear Warfare

The first fission weapons (atomic bombs) were developed in the United States during World War II in what was called the Manhattan Project. Two of those initial weapons were subsequently dropped on the cities of Hiroshima and Nagasaki, Japan. Relatively soon after the United States use of these weapons, the Soviet Union began their own nuclear weapons program, which lead to the Cold War and the development of more powerful devices (hydrogen bombs). At the height of the Cold War, the Untied States and the Soviet Union possessed enough nuclear weapons to destroy both countries and their allies many times over. The end of the Cold War failed to end the threat of nuclear weapon use, however. Fears have risen that nuclear weapons from cash starved former Soviet Union countries may be purchased by international terrorist groups. In modern times there are at least seven countries with functional nuclear weapons and both North Korea and Iran have active nuclear weapons programs.

A different type of radiation risk from that of nuclear weapons is the threat from radiological dispersal devices or "dirty bombs" that combine an explosive, such as dynamite, with radioactive material. According to the U.S. Nuclear Regulatory Commission, most dirty bombs "would not release enough radiation to kill people or cause severe illness – the conventional explosive itself would be more harmful to individuals than the radioactive material."[7] Such devices, however, have the potential to cause widespread anxiety within the population and produce significant property contamination.

The Threat

According to Lieutenant General Michael D. Maples, the 16th Director of the United States Defense Intelligence Agency, "several terrorist groups, particularly al-Qaida, remain interested in chemical, biological, radiological and nuclear weapons. Al-Qaida's stated intention to conduct an attack exceeding the destruction of 9/11 raises the possibility that future attacks may involve unconventional weapons."[8] In addition, the U.S. National Infrastructure Protection Plan states, "Current analysis of terrorist goals and motivations points to domestic and international Critical Infrastructure and Key Resources (CI/KR) as potential prime targets for terrorists."[9] Terrorist organizations, whether domestic or international, understand the value of targeting symbols of stability. Future attacks on economic, transportation, healthcare or government infrastructure, and key resources have the potential to result in mass casualties. This can adversely impact the economy and more importantly destroy public confidence, morale, and resolve. The best defense is knowledge of the most up-to-date equipment, technology, training, and performance expectations in confronting a disaster situation. This includes PPE.

The Hazards

In responding to disasters, healthcare providers may be exposed to toxic and infectious agents. Therefore, knowledge of PPE and why such equipment would be necessary is important. Matching the right PPE ensemble with the right hazard is essential to a proper response and most importantly, the health and well-being of the responder. One size or ensemble does not fit all hazards, training levels, or abilities.

Training and redundant safety systems can reduce the risk for a hazardous materials incident and the subsequent potential for mass casualties with serious injuries. Despite the relatively low rate of problems as a result of chemical exposures in the U.S. depicted in Table 13.1, there exists the need to educate and train all those who have the potential of becoming contaminated. Table 13.2 details the frequencies of injuries or symptoms by type of event.

The primary reason for providing training, education, and the proper equipment to those responding to victims of chemical, biological, and radiological exposures is to prevent the immediate and long-term health consequences that can result from both primary and secondary exposures.

Exposure

In chemical contamination, a primary exposure results from direct contact with the agent (solid, liquid, or vapor). A secondary exposure results from the evaporation or "off-gassing" of the material from a contaminated source at normal atmospheric pressure. In both cases, symptoms vary depending on the level and duration of exposure. Depending on the hazardous material, victims can experience respiratory difficulties, abdominal symptoms, painful skin lesions, damage to mucous membranes, and death. Long-term health consequences from exposure to toxic chemicals can result in chronic respiratory damage, chronic conjunctivitis, keratitis, and a predisposition to airway cancers. A relationship between a single exposure to some agents, such as mustard, and airway cancers has not been established.[11]

To address the special hazards from chemical warfare agents such as sulfur mustard, the U.S. Centers for Disease Control and Prevention (CDC) publishes recommended airborne exposure limits to protect the health and safety of workers and the public during treatment, transport, or disposal of these agents. The CDC continually evaluates and updates these guidelines.

Table 13.1: Frequency of Chemical Release by Substance Categories in All Events and in Events with Victims*[10]

Substance Category	*No. of Releases*	*(%)*¶	*No. of Releases with Victims*	*(%)*¶	*Percentage of Releases with Victims*
Acids	665	7.3	95	13.3	14.3
Ammonia	466	5.1	74	10.4	15.9
Bases	369	4.1	28	3.9	7.6
Chlorine	205	2.3	48	6.7	23.4
Formulations	16	0.2	1	0.1	6.3
Heteroorganics	80	0.9	4	0.6	5.0
Hydrocarbons	94	1.0	6	0.8	6.4
Mixture†	4,459	16.1	47	6.6	3.2
Multiple substance category	842	9.3	117	16.4	13.9
Other inorganic substances‡	1,533	16.9	44	6.2	2.9
Oxyorganics	550	6.1	59	8.3	10.7
Paints and dyes	289	3.2	13	1.8	4.5
Pesticides	407	4.5	31	4.3	7.6
Polychlorinated biphenyls	79	0.9	0	0.0	0.0
Polymers	193	2.1	11	1.5	5.7
Volatile organic compounds	1,256	13.8	54	7.6	4.3
Other§	569	6.3	82	11.5	14.4
Total	9,072	100.1	714	100.0	7.9

* Chemicals in events that involved multiple agents were counted only once in a substance category when all the chemicals were associated with the same category. If events involved multiple substances from different categories, they were counted only once in the multiple substance category.

† Substances from different categories that were mixed or formed from a reaction before the event.

§ All inorganic substances except for acids, bases, ammonia, and chlorine.

‡ Not classified.

¶ Percentages do not total 100% because of rounding. In a total of 9,105 events, 33 were excluded because they were not assigned a substance category. For these 33 events, 32 involved one substance each, and 1 event involved two substances that could not be categorized. Six of the excluded events had victims.

As an example, at the time of this writing, CDC recommends a maximum exposure of 0.003 mg/m^3 as a 5-minute ceiling limit for sulfur mustard and a general population limit for this agent of 0.00002 mg/m^3 averaged over 12 hours (referred to as a 12-h time-weighted average). These standards will meet carcinogenicity protection levels and keep exposures below thresholds for significant risk.[12] Such airborne exposure limits also dictate the type of PPE needed to protect workers in a given hazardous environment.

Most exposures to biological weapons will result in flulike symptoms or pneumonia, with the exception of botulinum contact. Other significant biological threats include emerging infectious diseases such as severe acute respiratory syndrome and pandemic influenza. Many of the issues encountered by first responders, healthcare providers, and public health officials will be the same regardless of the cause. As a result, the most effective response to any disease emergence will probably be rapid identification that an outbreak has occurred. During a bioterrorism incident, however, rapid isolation of the infectious agent to prevent further dissemination may not be possible. The illness may spread through the population for up to 10 days before an intentional release is suspected, so waiting for a definitive diagnosis in many cases is not practical. Therefore, implementing some type of syndromic surveillance would be prudent. The investigation of an illness that may represent terrorist activity must examine the epidemiological characteristics of those presenting with signs of infection. A complete clinical history is invaluable in determining whether the onset of symptoms is the result of an endemic disease or a biological weapon. A more detailed discussion of syndromic surveillance is available in Chapter 11.

Radiation exposure provides a much different set of variables that the healthcare provider must address. The actual energy absorbed by human tissue is the most important factor when determining the extent of damage inflicted. The more radiation to which an individual is exposed, the more damage is sustained and the greater the short- and long-term consequences. The dose amount is dependent on the following factors

- The number and energy level of the radiation particles emitted by the source

Table 13.2: Frequencies of Injuries or Symptoms by Type of Event*[10]

	Type of Event					
	Fixed Facility		*Transportation*		*All Events*	
Type of Injury	*No. of Injuries*	*(%)*‡	*No. of Injuries*	*(%)*‡	*No. of Injuries*	*(%)*‡
Chemical burns	91	3.4	20	6.5	111	3.7
Dizziness/central nervous system symptoms	302	11.4	11	3.6	313	10.6
Eye irritation	268	10.1	28	9.1	296	10.0
Gastrointestinal symptoms	354	13.3	15	4.9	369	12.4
Headache	381	14.3	27	8.8	408	13.8
Heart problems	10	0.4	1	0.3	11	0.4
Heat stress	11	0.4	0	0.0	11	0.4
Respiratory irritation	825	31.1	78	25.3	903	30.5
Shortness of breath	47	1.8	7	2.3	54	1.8
Skin irritation	162	6.1	13	4.2	175	5.9
Thermal burns	76	2.9	9	2.9	85	2.9
Trauma†	101	3.8	97	31.5	198	6.7
Other	28	1.1	2	0.6	30	1.0
Total	2,656	100.0	308	100.0	2,964	100.1

* The number of injuries is greater than the number of victims (1,835) because a victim could have more than one injury.

† Examining the 198 trauma injuries, 39 were chemical related, 134 were not chemical related, 7 were both chemical and nonchemical related, and the type of trauma was missing for 13 injuries.

‡ The injuries of one victim were not reported. Percentages do not total 100% because of rounding.

- The distance from the source (distance is especially important with α radiation; if one is more than a few centimeters from the source, the dosage approaches zero)
- The amount of exposure time
- The degree to which radiation dissipates in the air or in other substances between the source and the recipient
- The penetrating power of the radiation[13]

The potential long- and short-term health effects of radiation also depend on which organs of the body are most likely to absorb radiation.

- If ingested, radiation from some sources tends to accumulate in certain organs. For example, iodine-131 concentrates in the thyroid gland, where the β radiation, at high doses, can be effective in destroying hyperactive thyroid cells.
- Water containing tritium (a radioactive isotope of hydrogen) distributes β-emitting radioactivity throughout the body.[14]

It is critically important to match the appropriate PPE to the biological, chemical, or radioactive agent to ensure effective barrier protection against potential immediate and long-term hazardous effects.

Considerations for the Use of Personal Protective Equipment

Although the use of PPE is important, one must first understand that PPE is not the first choice for protection of workers or potential victims of exposure to hazardous materials. Protection is broken down into a hierarchy of levels organized in order of descending preference. Engineering controls, such as building ventilation systems, are the first priority and most effective means of protection. The second order of protection is administrative controls. Examples include the U.S. *Federal Manager's/Decision Makers Emergency Guide*, in which strategies for protecting victims from exposure are discussed and include evacuation versus sheltering-in-place for a short time.[15] PPE is considered the least desirable within the hierarchy because of dependence on the individual to consistently use the equipment correctly. PPE includes anything used by an individual for protection against an agent, for example, a hat to shield against the sun. PPE design and sophistication becomes more complex as the array of agents becomes more hazardous and multifaceted.

The selection of PPE is challenging and is based on several factors: 1) the environment in which the hazardous agent is deployed, 2) the concentration of the agent, 3) the type of threat encountered (infectious particle, liquid, vapor, or radiation) and 4) the duration of an individual's exposure to the hazardous agent. Additionally, the individual who will use the PPE has an impact on the type of equipment. Not all respirator designs can be worn by all individuals. Industrial hygienists, safety professionals, and manufacturers should be consulted when selecting PPE.

In general terms, several organizations have developed guidelines for ensembles of PPE that are effective under increasingly hazardous conditions and have classified them into levels. This equipment is designed to offer increasing levels of safety for eyes,

Table 13.3: Decontamination Suit Ensembles Levels A–D

	Description	*Advantages*	*Disadvantages*	*Example*
Level A	Fully encapsulated suit with self-contained breathing apparatus (SCBA)	The highest level of protection, offers protection against contact and inhaled hazards.	The expense, training, and program maintenance restricts the use of this level to specialized hazardous response teams. The lack of mobility in the ensemble, increased heat/physical stresses, and limited air supply restrict the personnel who can utilize this capability.	
Level B	Suit with sealed seams, supplied air respirator or SCBA	A high level of protection. Utilized in an unknown environment. This ensemble offers more dexterity and mobility then Level A.	Dependent on an air line or limited air supply. Expense, training, and program maintenance are limiting factors. Heat/physical stresses remain an issue. Fit testing is required. Does not protect in a vapor-IDLH environment.	
Level C	Splash suit and air-purifying respirator (APR)	Compared with Level A and B suits, mobility is significantly increased; heat/physical stresses are reduced. Operational time in the ensemble is increased with a high level of protection against a limited number of chemical agents. Fit testing is not required if hood is used. Moderate expense and training.	The Level C ensemble is not adequate for exposure to substances at high concentration levels, high risk of significant splash contamination, and low oxygen atmospheric levels.	
Level D	Work clothes with standard precautions (gloves and splash protection)	Highest mobility, low heat/physical stresses, operational time unlimited. Expenses and training minimal.	No protection against chemical and a variety of other hazardous materials.	

skin, and the respiratory system. In the U.S. the Environmental Protection Administration (EPA) and Occupational Safety and Health Administration (OSHA) are the two prominent organizations with significant responsibilities for PPE levels and classifications. EPA and OSHA use levels A through D to organize ensembles of PPE (Table 13.3). Level A provides the greatest degree of protection utilizing a totally encapsulating chemical-protective suit, whereas level D provides the least protection, essentially utilizing cloth garments. The level A suit is mandatory in an environment that is immediately dangerous to life and health (IDLH). IDLH refers to the maximum concentration level of a substance from which an individual could escape within 30 minutes of exposure without incapacitation or that would result in irreversible toxic effects. For example, the IDLH limit for hydrogen sulfide is 300 parts per million. Levels B and C provide intermediate protection between levels A and D, shielding the skin, eyes, and respiratory system without encapsulating the wearer. Level B provides maximal eye and respiratory protection, mandating the use of atmosphere-supplying respirators. It is less effective in preventing skin exposure, especially in a concentrated vapor environment. Level C should only be used when both the offending agent and its concentration are known, and an IDLH environment does not exist. Level D, in combination with standard precautions, is sufficient protection when caring for many biological casualties and victims contaminated with radioactive material. When encountering certain biological entities, such as viruses, or very fine radioactive particles, a respirator may be necessary. This situation is controversial, and some experts recommend level C.

When selecting PPE for protection from hazardous materials, particularly ones in which an IDLH situation is suspected, begin with level A protection and then gradually reduce the level of PPE based on a hazard analysis. The U.S. Department of Homeland Security and other organizations frequently refer to these levels when making recommendations for protection. As an example, the final work product of the *Working Group on Radiological Dispersal Device (RDD) Preparedness – Medical Preparedness and Response Sub-Group* discusses medical guidelines for radiological protection of first responders and first contact medical personnel. It states, "Level C is generally sufficient for particulates . . . If chemical agents are suspected, level B or higher protection is required."[16]

In addition to EPA and OSHA, the U.S. military and the National Fire Protection Association have classified PPE into ensemble levels of protection designed to meet their anticipated needs. When reviewing ensemble levels developed by different organizations, one needs to keep in mind that the elements described with separate terminology all use the same PPE. The only difference is they assemble the equipment into unique combinations. Therefore, the selection of PPE is still based on the same principle, that defined by the degree of protection the PPE can provide, not on a level or classification. The National Fire Protection Association 1994 organizes PPE into the following classes[17]

- Class 1, being the most protective for unknown agents
- Class 2, designed for instances in which victims are not ambulatory and there is probable direct contact with a hazardous agent
- Class 3, designed for instances in which victims are ambulatory and direct contact with the hazardous agent is possible

When deciding which of these ensembles is appropriate, one must keep in mind that these classifications provide for adjustments within each level based on hazard assessments. Such variations include the type of gloves and type of air purifying respiratory protection selected. Hazard assessments are a significant necessity when selecting assembles and cannot be overlooked or omitted from the process. The U.S. Office of Personnel Management, when planning for civilian workforce protection, stated in their publication, *A Federal Employee's Emergency Guide*, that each agency will "determine the risks faced by its employees, develop a comprehensive strategy, and assess the benefits provided by any protective equipment."[18]

In the United States, Homeland Security Presidential Directive 8, National Preparedness, dated December 17, 2003, defines the term *first responder* as, "those individuals who in the early stages of an incident are responsible for the protection and preservation of life, property, evidence, and the environment." These personnel include, "emergency management, public health, clinical care, public works, and other skilled support personnel (such as equipment operators) that provide immediate support services during prevention, response, and recovery operations." The term *first receivers* was coined at a later date and applies to individuals who did not travel to a site contaminated by hazardous agents but received personnel and equipment from the incident scene. In effect, the disaster site moves as victims and first responders begin arriving at medical care facilities. In theory, there exists more flexibility for determining PPE requirements for first receivers based on the presumption that these individuals would 1) have more information before contaminated personnel and equipment arrived, 2) have less exposure being away from the incident site, and 3) have a more easily controlled environment. Specifically, a lower level of chemical protective clothing and equipment could possibly be used by personnel involved in decontamination at sites distant from the initial exposure.

Early determination of the appropriate level of PPE for healthcare facility first receivers is complicated by the fact that information may be limited in the early period following a hazardous materials event. In addition, the communication of data from distant scenes to the hospital can be severely limited. The Tokyo sarin attacks represent the challenges that can occur with communications and lack of a well-rehearsed disaster response system. At 8:35 AM on March 20, 1995 the first of the 3,227 victims seeking medical care began arriving at Tokyo hospitals, and it was not until 11:00 AM that healthcare facilities received confirmation that the agent responsible for the acute illness was sarin.[19]

Although the ideal level of PPE for hospital first receivers remains controversial, OSHA's *Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances* addresses this issue. OSHA's publication made several assumptions in making their recommendation for level C. These assumptions include 1) hazardous substances would not be released near hospitals, 2) at least 10 minutes would elapse between the time of exposure and the time that victims would begin arriving at healthcare facilities, permitting off-gassing, and 3) no victim contaminated with a large amount of agent would survive to hospital arrival. If any of these assumptions are not applicable to a given event, the level C recommendation will not apply. In fact, an event occurring during the year 2000 in the U.S. state of Georgia demonstrated that an individual heavily contaminated with a toxic agent (industrial strength organophosphate) could survive to hospital arrival. Although neither the patient nor any healthcare provider died as a result of the exposure, one provider required intubation.[20] Other U.S. government agencies have also addressed the issue of PPE. The Army Center for Health Promotion and Preventive Medicine's Technical Guide provides PPE recommendations to the Army's military medical treatment facility personnel handling weapons of mass destruction casualties at their fixed facilities. This publication states, "Level B may be ideal . . . " and "Level C may be sufficiently protective" based on the use of intuitive judgment. It is clear the solution to this dilemma remains elusive.[21]

Table 13.4: Issues Effecting Selection of the Proper Respirator

Contaminant Factors	*Workplace Factors*
Concentration	Environment of Use (confined space, hot, cold, outdoors)
Buoyancy	Employee Fitness
Physical State (particle, liquid, vapor, gas)	Activities of the Employee during Respirator Use
Particle Size	
Vapor Pressure	
Warning Properties (odor, taste, irritation)	
Toxicity/Virulence	

When selecting a respirator, one must consider many contributing factors (Table 13.4). Using a respirator in a toxic environment where conditions may change is challenging. Here, this nonstatic environment can compromise safety when the individual using the equipment must perform tasks that are complex or that change under different conditions. An additionally important consideration when selecting protective equipment is the population who will be using it. As an example, when the military selects protective equipment, it assumes a relatively young, physically fit, and compliant workforce. In contrast, the civilian workforce that would normally respond to victims of exposure to a hazardous material consists of individuals with varying body sizes and a wide variety of physical capabilities and fitness. Therefore, the PPE selection process must include all these human variables and characteristics in addition to a complete hazards vulnerability assessment.

There are two types of respirators.[22]

1) Air-Purifying Respirators – Air-purifying respirators (APRs) use canister or cartridge filters designed to remove specific agents from ambient air. Individuals inhale air through the cartridges, removing the contaminant. These respirators only protect wearers when the filter selected is designed for the specific hazardous agent encountered. An APR fitted with canisters designed to absorb ammonia may not provide adequate protection against organic vapors. In addition, the concentration of the toxic substance must not exceed the filter's capacity and there must be adequate oxygen in the environment. Surgical masks are not respirators; however, they can be used as PPE for some biological agents and/or infectious agents that do not remain suspended in air. APRs include those that incorporate the filter as part of the mask, use cartridges or canisters, or use a powered device to move air through the filters. These later devices are known as powered

Figure 13.1. APR and PAPR with hood. See color plate.

APRs or PAPRs. Level C protective ensembles frequently use PAPRs to provide filtered air (Figure 13.1).

2) Atmosphere-Supplying Respirators – Atmosphere-supplying respirators provide clean air directly to the user from a source other than the ambient air. The two most common delivery systems use either bottled air carried by individuals typically on their backs (self-contained breathing apparatus [SCBA]) or air supplied by a hose from a fixed source (see Figure 13.2). These respirators are used in level A and B protective ensembles.

The National Institute for Occupational Safety and Health (NIOSH) is another U.S. federal agency that works with OSHA to maximize workplace safety. NIOSH has determined that APRs employed in chemical, biological, radiological, and nuclear (CBRN) events should not be used in atmospheres in which hazard concentrations exceed IDLH levels or oxygen is deficient (containing $<$19.5% oxygen). Guidelines established by NIOSH dictate that if healthcare workers encounter an unknown hazardous material or high concentrations of known toxic agent (IDLH environment), the user should immediately leave the area. Under these conditions, NIOSH's respiratory protection guidelines, which are supported by OSHA, dictate that use of the most protective respiratory protection (i.e. level A) is indicated until a determination is made that a lower level of protection can safely protect the user. NIOSH has published detailed user guidance for the CBRN APR. In 2004, the Department of Homeland Security adopted the NIOSH criteria for testing and certifying respirators for protection against CBRN exposures. In a scenario in which the agents or their concentration cannot be determined in advance, use of atmosphere-supplying respirators instead of APRs is required.[23]

Figure 13.2. Atmosphere-supplying respirators: SCBA and supplied air shown with level B suits.

There are some CBRN agents that may not cause immediate symptoms in victims when exposure occurs but can result in later impairment.[23] Therefore, it is imperative to obtain adequate advanced information whenever possible and have the correct respiratory protection available. Postponing respirator selection decisions until the effect of an agent is observed can create additional variables that reduce safety for the user and those in the immediate vicinity. Nevertheless, when individuals wear assigned PPE for a specific operation or environment, program administrators need to monitor the environment and may need to adjust protection due to changing conditions.[24] In the U.S., OSHA regulations specify that civilian employees use only NIOSH-approved respirators.[25] A NIOSH-approved respirator has a certification number and specific instructions for appropriate use. These instructions are printed on the manufacturers' containers as a condition for the safe use of their product; however, OSHA acknowledges that unique situations can arise. Therefore, they state in their respiratory protection standard that they will examine, on a case-by-case basis, situations involving the use of non-NIOSH-tested respirators. An example of such a situation is the use of respirators approved by other federal agencies against unique contaminants.[26] NIOSH approval is such an

Figure 13.3. NIOSH-approved N95 respirator. See color plate.

important endorsement that the Defense Logistics Agency in the United States recognizes the need for nonmilitary personnel under their employment to use respirators with NIOSH certification.[27]

Bacteria and viruses are particulate elements that can be removed by specifically designed filters.[28] Most of these devices are either N95 respirators (Figure 13.3) or designated high-efficiency particulate air (HEPA) filters (Figure 13.4). N95 devices can remove 95% of oil-free particulate aerosols 0.3 μm in diameter and HEPA filters can remove at least 99.97% of airborne particles of the same size. Most bacteriological agents can be filtered with an N95 respirator. As the agent becomes smaller, for example some viruses, there are greater demands placed on the filter and HEPA respirators may be more appropriate. Additionally, not all hazardous biological agents require a respirator for protection due to the nature of dispersal, e.g., large droplets. Surgical masks are sufficient in these situations.

Particulate respirators are not likely to reaerosolize biological particles collected by the filter. There is no evidence that biological particles can become an aerosol hazard again after impacting a respirator filter.[29] Conversely, a respirator's outer surface area may be contaminated and can be a tactile hazard, so effective infection control procedures are mandatory.

Radiological agents can also pose the hazard of internal contamination if such particles are inhaled. Based on the particulate size, filtration by surgical mask, N95 respirator, or HEPA filters is usually effective. PPE should start with the most protective level and can be reduced based on an on-site hazard assessment. In summary, particles act in a manner consistent with their physical nature, which is why particulate filter selection logic can be the same for any type toxic particle.

Figure 13.4. NIOSH respirator with HEPA filters. See color plate.

Repeated use of respirators by employees is allowed when the manufacturer specifies that the respirator is designed for that application. Repeated use of respirators refers to the redonning of a respirator by the same employee without removal from service. In other words, the employee dons, removes, and then redons the same respirator during a single event. This behavior is acceptable as long as the respirator can maintain an airtight seal between the face and mask.

Training is required for those administering a respirator program, as well as for those who will wear the devices. There are no specific respiratory protection program training requirements for such an administrator, even for the performance of fit tests. Consequently, OSHA has created regulation 29 CFR 1910.134(c)(3). It states that a program administrator must be "qualified by appropriate training or experience that is commensurate with the complexity of the program to administer or oversee the respiratory protection program and conduct the required evaluations of program effectiveness." Simply stated, those performing fit tests are required to have the necessary training to perform that function and OSHA considers training to be both formal education and performance-based instruction. Details on respiratory protection courses are available from OSHA's web page.[30]

A major disadvantage of equipment providing respiratory protection is that it requires an airtight seal against the face to function. An important exception is the PAPR that uses a hood instead of a mask to deliver filtered air. Devices such as an N95 respirator, many PAPRs, and SCBAs must be fit-tested to provide proper protection. Fit testing is required for all respirators that rely on an airtight seal between the mask and face. An annual check of this seal is necessary with either qualitative or quantitative methods to determine whether the respirator provides an acceptable fit. This is the primary component of a respiratory surveillance program. The qualitative fit-test procedures rely on a subjective detection (taste, irritation, or smell) by the respirator wearer of a particular test agent. If the respirator fits properly, individuals cannot detect the test substance to which they are exposed. The quantitative fit-test procedures utilize measuring instruments to determine if there is a leak between the face and respirator.

The relative workplace exposure level determines what constitutes an acceptable fit and which fit-test procedure is required. Negative-pressure APR users may rely on either a qualitative or a quantitative fit-test procedure for exposure levels less than 10 times the occupational exposure limit. Exposure levels greater than 10 times the occupational exposure limit must use a quantitative fit-test procedure for these respirators. Fit testing of tight-fitting atmosphere-supplying respirators and tight-fitting PAPRs should be accomplished by performing quantitative or qualitative fit testing in the negative-pressure mode.

Beyond consistently using the equipment correctly, the seal or fit of a respirator becomes more important as the toxicity and concentration of the hazardous agent increases. When the fit is compromised, air, like water traveling down hill, will take the path of least resistance. The result is air traveling around the filter and some level of unfiltered contaminated atmosphere being inhaled. Additionally, the use of a tight-fitting respirator can have a negative medical impact on individuals who already have diminished lung capacity. This is one reason OSHA advises that a medical assessment be performed before providing a worker with a respirator.[31]

The need for a functioning seal is emphasized by both the certifying agency (NIOSH) and the products manufacturers. It is evident that during emergency incidents, seals are often not maintained by users who have not undergone extensive training. The only exception to the fit testing of respirators designed to have a facemask seal is when respirator use falls under the voluntary provisions of the OSHA respiratory protection standards (29 CFR 1910.134). A beard of facial hair of more than 1 day's growth that comes between the sealing surface of the respirator and the face is considered by OSHA to potentially compromise the respirator fit.[31,32] If the employee detects a leak in the respirator, the employee must leave the respirator use area, and the employer must replace or repair the respirator before allowing the employee to return to the respirator use area.[33] Equipment such as corrective glasses or goggles or other PPE cannot be worn in a manner that interferes with the facemask seal.[34]

Although PPE is accepted as a necessary tool for the protection of individuals exposed to hazardous agents, implementing the use of PPE is not easy. The number of variables that must be addressed and the potential for problems to arise with the equipment dictate the need to proceed with caution when using this method of protection. According to a 2002 U.S. Bureau of Labor Statistics survey, there were 3.3 million employees using respirators. Only approximately half of those workers, however, knew why they were wearing the respirator or were taught how to use it properly. Describing the emergency response work following the U.S. terrorist attacks of September 11, 2001 the publication *Protecting Emergency Responders* states, "One special-operations panelist described his APR as 'nothing but a cup sitting there under your chin' collecting dust that he would breathe into his lungs when he put the mask back on."[35]

RECOMMENDATIONS FOR FURTHER RESEARCH

The use by hospital personnel of PPE is relatively new. As such, most of the recommendations regarding selection of appropriate equipment are based on consensus. Currently, limited research exists that offers evidence for the best PPE for healthcare workers. In addition, most of the equipment available was designed for military or industrial use. While this chapter has described levels A through D PPE, other classification systems exist that may be country specific or applicable to certain sectors, e.g. the U.S. military's Mission Oriented Protective Posture or MOPP gear. In a hospital setting the ideal equipment that meets personnel requirements should, at a minimum, be lightweight, provide a reduced amount of heat stress, permit maximal dexterity, facilitate verbal communication, and ensure rapid donning. A hospital (or level H) suit that provides all of these important features and characteristics does not currently exist. Development of a level H suit in the future would significantly improve the care of contaminated victims.[36] The military continues research and development on PPE emphasizing many of the characteristics required for use by hospital personnel. As a result, efforts to ensure the military technology is available for use in the civilian healthcare sector must be supported.

In recent times, new approaches to respirator design have resulted in the development of improved respiratory protection. Standard facemask-style respiratory devices have a variety of limitations in the healthcare setting, such as field of vision limitations, claustrophobic reactions, and fit-test requirements. The hood-style mask eliminates many of the limitations associated with devices that must seal against the face and appears to improve respiratory protection. By combining the hood-style mask with a blower unit, researchers have found improved results in the level of respiratory protection. Ongoing research through a U.S. and Israeli joint venture, known as the Agreement on Cooperative Research and Development Concerning Counter-Terrorism, incorporates the hood-style mask with a blower unit. The result from the combination hood-style blower system has achieved protection factors of 50,000 in preliminary test results.[37] Continued research and development is focusing on a design that will enhance the best features of both technologies for chemical/biological protection.

Although research and development to further improve technologies and capabilities is required if healthcare personnel are to protect themselves and the healthcare infrastructure, it is also equally important that all healthcare personnel be trained and educated on the use of PPE and decontamination techniques. Educating and training a select few who will serve on a specialized "Decon Team" may be shortsighted. Planning for any scenario that will create victims in numbers greater than the one or two patients most healthcare facilities are prepared to handle will require participation by a wide range of healthcare personnel. Education and training designed for all personnel is needed.

Additional Background Information

NIOSH Respirator Selection Logic (RSL) 2004

"This RSL is not intended to be used for selection of respirators for protection against infectious agents or for chemical, biological, radiological, or nuclear (CBRN) agents of terrorism. While respirators can provide appropriate protection against these agents, the information necessary to use the selection logic is generally not available for infectious disease or bioterrorism agents (e.g., exposure limits, airborne concentration). Similarly, CBRN terrorism events may involve chemicals that can quickly degrade respirator materials or have extremely low toxic levels that are difficult to measure."[38]

29 CFR 1910.134(d)(1)(iii) states, "Where the employer cannot identify or reasonably estimate the employee exposure, the employer shall consider the atmosphere to be IDLH."

29 CFR 1910.134(d)(2)(ii) states, "Respirators provided only for escape from IDLH atmospheres shall be NIOSH-certified for escape from the atmosphere in which they will be used."

OSHA's preamble states, "Although the Department of the Army argued strongly for OSHA recognition of Army authority to test and approve respirators, the Department of the Air Force commented that it uses only NIOSH-certified respirators, and requested no exception (Ex. 54–443A). OSHA will examine on a case-by-case basis those situations involving civilian contractors whose employees wear non-NIOSH tested respirators that they believe protect employees adequately and have been tested and approved by other Federal agencies and/or departments for use against unique contaminants."[39] NIOSH has indicated that some CBRN agents may not present immediate effects from exposure, but can subsequently result in impairment, illness, or death.[40]

The 0.3-μm diameter used in the certification testing is approximately the most penetrating particle size for particulate filters. Although it seems contrary to expectation, smaller particles do not penetrate as readily as 0.3-μm particles.[40]

NIOSH Guide to Industrial Respiratory Protection, Publication No. 87–116 states, "Respirator selection is very complex and should be performed by an Industrial Hygienist or other professional knowledgeable in respiratory protection devices."[41]

OSHA provides guidance concerning the selection of those responsible for respirator use. Inspection Procedures for the Respiratory Protection Standard (CPL 2–0.120): "Program Administrator: A 'respiratory protection program administrator' is required to oversee and evaluate the respirator program. This individual must be suitably trained and have the appropriate accountability and responsibility to manage the full respiratory protection program."[31] Where significant program deficiencies are discovered, compliance officers should discuss questions about the program with the program administrator to determine how familiar the program administration is with respirators, the hazards in the workplace, respirator use in the facility, the respirator standard, and the company's respirator program.

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Decontamination

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DEFINITION OF DECONTAMINATION

Decontamination is the reduction or removal of contaminating material by a dilutional, chemical, and/or mechanical process. It should be performed whenever there is likelihood of contamination or risk of secondary exposure.

In general, decontamination is accomplished by removing the victim's clothing followed by copiously rinsing the patient with tepid water.[1] Gently scrubbing the skin with soap and a soft brush removes any remaining fat-soluble chemicals and solid materials. Eliminating contaminants from a victim's skin and clothing is important for two reasons. It reduces the risk for further absorption or inhalation and the subsequent toxicity caused by the offending agent. In addition, decontamination helps to prevent others from becoming secondarily exposed or contaminated.[2]

The degree of decontamination performed depends on the situation. In general, removing and bagging the victim's clothing eliminates 60%–90% of the contaminants (depending on the extent of clothing worn at the time of exposure) and minimizes the risk of spreading the toxic agent to others.[3,4] This initial step in the decontamination process should always be performed regardless of the agent or setting. Depending on the availability of resources, the victim's symptomatology, and the availability of resources, additional decontamination measures may be necessary.[2]

In this chapter, discussion will be limited to the decontamination of humans after exposure to a hazardous substance. Issues related to regulatory standards, personal protective equipment (PPE), and training are addressed elsewhere.

OVERVIEW

Hazardous materials, in various forms, quantities, and configurations, are ubiquitous. They are incorporated into communities in the form of manufacturing, commercial and retail establishments, medical facilities, and laboratories, as well as in various configurations in the home. Hazardous materials also move through communities in the transportation process, by truck, rail, ship and pipeline. For example, in the United States, over 800,000 shipments of these materials occur daily – more than 90% of which occur via highways.[5] Europeans spend approximately 40 billion Euros per year managing the logistics of shipping nearly 2 billion tons of chemicals across their continent (i.e., 8% of the total volume of freight shipped).[6] Modern societies must use hazardous materials to produce goods and services vital for healthy living and a robust economy. An often overlooked byproduct of this economic growth is the creation of hazardous waste. In Canada alone more than 3 million tons of it is generated yearly.[7]

The potential for an environmental release of a hazardous material, regardless of etiology, is significant. In the U.S. there are approximately 850,000 facilities that manufacture, store, or use hazardous or extremely hazardous substances. Many of these sites are located in urban areas with populations at risk exceeding 1 million.[2] In 2004 more than 7,700 acute releases of hazardous materials were reported to the U.S. Agency for Toxic Substances and Disease Registry in 15 states. During this reporting period, 620 events (8.0% of all reported events) resulted in a total of 1,838 victims, 41 of whom (2.4%) died. The most frequently reported injuries were respiratory irritation, headaches, and dizziness/central nervous system symptoms. Health officials ordered evacuations during 499 (6.4%) events.[8]

Individuals may become contaminated through direct contact with chemicals in their various physical states (vapor, gas, mist, liquid, or solid) or from others who are already contaminated. In most cases of airborne releases, simply evacuating persons from the source and removing their outer clothing when possible is sufficient to prevent further exposure or injury.[9–11] Clothing can act like an occlusive dressing; failure to remove it quickly after chemical exposure may prevent the evaporation of volatile skin contaminants.[9] In chemical mass casualty incidents, procedures geared toward detaining ambulatory victims near the scene to direct them through a mass showering system (e.g., tents or trailers) needlessly delays evacuation and treatment. This commonly practiced approach may inadvertently increase the potential for harm to the victims as well as to the first responders and the first receivers caring for these individuals.[9,12]

Those contaminated with liquids or solids require copious skin lavage and wound irrigation with water within minutes of skin contact to minimize the degree of injury. Rinsing the patient with a high-volume, low-pressure water source dilutes, neutralizes, and helps rid the skin of reactive surface contaminants. In the case of corrosive agents, decreasing the duration of skin contact helps restore tissue to its normal pH, thereby minimizing the incidence of full-thickness burns.[9,13–17] Using soap to help emulsify fat-soluble agents and a soft brush to remove mechanically any remaining solid materials is also beneficial.

The intensity of chemical injury is based on a number of factors, including concentration and reactivity of the agent, pH, duration of skin contact, and the integrity of the skin.[9,16,18–20] When the duration of skin contact is prolonged, the potential for tissue damage, agent absorption, and systemic toxicity is increased. Pesticides, hydrogen fluoride, and phenolic substances rapidly penetrate the skin and enter the general circulation (e.g., malathion penetrates the skin almost immediately upon contact).[20] Corrosives and solvents damage the outer skin layers within minutes, yet beneficial effects have been seen even when irrigation was delayed up to 1 hour.[9,14] It appears that treatment within an hour of injury is critical in reducing the severity of burns.[9,13,14] Decontamination beyond this "golden hour" is most beneficial in reducing the risk of secondary contamination of emergency personnel and may offer some psychological benefit to exposed patients.

Water reacts exothermically when combined with metallic substances such as sodium, potassium, lithium, cesium, and rubidium, and its use is contraindicated when these rare agents are present or suspected. Other agents such as white phosphorus, sulfur, strontium, titanium, uranium, zinc, and zirconium will ignite on contact with air. If any of these materials are present they will react with the ambient air and the moisture on the victim's skin until the proper method of decontamination is performed. After these exposures, despite the potential for reactivity, quickly removing the victims' clothing and flushing them with large volumes of water should minimize the injury.[21]

Decontamination for radiological agents is the same as used for chemicals. Stable patients should have their clothing removed and double bagged, followed with a soap and water showering. Unstable victims, or those with life-threatening injuries, should have gross decontamination (i.e., clothing removal) performed quickly so life-saving interventions can be initiated immediately. The presence of radioactive materials is of minimal risk to providers and should not delay these activities. Specialized detectors can confirm and measure the presence of radiation as well as serve as a guide to the effectiveness of the decontamination process.

The proper decontamination procedure for biological agents has not been established. Historically, these agents were classified as nonvolatile and exhibited no absorption capability in the presence of intact skin. They were also thought to pose minimal risk of re-aerosolizing, a belief that changed after the intentional release of anthrax through the U.S. Postal Service in 2001. In general, a biological agent exposure does not require decontamination, although it is worthwhile to instruct patients to remove and wash their clothing and take a shower at home. If dermal or mucous membrane contamination is suspected, the area should be thoroughly irrigated with water.

The science of decontamination is in its infancy. Much of the current knowledge surrounding decontamination and the management of the contaminated patient is based primarily on anecdotal evidence, personal experience, and common sense. The U.S. military and fire services have contributed considerably to the procedural approach to the contaminated patient; however, research designed to advance knowledge on the proper care of the contaminated patient does not lend itself to placebo-controlled, double-blind studies. As a result, the advantages of using water in the decontamination process are derived indirectly from studies of burns. This research demonstrated the benefits of hydrotherapy on cutaneous skin pH and clinical outcomes when experimental skin models were contaminated with harsh chemicals.[13–16] The urgency of decontamination after exposure is derived from measuring chemical absorption rates in animal skin models.[16,17,19] Finally, the essential role of clothing removal in the decontamination process is based on studies using clothed manikins where evaporation rates and exposure levels of volatile agents are easily measured.[22] Despite these advances, a number of questions remain.

HOW CLEAN IS CLEAN?

The effectiveness and completeness of decontamination is difficult to measure objectively. The goals of decontamination are to terminate a substance's harmful effects on the patient (eliminate continued absorption), reduce the risk of secondary exposure/contamination to other people and to eliminate the need for an advanced level of PPE (beyond standard precautions) for caregivers working in the treatment area. Yet it is difficult to determine when decontamination efforts are sufficient to achieve these goals and can therefore be stopped. This concept has been expressed by the phrase "how clean is clean?" In most instances, a thorough washing with soap and water accomplishes this objective; however, some insoluble chemicals are resistant to soap and water decontamination and other primary decontamination agents must be identified. For example, tars and heavy oils require the use of petroleum-based solvents (e.g., petroleum jelly, mineral spirits, or vegetable oil) to degrade the agents, followed quickly by standard soap and water decontamination.

Clinical determination of the effectiveness of soap and water decontamination is unreliable because symptoms may persist despite adequate decontamination. Likewise, victims cannot be continuously decontaminated until symptoms resolve. The longer they remain in the system, the more wastewater is generated and the more resources are consumed. Furthermore, responders cannot wear advanced levels of PPE indefinitely because it impacts body temperature, hydration status, and stress levels, and may lead to injuries such as falls. An unnecessary prolongation of the decontamination process may divert personnel resources from other critical services.

Studies have indicated that 5–6 minutes of thorough decontamination is adequate to dilute and remove most contaminants. Some chemicals, such as ammonia and chlorine, are highly water soluble and will virtually disappear within the first few minutes of decontamination. Human senses, however, may still detect the presence of various agents even though the actual skin concentration is well below a harmful threshold as confirmed by studies of swab samples from specific areas of the victim's body pre- and postdecontamination.[23]

The process of decontamination also influences its effectiveness. Washing in a head-to-toe manner reduces the likelihood of drawing contaminants from the lower extremities back into vital areas such as the face, eyes, and airway. Also, irrigating open wounds first and covering them with water occlusive dressings reduces the amount of contaminated wash flowing into the wound. Similarly, a thorough washing of the victim's hair and other body recesses reduces the retention of contaminants.

All devices applied to the patient at the initial site of exposure (e.g., cervical collars, splinting devices, backboard, and intravenous lines) should be considered contaminated and ought to be either replaced or cleaned during the decontamination process. It is clearly disadvantageous to focus efforts solely on decontaminating the patient's skin while contaminants may remain on these devices.

Decontamination effectiveness is directly correlated with the patient's ability to self-decontaminate, evidence-based, standardized protocols and procedures, and the identification of the contaminants and their properties. Individuals who are able to walk into a shower and clean themselves receive a more thorough decontamination than nonambulatory individuals. Although detectors are available for chemical and biological agent identification, they play a very limited role in determining the effectiveness of decontamination. Radiological detectors, on the other hand, are more prevalent and have a defined role in decontamination.

Other agents such as bleach and specialized soaps have very little impact on the overall effectiveness of decontamination. Soap and water has clearly been shown to be the most effective and readily available decontamination solution. Nonabrasive liquid soap should be used and should not contain perfumes, lanolin, or other additives.

In addition to soap, water temperature dramatically impacts the effectiveness of decontamination. Cold water reduces victim compliance and may make some agents more viscous and difficult to remove. Showering in cold water may also trap volatile contaminants in constricted skin pores, increasing the likelihood that release of these agents from the skin will continue (i.e., off-gassing) once the victim is removed to a warmer environment such as the emergency department. In addition, cold water may lead to hypothermia in victims, particular in cooler climates. On the other hand, victims suffering from skin lesions or burns may not tolerate hot water. Water at an elevated temperature may also cause pores to open thereby increasing the skin's surface area and absorption rate of the agent. Tepid water is the ideal temperature for optimum results.

WHEN SHOULD EARLY TREATMENT/ STABILIZATION SUPERSEDE COMPREHENSIVE DECONTAMINATION?

Aggressive patient treatment must be balanced with caregiver protection. Intuitively, the sicker the patient the greater perceived need for emergent intervention. If, however, the victim's critical injuries or state of distress is a direct result of chemical exposure, the responders must don appropriate PPE prior to providing care or they may become victims themselves. This key principle is counterintuitive to the normal desire to provide immediate aid to the victim.

Responders should provide emergent patient care simultaneously with decontamination; however, the advanced level of protection required in most decontamination scenarios dramatically affects the caregiver's ability to render care. In most circumstances, basic life support skills such as maintaining a patent airway, stabilizing a fracture, and controlling significant bleeding can be accomplished concurrently with providing decontamination. Advanced life support techniques, however, must often be delayed until immediately after decontamination when caregivers can wear a reduced level of protective attire (e.g., standard precautions) that allows them greater mobility, dexterity, sight, and hearing.

In some circumstances, previously exposed staff, such as emergency medical services personnel who transported the patient, may be called on to provide additional stabilization before patient decontamination to increase the chance that the patient will survive through the decontamination process.

WHO PERFORMS DECONTAMINATION?

With a proper system in place, the vast majority of contaminated victims are ambulatory and can be guided to remove their own clothing, package and manage their personal valuables, and thoroughly wash themselves. Creating an environment where decontamination can be self-administered is essential. Some individuals are debilitated to the point at which responders must assist or intervene in the decontamination process.

Although some patients require total assistance, others may have only minimal injuries or existing conditions that inhibit their ability to ambulate through the decontamination process. Placing these individuals on backboards and accompanying them through decontamination is labor intensive, potentially dangerous to the caregivers and victims, and may be a less effective means of fully removing the contaminants compared with aggressive self-decontamination.

Patients who can walk with assistance and sit unattended can be categorized as semiambulatory. These individuals may be placed in chairs inside the decontamination unit and in most circumstances can thoroughly wash all accessible areas themselves with minimal intervention or assistance. Decontamination team members in appropriate PPE should wash those areas of the body that are not readily accessible to the patients themselves. Once complete, victims can then be assisted out of the decontamination area to an awaiting wheelchair or other mobility device. This simple procedure reduces the physical demands placed on responders and may be inherently safer for the patient.

WHO SHOULD BE DECONTAMINATED?

Anyone suspected of being acutely exposed to or contaminated by a potentially toxic material whether it is chemical, biological, or radiological should be provided adequate decontamination. Decontamination procedures vary depending on the type and degree of exposure. For example, those individuals exposed to vapors require only clothing removal, whereas persons contaminated from direct contact with hazards require clothing removal followed by aggressive washing with soap and water.

WHAT INFORMATION RESOURCES ARE MOST USEFUL IN AN EMERGENCY DECONTAMINATION OPERATION?

Planners should identify decontamination resources prior to an event. These may include chemical databases (e.g., Internet based), information from government authorities, and phone numbers for Poison Control Centers. Responders should participate in pre-event exercises that include how to access key information so that the process becomes second nature when an event occurs. Although external resources may offer vast amounts of information, the decontamination process should not be delayed while awaiting this intelligence. In the case of a hazardous material exposure from a transportation incident, vehicle placards are useful to help determine the type of substance involved. In addition, the patient may be a good source of information regarding the nature of the exposure, its related toxicity, and the number of other victims.

IN A CHEMICAL MASS CASUALTY INCIDENT, IS CLOTHING REMOVAL SUFFICIENT?

Historically, mass exposure to chemicals has been due to agents in the form of a vapor or gas. In the majority of circumstances (>80%) the survivors are ambulatory and have had minimal to no symptoms once they have evacuated the immediate release area.[24] Once patients are removed from the vapor source, the chemical agent remains on the clothing, but its effects on the skin, eyes, and lungs typically dissipate quickly.[9,10] Clothing removal essentially completes the decontamination process. Although some may consider soap and water showering to be ideal after a chemical exposure, when large numbers of casualties are involved, the time and resources needed to initiate and complete the process successfully must be weighed against the marginal benefit that results. Resources that are diverted to shower minimally impacted, ambulatory victims may not be available for the rescue and care of the nonambulatory survivors whom the release affects most severely.[9]

STATE OF THE ART

Although several advances in the field of decontamination have been reported in trade papers and by manufacturers, very few peer-reviewed scientific publications are available regarding the state of the art. Notable works include publications on disaster planning for medical facilities and the need to use the best available evidence for disaster planning. However, peer-reviewed articles specifically focusing on decontamination methods and evidence are rare.[25–27] Due to the paucity of scientifically rigorous publications in the field, a synthesis of review papers and expert consensus serves as the best available scientific evidence.

The ideal approach to decontamination consists of several key steps

- Rapid recognition that a contaminant is present
- Identification of the contaminant (or its basic properties if identification is not immediately possible)
- Prevention of further contamination
- Stabilization of victims' immediate medical conditions
- Removal of contaminant from victims
- If appropriate, preservation of evidence
- Removal of contaminant from the environment
- Disposal of contaminant

RECOGNITION OF A CONTAMINATION EVENT

Recognizing that contaminated victims are present is the first critical step for a successful decontamination program. Several clues may help first responders determine that victims of an event are contaminated. These include identifying of a constellation of signs and symptoms that suggest a specific poisoning class (i.e., toxidrome), observation of suspicious materials, previous warnings of a contamination event, or labels identifying contaminating agents as present in the response area. Upon recognition of a contamination event, first responders must activate a coordinated response, which rapidly removes victims from the contaminated area and contaminant from the victims. These steps must occur while providing for stabilizing medical care and protecting responders and public safety. It is also incumbent on responders to recognize that victims may present with symptoms without a known exposure; even if it is determined that a particular victim is definitely not exposed to the contaminant, symptoms consistent with psychogenic illness may be present and necessitate treatment.[28] In the initial aftermath of an exposure, it may be difficult to determine whether patients have actually been contaminated or are merely concerned about contamination and exhibiting symptoms. Resources must be available for patients who have not been truly exposed as well as for those who have.

IDENTIFICATION OF CONTAMINANT

Although general decontamination measures can proceed without contaminant identification, determination of the specific material can focus decontamination methods and make the process more efficient. In some cases, it can also increase safety for victims and responders. For example, certain metals are explosive when mixed with water; as water is the most common choice of decontamination agent, failure to identify these metals as the contaminant could prove dangerous.

The most reliable method of identifying a contaminant is to have advance knowledge of which contaminants are present in the environment where the exposure occurred. This is feasible in the context of laboratory or research settings, as well as incidents involving properly labeled shipments of hazardous materials or those occurring at regulated industrial sites. In the setting of a criminal act or a release at an unregulated site, it is much less likely that responders will have advance knowledge of the contaminant.

Detectors for various chemical and biological agents exist, but suffer from imperfect reliability. Recognition of a specific toxidrome is potentially the most reliable method for rapidly identifying the class to which a particular chemical contaminant belongs. Biological contaminants, by virtue of causing disease, may be more recognizable by the presentation of victims; however, their usually delayed presentation may make overall recognition of a biological release event more difficult. Radiological contaminants can be easily identified by the use of radiological detectors such as Geiger counters.

If witnesses to the contamination event are able to identify the phase of a chemical contaminant (i.e., solid, liquid, or vapor/gas), the decontamination process can be further streamlined. Patients exposed to solid/powder and liquid contaminants will benefit from soap and water decontamination, whereas vapor/gas contaminant exposure, in general, requires only clothing removal to mitigate further injury to the victims or threat to responders.[9]

PREVENTION OF FURTHER CONTAMINATION

A basic tenet of emergency response is ensuring scene safety; failure to ensure the safety of responders and other nearby persons risks the creation of more victims. Contaminated persons and items should be kept separate from non-contaminated persons and items. PPE should be used at all times (discussed further in Chapter 13). Guidelines from several countries state that when faced with an unknown contaminant, the highest available level of PPE should be used.[29–32] Identification of the contaminant will likely allow the use of a lower level of PPE. There is no current consensus on which PPE level should be used when medical procedures are urgently indicated on contaminated patients; studies have been performed indicating that higher-level protection may significantly impair the ability of medical personnel to perform life-saving procedures such as airway stabilization or obtaining intravenous access for medication administration. The creation of a hospital-specific category of PPE to help maximize procedural ability and minimize risks to hospital staff has been suggested.[1]

STABILIZATION OF ACUTE MEDICAL CONDITIONS

An ongoing debate exists as to the level of medical treatment that responders should provide prior to and during decontamination. In general, life-saving care such as airway management should be provided, if possible, even if decontamination has not been completed. It is critical, however, to maintain responder and civilian safety while performing these interventions. If a treatment cannot be provided without contaminating and therefore endangering responders and other persons, that treatment should be withheld until safety can be reasonably assured. Treatment that can safely be deferred should be delayed until the patient has been decontaminated. Ideally, decontamination should occur at (or close to) the incident scene(s), with transport of victims occurring after decontamination; this approach minimizes the spread of contaminant. This ideal must be balanced with the need to remove victims promptly from a contaminating source to minimize further contamination.[9] In addition, victims may self-present to healthcare treatment sites distant from the site of exposure without first undergoing decontamination. Hence, first-receivers must be prepared to decontaminate victims.

In addition to people, transportation vehicles and medical equipment applied to or used on victims may become contaminated (unless the contaminant is a vapor or gas). Accordingly, replacement equipment (e.g., cervical collars, backboards, and splints) should be available for exchange at the conclusion of the decontamination process.

REMOVAL OF CONTAMINANT FROM VICTIMS

Several resources exist to describe both general decontamination approaches as well as individual decontamination methods for specific agents.[33–37] A discussion of the complete details for every agent is beyond the scope of this chapter; the focus will be on general decontamination principles.

Koenig coined the term "strip and shower" to describe the most common decontamination method, the use of soap and water after removal of all clothing and other items from a contaminated victim.[1] Although considered largely effective, and relying on inexpensive materials, several logistical concerns are raised when employing this method. Patient throughput (the number of patients that can be decontaminated per hour) may be limited by the availability of private areas with access to running water. In cold weather, stripping and being washed may cause icing injury to responders and equipment and could result in hypothermia if decontamination is prolonged, particularly if warm water is unavailable. Having water available may require the use of high-pressure systems (such as fire apparatus), which could injure people, or, if at a fixed facility, the acquisition of equipment requiring maintenance and capital investment. Privacy is also an issue. Despite these concerns, this technique remains the most common decontamination method in use today.

Dry powder decontamination is an alternative method used in Israel and many other countries to absorb liquid substances. After removal of clothing, a dry powder such as Fuller's Earth (a highly absorbent, claylike earthy material) is applied to the victim. The adsorbent nature of the powder helps remove contaminant from the victim. This method is more cumbersome to apply and requires the availability of the powder. It is an attractive option when the contaminant is a thickened agent, when access to water is limited, or when the agent is known to be reactive with water.

Foam is a more recent innovation for decontamination. Several foam agents are being investigated at the time of this writing. Advantages include less production of waste products, a potential for enhanced skin coverage, and activity against a broad range of agents. Disadvantages include expense and the need to store large quantities of decontamination agent.

Whatever decontamination method is used, orifices, mucous membranes, and injured areas require special attention. In general, these areas should be decontaminated first to most rapidly minimize the continued absorption and effects of the contaminant. Water-based methods are the most rapid and appropriate means of decontaminating these areas.

PRESERVATION OF EVIDENCE

Many contamination incidents will result in investigation by either occupational health and safety agencies or by law enforcement. In either case, contaminated items may be crucial pieces of evidence to assist in investigations. Although preservation of evidence is clearly a lower priority than the preservation of life and health, whenever possible, evidence should be maintained by identifying, isolating, and maintaining the chain of custody for evidentiary items. Because evidence preservation is resource intensive and may not be necessary for a given event, determination that evidence collection is desirable should be made early in conjunction with the appropriate agencies. Procedures may include the removal of personal items from contaminated victims and sealing them in a nonreactive container (a plastic bag will often suffice). Containers should be labeled and maintained in a secure area, or if possible, with the patient. Coordination with the investigating agency/agencies during the early stages of the incident will help determine the need for and extent of evidence preservation.

REMOVAL OF CONTAMINANT FROM ENVIRONMENT

After adequately addressing decontamination and the medical needs of victims, responsible officials should begin a more thorough assessment of the incident scene and surrounding environs.

Although environmental cleaning will almost certainly be conducted by different response crews at a later time, first responders can mitigate later work by their initial actions. For example, directing the flow of water such that entry into watersheds and storm drains is minimized is beneficial in limiting contamination of the environment. As with evidence collection, environmental concerns are a lower priority than the preservation of life and safety.

DISPOSAL OF CONTAMINANT

To assist with environmental protection, medical and health workers should dispose of contaminant and contaminated items in a fashion consistent with safe practices. In the U.S., specialized contractors and governmental agencies are generally better equipped and more familiar with regulatory issues regarding disposal of hazardous waste than individuals or small agencies and facilities. Any waste disposal should be performed with careful attention to regulatory guidance. One particular issue regarding disposal of contaminant is management of wastewater produced during water decontamination. In general, it is preferred that water be contained for later treatment or disposal; however, the U.S. Environmental Protection Agency has issued guidance that in emergency situations with no other alternatives, discharge of wastewater into sewers is acceptable to preserve life. Specifically, avoidance of contaminated runoff "should not impede necessary and appropriate actions to protect human life and health."[38]

SPECIAL CONSIDERATIONS

Decontamination in the Healthcare Facility Setting

Although many community decontamination plans describe methods for providing decontamination at the exposure site, after a mass casualty contamination event, many victims will spontaneously present at medical facilities distant from the location of exposure for treatment.[25,39–42] Treatment of contaminated victims has resulted in injuries to facility medical staff.[41–45] It is imperative that medical facilities have a decontamination program, both for the case in which they receive contaminated victims from a distant location and also for situations in which they are the site of exposure.[46]

Decontamination in the hospital or other healthcare facility setting follows the same principles delineated earlier. A crucial step is to minimize the risk to other patients and to facility staff by minimizing exposure. Decontamination should occur in a designated area with staged equipment to allow for mitigation of the contaminant without the need to move the patient through other areas of the hospital. The designated decontamination area should have restricted access.

Special Populations

Children, elderly, and disabled victims will likely present additional challenges to the decontamination team. Children will have additional difficulty following instructions and may not be developmentally able to participate in self-decontamination measures. The elderly and disabled may also be unable to self-decontaminate due to decreased mobility. Although the basic tenets of medical stabilization and contaminant removal do not change, additional personnel (appropriately protected) may be required to assist these populations. With appropriate safety measures, involvement of the victims' families or caregivers may help alleviate victim anxiety and enhance efficiency of the decontamination process.

Recommendations for Further Research

There is still much that needs to be learned about patient decontamination. Scientific studies are lacking and most current guidelines are based predominantly on personal experience and dogma. Questions for future research include the following:

- How does one measure the adequacy of decontamination?
- Should this determination be based on victim symptomatology, duration of showering time, measurements made from new promising technology, or other parameters?
- Is traditional soap and water showering appropriate decontamination for victims of a chemical mass casualty incident?
- How frequently should healthcare facility staff be trained so that they will maintain their knowledge, skills, and abilities related to the use of PPE, patient decontamination, and other related competencies?
- Is annual training sufficient (as dictated by U.S. federal standards) or does knowledge quickly wane after the initial instruction period?
- Who should be trained?
- In the hospital setting, who predominantly performs decontamination (what level of staff: medical or nonmedical personnel)?
- Does age or sex make a difference? Does currently available PPE and decontamination equipment adequately address the needs of both sexes, various age groups, and the unique demands of the hospital?
- What medical interventions (e.g., airway management, intravenous catheter placement, and insertion of chest tubes) can staff wearing PPE be expected to perform?

Conclusion

A decontamination program must be multidisciplinary and integrated; it requires planning, retraining, and teamwork to be effective. The fact that an exposure has occurred must be recognized early. First responders, first receivers, and facilities must be adequately protected and decontamination must be performed quickly, safely, and efficiently. The involvement of multiple categories of personnel (e.g., medical staff, administrators, trainers, security personnel, and regulatory officials) demands a unified approach including collaborative and detailed pre-event planning. An incident command system, such as that promulgated by the U.S. National Incident Management System, is an excellent framework within which the structure of a decontamination response can be formed. Ongoing training will help ensure that response team members are familiar with their roles and are capable of achieving the goal of rapid contaminant removal and victim stabilization while protecting themselves and the public from injury.

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15

Quarantine

Donna Barbisch and Lawrence O. Gostin

OVERVIEW

Quarantine has been used for centuries to sequester potentially infectious individuals, plants, and animals until they are deemed safe for reintroduction to the rest of society. Criteria for the use of quarantine have often been subjective or based on discriminatory practice; individuals and entire communities were often cast from society and denied access to essential services. Crude efforts have been largely ineffective.[1] Definitive protocols on time and distance necessary to contain the disease are often missing, and the efficacy of differing levels of separation is not well documented. The legal authority to quarantine exists within many jurisdictions worldwide, under many state laws in the U.S. Clear and convincing evidence to support the action is, however, frequently difficult to establish, creating significant concerns over civil liberties.[2] When quarantine is instituted, enforcement poses significant challenges. In addition, there are limited effective plans on how to provide or pay for the secondary effects of quarantine: lost wages, impact on business and services, and logistical support such as food, water, and medical services for those individuals in confinement.

The overall objective of quarantine is to prevent the introduction, transmission, and spread of communicable diseases. The World Health Organization (WHO) has determined that crude methods of quarantine are ineffective. Current guidelines diverge from quarantine and predetermined measures concentrated at borders alone to containment strategies focused on real-time epidemiology and evidence-based data.[1]

Establishing an optimal containment strategy is essential to reduce the progressive adverse outcomes due to person-to-person spread of highly infectious disease. The impact of any quarantine-related activity has the potential to significantly affect a society. Clarifying objectives, defining terms, and establishing realistic policies can effectively reduce the impact of an outbreak of contagious disease.

In a world integrally linked through international travel, questions remain as to whether or not government can effectively separate populations in a timely fashion. How will populations manage when children are separated from their parents? How will essential services be delivered and maintained? Are the existing legal guidelines adequate? Can they be enforced? Is the evidence-based data sufficient to counter the impact on civil liberties caused by an involuntary quarantine? This chapter will review the complexities of quarantine related to three separate but tightly linked perspectives: efficacy; legal authority; and ethical, as well as logistical, challenges in implementation.

CURRENT STATE OF THE ART

Defining Quarantine

Defining and appropriately using terms may resolve some of the ambiguity related to quarantine. Quarantine has often been used interchangeably with isolation and civil commitment. The concept refers to separating the healthy from those with disease and has been seen in Biblical and Koranic references dating back to isolation of lepers. The term quarantine was used in the 14th century when ships were detained for 40 days to protect against "foreign" diseases. The word is derived from the Italian *quaranta* meaning "forty."[1]

The U.S. Centers for Disease Control and Prevention (CDC) provides a fact sheet that distinguishes quarantine from isolation and provides additional data on legislative authorities, enforcement, and historical uses of quarantine within the United States (Figure 15.1).[3] In short, *quarantine* is applied to exposed (potentially infected) persons whereas *isolation* is the term used to denote the process of separation of people who are ill (with confirmed contagious infectious diseases).

Several guidance documents exist to help define or redefine public health emergency issues focused on containment strategies such as quarantine and isolation. In the United States, two model public health laws, the *Model State Emergency Health Powers Act* (MSEHPA)[4] and the *Turning Point Model State Public Health Act* acknowledge that traditional public health powers such as surveillance, quarantine, and isolation are among the most outdated provisions in existing state laws (Table 15.1). From an international perspective, the International Health Regulations 2005 (IHR-2005) addressed the need for revising and

CDC Quarantine and Migration Health

Legal Authorities for Isolation and Quarantine

By Executive Order of the President, federal isolation and quarantine are authorized for these communicable diseases:

- **Cholera**
- **Diphtheria**
- **Infectious tuberculosis**
- **Plague**
- **Smallpox**
- **Yellow fever**
- **Viral hemorrhagic fevers**
- **SARS**
- **Flu that can cause a pandemic**

The President can revise this list by Executive Order.

Isolation and quarantine

Isolation and quarantine are public health practices used to stop or limit the spread of disease.

Isolation is used to separate **ill** persons who have a communicable disease from those who are healthy. Isolation restricts the movement of ill persons to help stop the spread of certain diseases. For example, hospitals use isolation for patients with infectious tuberculosis.

Quarantine is used to separate and restrict the movement of **well** persons who may have been exposed to a communicable disease to see if they become ill. These people may have been exposed to a disease and do not know it, or they may have the disease but do not show symptoms. Quarantine can also help limit the spread of communicable disease.

Isolation and quarantine are used to protect the public by preventing exposure to infected persons or to persons who may be infected.

In addition to serving as medical functions, isolation and quarantine also are "police power" functions, derived from the right of the state to take action affecting individuals for the benefit of society.

Federal law

The federal government derives its authority for isolation and quarantine from the Commerce Clause of the U.S. Constitution.

Under section 361 of the Public Health Service Act (42 U.S. Code § 264), the U.S. Secretary of Health and Human Services is authorized to take measures to prevent the entry and spread of communicable diseases from foreign countries into the United States and between states.

The authority for carrying out these functions on a daily basis has been delegated to the Centers for Disease Control and Prevention (CDC).

CDC's role

Under 42 Code of Federal Regulations parts 70 and 71, CDC is authorized to detain, medically examine, and release persons arriving into the United States and traveling between states who are suspected of carrying these communicable diseases.

As part of its federal authority, CDC routinely monitors persons arriving at U.S. land border crossings and passengers and crew arriving at U.S. ports of entry for signs or symptoms of communicable diseases.

When alerted about an ill passenger or crew member by the pilot of a plane or captain of a ship, CDC may detain passengers and crew as necessary to investigate whether the cause of the illness on board is a communicable disease.

Continued...

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Figure 15.1. Legal Authorities for Isolation and Quarantine.

updating the IHR on global health security, epidemic alert and response, and the need to ensure global public health (Table 15.2).

MSEHPA specifically distinguishes the word quarantine from the word isolation. Quarantine refers to the physical separation and confinement of an individual or groups of individuals who are or may have been exposed to a contagious or possibly contagious disease but who do not show signs or symptoms of infection. The purpose of such separation is to prevent or limit the transmission of the disease to nonquarantined individuals. Isolation is the physical separation and confinement of an individual or groups of individuals who are infected or reasonably believed to be infected with a contagious or possibly contagious disease. The purpose of this isolation is to prevent or limit the transmission of the disease to nonisolated individuals. The

Legal Authorities, *cont.*

State, local, and tribal law

States have police power functions to protect the health, safety, and welfare of persons within their borders. To control the spread of disease within their borders, states have laws to enforce the use of isolation and quarantine.

These laws can vary from state to state and can be specific or broad. In some states, local health authorities implement state law. In most states, breaking a quarantine order is a criminal misdemeanor.

Tribes also have police power authority to take actions that promote the health, safety, and welfare of their own tribal members. Tribal health authorities may enforce their own isolation and quarantine laws within tribal lands, if such laws exist.

Who is in charge

The federal government

- Acts to prevent the entry of communicable diseases into the United States. Quarantine and isolation may be used at U.S. ports of entry.
- Is authorized to take measures to prevent the spread of communicable diseases between states.
- May accept state and local assistance in enforcing federal quarantine.
- May assist state and local authorities in preventing the spread of communicable diseases.

State, local, and tribal authorities

- Enforce isolation and quarantine within their borders.

It is possible for federal, state, local, and tribal health authorities to have and use all at the same time separate but coexisting legal quarantine power in certain events. In the event of a conflict, federal law is supreme.

Enforcement

If a quarantinable disease is suspected or identified, CDC may issue a federal isolation or quarantine order.

Public health authorities at the federal, state, local, and tribal levels may sometimes seek help from police or other law enforcement officers to enforce a public health order.

U.S. Customs and Border Protection and U.S. Coast Guard officers are authorized to help enforce federal quarantine orders.

Breaking a federal quarantine order is punishable by fines and imprisonment.

Federal law allows the conditional release of persons from quarantine if they comply with medical monitoring and surveillance.

Federal quarantine rarely used

Large-scale isolation and quarantine was last enforced during the influenza ("Spanish Flu") pandemic in 1918–1919.

In recent history, only a few public health events have prompted federal isolation or quarantine orders:

- In 1963, a passenger arriving into the United States was placed under a federal quarantine order as a suspected case of smallpox.
- In 2007, a traveler with drug-resistant TB was placed in isolation.

During the 2003 outbreak of SARS, CDC did not issue isolation or quarantine orders. However, CDC did conduct active surveillance, visual screening of passengers, and handed out Travel Health Alert Notices.

For more information, visit : www.cdc.gov/ncidod/dq

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Figure 15.1. Legal Authorities for Isolation and Quarantine.

MSEHPA defines *quarantine* as "the restriction of the activities of *healthy* persons who have been exposed to a case of communicable disease during its period of communicably to prevent disease transmission during the incubation period if infection should occur." *Isolation* is defined as "the separation, for the period of communicability, of *known* infected persons in such places and under such conditions as to prevent or limit the transmission of the infectious agent." Finally, *civil commitment* is "the detention (usually in a hospital or other specially designated institution) for the purposes of care and treatment."[2] The definitions imply that quarantine applies to the healthy population, and that in the strict interpretation of the term "quarantine," there may be minimal application to patients within healthcare facilities. During the severe acute respiratory syndrome (SARS) outbreak, a

Table 15.1: The Model State Emergency Health Powers Act and the Turning Point Model State Public Health Act are U.S.-based tools developed to assist state and local governments in assessing their public health laws

The Model State Emergency Health Preparedness Act developed in 2001 provides guidance in refining state policy. Developed after the anthrax incidences of 2001, the guidance was offered to assist states in updating antiquated public health law.
It addresses:

Purposes and Definitions
Planning for a Public Health Emergency
Measures to Detect and Track Public Health Emergencies
Declaring a State of Public Health Emergency
Special Powers During a State of Public Health Emergency: Control of Property
Special Powers During a State of Public Health Emergency: Control of Persons
Public Information Regarding a Public Health Emergency

The Turning Point Model State Public Health Act contains templates and checklists designed to assist in public health law reform. It adopts a systematic approach to the implementation of public health responsibilities and authorities, presents a broad mission for state and local public health agencies, and balances the protection of the public's health with the respect for the rights of individual and groups. It addresses:

Purposes and Definitions
Mission and Functions
Public Health Infrastructure
Collaboration and Relationships with Public and Private Sector Partners
Public Health Authorities/Powers
Public Health Emergencies
Public Health Information Privacy
Administrative Procedures, Civil and Criminal Enforcement and Immunities

Table 15.2: The International Health Regulations (2005) (IHR-2005)

Developed by the World Health Organization, the IHR-2005 is a legally-binding agreement providing a framework for the coordination of the management of events that may constitute a public health emergency of international concerns. It was designed to improve the capacity of countries to detect, assess, notify and respond to public health threats. Member States are urged to build, strengthen and maintain the required capacities identified in the IHR-2005 and to collaborate to ensure their effective implementation and to develop the necessary public health capacities and legal and administrative provisions within the regulation. Specifically, the IHR-2005 addresses:

Definitions, purpose and scope, principles and responsible authorities
Information and public health response
Recommendations
Points of entry
Public health measures
Health documents
Charges
General provisions
IHR roster of experts, the emergency committee, and the review committee
Final provisions

number of civil confinement strategies were used. They included medical isolation, home quarantine, work quarantine, travelers quarantine, institutional quarantine, and cordon sanitaire (Table 15.3).[5]

Quarantine has also been referred to as a "contact management strategy that consists of active monitoring plus activity restrictions." Such restrictions can be voluntary or involuntary. The use of quarantine raises legal, social, financial, and logistical challenges that require effective planning and implementation.[6]

Travel restrictions and criteria for quarantine and isolation are identified in the WHO International Health Regulations. As recently as 1994, countries often implemented excessive travel restrictions to thwart the spread of disease resulting in undue economic hardship.[1] The WHO strategic plan has evolved to a proactive risk management process focusing on containment at the source, active surveillance, prompt detection, isolation of new cases, and rapid tracing of contacts. In addition, the plan calls for building capacity to cope with an inevitable pandemic.[1] The IHR were revised in 2005 with an emphasis on evidenced-based data, taking a strategic approach to the public's health.[7] IHR-2005 are designed to "prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade."[8] The IHR-2005 were implemented on June 15, 2007. As of February 5, 2008, 194 States were parties to it.[9] The WHO believes that the strategic shift from "control at the borders to containment at the source; from a list of diseases to all public health threats; from preset measures to an adapted response – will require a shift in understanding that will take time to assimilate."[1] The IHR-2005 focuses on early identification and intervention based on appropriate decision making. Annex II of the IHR-2005 depicts the decision instrument for the assessment and notification of events that may constitute a public health emergency of international concern (Figure 15.2).

The concept of separating highly contagious individuals from those susceptible is a sound principle for limiting the spread of infection; however, the execution of policies to maintain the separation during the time of infectivity is riddled with critical points of failure. Research suggests that quarantine can be effective given a compliant community and appropriately managed resources.[1]

A comprehensive containment strategy should include elements of quarantine, but must acknowledge that quarantine alone will not prevent the spread of disease. Operational shortfalls exist if planning is done without considering the larger context of the disease outbreak; the execution of limited strategies will result in critical points of failure. Global travel, quarantine enforcement, employment and financial considerations, and the population's medical needs have the potential to obviate a quarantine plan. In addition, a host of logistical support issues affecting those confined, as well as the impact on individuals who rely on confined personnel for life support, must be considered when projecting the efficacy of quarantine.[10]

Historically, it has been noted that crude quarantine measures were largely ineffective. No data exist to discern the impact of modern quarantine methods in realistic environments. More recently, quarantine implementations have occurred in an environment associated with improved public health responses. As such, quarantine has been accompanied by improvements in sanitation, mass immunization, and epidemiological investigation.

Table 15.3: Efficacy of Differing Civil Confinement Strategies

Type	*Pros*	*Cons*	*Efficacy*	*Control*
Isolation	■ Known infectious patient ■ Closely monitored	■ Lack of capacity for large scale events	Widely accepted as effective	Compulsory or voluntary
Home quarantine also called: ■ self quarantine ■ sheltering in place ■ snow days	■ Less onerous ■ Logistically simpler ■ Socially and politically acceptable	■ Difficult to monitor and enforce ■ May place family members at risk ■ Requires significant logistical support, e.g., for medical care, heating, food, and water	Thought to be effective	Voluntary but could be compulsory
Work Quarantine (generally for healthcare workers: permitted to work, but restricted to home when not working)	■ Keeps essential employees at their jobs ■ Closely monitored	■ Risk of transmission of infection to vulnerable patients congregated together	Unknown	Voluntary but could be compulsory
Travelers Quarantine	■ Addresses the risk of transmission from areas with suspected disease ■ Population is confined to the transport vehicle	■ Confines unexposed without confirmation of suspected disease ■ Cohorting may expose susceptible individuals to disease	Unknown	Compulsory
Institutional Quarantine (applies to institutions or geographic areas)	■ Cohorting is easier than assessing individuals	■ Rapid spread of disease in confined and crowded areas	Unknown	Compulsory
Cordon Sanitaire also called: ■ Perimeter quarantine ■ Geographic quarantine	■ Restricts travel into or out of an area	■ May restrict unnecessarily	Unknown	Compulsory

WHO workshops on preparedness have included containment strategies, recognizing that containment alone may be ineffective in stopping or impeding a pandemic.

The challenges created by today's global travel can be seen in Figure 15.3. The model, developed by the Center for National Preparedness at the University of Pittsburgh, depicts the locations of travelers within 4 hours of arrival based on flights from Europe to North America.[11] The model suggests potential exposure from infectious individuals to susceptible individuals will occur nearly simultaneously across the U.S. within hours; the probability of stopping a highly infectious disease at the border is limited at best. Even in known cases, noncompliant individuals can travel worldwide before they can be curtailed. In 2007, a man with drug-resistant tuberculosis boarded a plane in Atlanta.[12] He ignored travel restrictions and flew from Atlanta to Paris, Greece, Italy, Prague, and Montreal exposing more than 600 individuals before authorities detained him after his 12-day trek.[13]

Contact network modeling can predict the impact of quarantine. The models suggest that simultaneous case–patient isolation and quarantine of close contacts substantially improves containment. With the addition of ring vaccination, quarantine can prevent the spread of diseases. The data are conclusive in identifying the impact of eliminating contacts between infected and susceptible persons; however, the study identifies a requirement for a strong surveillance infrastructure, reliable rapid diagnostic tests, and social acceptance, all of which may not be available.[14]

So what can be done if quarantine in and of itself is ineffective? It must be understood that quarantine is a measure of last resort. It is used after an infectious and highly contagious disease is introduced into society. Without immunity, separation of infectious from noninfectious individuals is the only course of action. As identified in the IHR-2005, the objective is to stop the disease at the point of origin. When travelers become vectors, the public's health will be compromised. Mass casualties should be expected. The strategy to prevent spread of disease will include quarantine, however strategies to augment surge capacity must also be implemented in order to optimize population outcomes.

Healthcare facilities have isolation procedures and methods for separation of infectious patients from the general population. Therefore, a review of internal infection control procedures is warranted to identify current capability and capacity to optimally prevent or limit transmission of an infectious agent. The U.S. CDC Pandemic Influenza Plan identifies isolation of infectious patients in private rooms or cohort units as a measure to control transmission in healthcare facilities. It also identifies cohorting healthcare workers assigned to an outbreak unit.[15] This practice, however, has been reported to have caused transmission of SARS to healthy individuals when those without the disease were exposed and confined with the cohort.[16]

During the SARS events of 2003, quarantine was an integral part of the control strategy. Multiple studies have reviewed containment strategies but the full impact and effectiveness of quarantine alone in a realistic environment has not been quantified. Voluntary compliance during SARS was greater than 90% in most settings; generalized studies indicate that 100% compliance may not be necessary.[17] Studies on the use of quarantine consistently identify the challenges in managing and controlling the

ANNEX 2

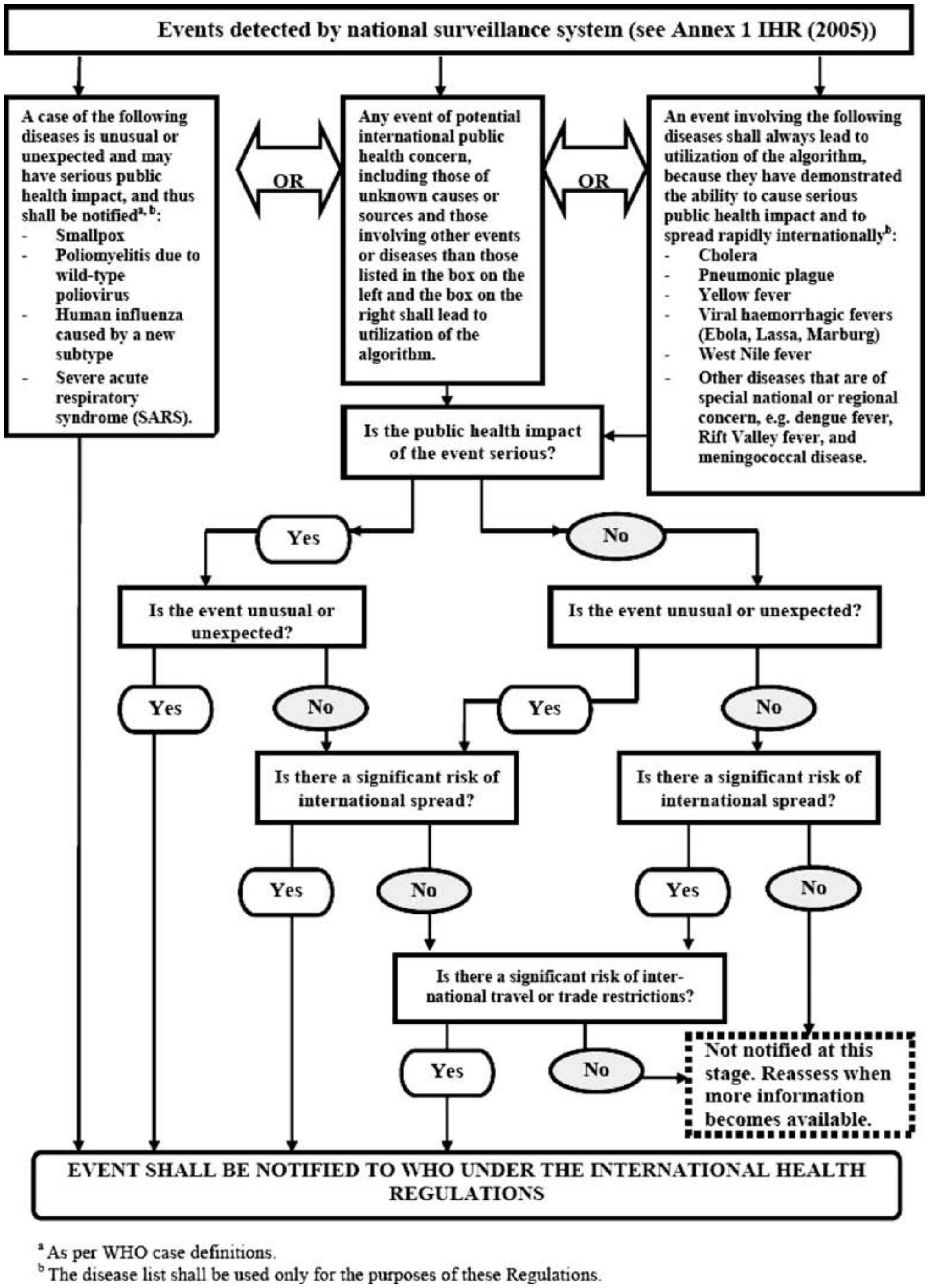

Figure 15.2. Decision Instrument for the Assessment and Notification of Events that May Constitute a Public Health Emergency of International Concern INTERNATIONAL HEALTH REGULATION 2005. World Health Organization. *The World Health Report 2007: A Safer Future, Global Public Health Security in the 21st Century*. Geneva: WHO.

restrictions in movement. This is resource intensive and logistically challenging and raises legal, financial, and social issues.

Legal Issues of Quarantine

Public health powers for quarantine exist at all levels of governance. Every nation, state, and local government has responsibility for its respective jurisdiction. The complexity of governance creates numerous overlaps as well as gaps in containment of the disease spread. The cross-jurisdictional issues require clear guidance and defined lines of authority to execute appropriate powers.

The WHO addresses the legal issues of quarantine and outlines a collective defense strategy. It published legal guidance in

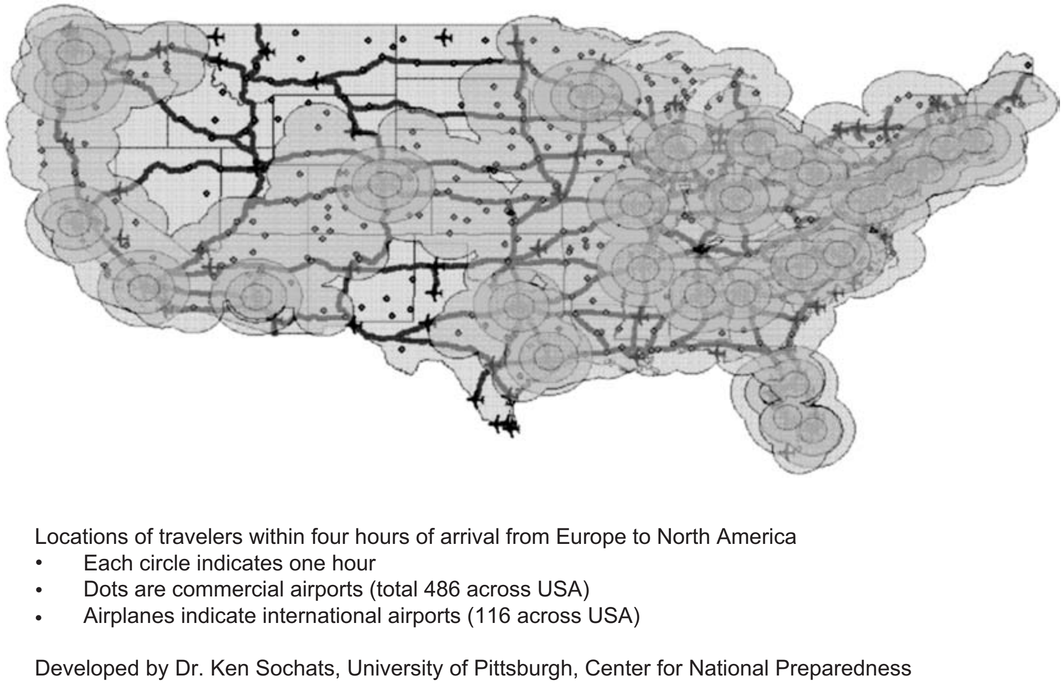

Figure 15.3. Potential Exposure Across the U.S. within 4 hours.

the IHR-2005. The 2005 changes to the IHR address not only the diseases subject to quarantine, but also an inclusive approach of proactive risk management. The IHR-2005 requires states that are parties to the IHR to establish policies and procedures to address containment strategies that include quarantine. The regulations urge states to develop the necessary public health capacities and legal and administrative provisions of the IHR. They should initiate the process for creating a decision instrument designed to ascertain when to notify the WHO of events that may constitute a public health emergency of international concern.[18]

Many laws governing quarantine are old; they do not reflect current evidence-based disease management.[19] The Center for Law and the Public's Health at Georgetown and Johns Hopkins universities drafted model acts to modernize U.S. public health law. The models guide states in the development of legal powers to respond as well as provisions for due process to protect civil liberties.[20] More than 37 U.S. states have adopted some portion of the MSEHPA and updated their laws governing quarantine at the time of this writing.[4]

Canada updated its *Quarantine Act* in 2004 as a result of its experience with SARS. Much like other countries, their legal guidance had been largely unchanged since initially enacted in 1872. Influenced by guidance in the IHR-2005, Canada introduced a bill amending the recently revised *Quarantine Act* on December 12, 2006 and immediately implemented this legislation.[21]

In the United States, public health and safety are primarily state and local responsibilities. The federal government does have some jurisdiction over this area and its guidance is found within U.S. Code: Title 42.[22] Federal authorities govern the introduction of diseases, both foreign and interstate, and have the power to enact and enforce quarantine rules.[23] The federal government also has the responsibility to assist states in the execution of their quarantine laws. Although the state's responsibility for quarantine has been upheld by the courts,[24] the federal government can preempt state power if necessary to control disease at international borders or during interstate commerce.[25]

Under Title 42, the Secretary of the Department of Health and Human Services (HHS) has the responsibility for preventing the introduction, transmission, and spread of communicable diseases from foreign countries into the United States. HHS has assigned the responsibility for federal quarantine to the CDC. Specific diseases subject to quarantine must be authorized by Executive Order of the President (Table 15.4).[26] This means that each time a new disease emerges, the Executive Order must be amended to add it to the list of quarantinable diseases. A more effective approach might be to revise the policy to include any contagious infectious disease that could be a threat to the public

Table 15.4: U.S. Diseases Subject to Quarantine*

- Cholera
- Diphtheria
- Infectious tuberculosis
- Plague
- Smallpox
- Yellow fever
- SARS
- Viral hemorrhagic fevers
  - Lassa
  - Marburg
  - Ebola
  - Crimean-Congo
  - South American
  - Others not yet isolated or named
- Influenza (caused by novel or reemergent influenza viruses that are causing, or have the potential to cause, a pandemic)

* Defined in Executive Order 13295

health and safety and avoid listing each one. To update the current antiquated federal quarantine rules, the CDC proposed communicable disease control regulations in late 2005,[27] but these proposed rules have never been finalized.[28]

Empowering authority for a quarantine order is found in federal regulations. They provide specific guidelines authorizing the Secretary of HHS, "to make and enforce regulations that in his judgment are necessary to prevent the introduction, transmission, or spread of communicable diseases." The authority extends to individuals coming into a state or possession from a foreign country or possession, or from state to state for infected individuals. Title 42 requires the President, upon recommendation of the National Advisory Health Council and the Surgeon General of the United States, to define, by Executive Order, those diseases subject to quarantine.

The Secretary of HHS is authorized to support state and local authorities in enforcing their quarantine and health regulations. State quarantine laws remain valid until displaced by federal law. The responsibility to protect the public's health must not unduly infringe on personal freedom to travel. There must be a compelling argument that clearly demonstrates travel to or from an infected area puts the greater population in danger.

In 2007, during the well-publicized Andrew Speaker case, the CDC issued the first federal quarantine order since a suspected smallpox carrier was quarantined in 1963.[29] Quarantine authority under Title 42 was initially the responsibility of the Treasury Department. It was transferred to the Federal Security Agency in 1939. Subsequently, in 1953, it was transferred to the Department of Health, Education and Welfare, later redesignated HHS.

HHS assigned border control containment issues to the CDC, Division of Global Migration and Quarantine, which operates quarantine stations as part of the U.S. comprehensive quarantine system network. The stations are located at 20 ports of entry and land border crossings focused on the arrival of international travelers. Health officers determine the appropriate measures to use if they identify an ill person attempting to enter the United States. If diagnosed with a disease subject to quarantine, the CDC has the legal authority to detain, admit to a hospital, or confine individuals to a home for a certain amount of time to prevent the spread of disease.[30] An Institute of Medicine study found that "most practices of the quarantine stations and their surrogates lack a scientific basis." It also found that the practice of quarantine was based primarily on "experience and tradition." The Institute of Medicine recommended the development of "scientifically sound tools to measure the effectiveness and quality of all operational aspects of the quarantine system."[31]

The Center for Law and the Public Health at Georgetown and Johns Hopkins universities, in collaboration with the CDC, the National Governors Association, and other public health associations proposed the MSEHPA. The Act suggests that failure to obey a quarantine or isolation restriction shall constitute a misdemeanor. As a misdemeanor, the level of force appropriate to ensure enforcement is a potential challenge.

Other guidelines regarding healthcare facilities and the control of the spread of infectious diseases can be found in the U.S. CDC Guidelines for Environmental Infection Control in Healthcare Facilities, 2001.[32] Isolation guidelines recommend at least one room equipped to house patients with infections communicable through airborne routes, and further identify engineering standards for healthcare facilities. Smallpox and hemorrhagic fevers are specifically referenced with regard to their airborne transmissibility and potential for infectious waste. The guidelines do not, however, address policies aimed at managing large numbers of contagious patients.

The Joint Commission, which provides accreditation standards for healthcare facilities in the United States (and some other countries through its Joint Commission International division), issues additional guidance as a deeming authority for Medicare. The Joint Commission standards require leaders and managers to comply with applicable laws and regulations and spell out specific responsibilities of the facility when governmental authorities establish quarantine.[33]

Ethical Issues of Quarantine

Limited definitive guidance exists on requirements to effectively stop the spread of highly contagious disease. Without evidence-based data to support the efficacy of quarantine, ethical issues will arise. Government policies that restrict individual rights and impact financial security impose hardship on individuals. Historically, punitive actions and deprivation of liberty have been associated with quarantine. Civil commitment is seen, especially in the United States, as a "massive curtailment of liberty."[34] Governmental bodies have a responsibility to establish that a significant risk of transmission exists before detaining individuals against their wills.[35]

If it can be determined that quarantine is warranted, governments have the responsibility to provide for life-sustaining support such as food and water, medical support, and appropriate sanitary conditions. If a government plan includes quarantine, it is imperative that the plan provide logistical support for the detained population.[1] Containment strategies should focus on the "human rights principles: the least restrictive alternative, safe and habitable environments, and fulfilling individual needs for medical treatment and necessities of life."[2] In reality, the magnitude of large-scale events often makes adequate support nearly impossible.

RECOMMENDATIONS FOR FURTHER RESEARCH

Quarantine is a tool used in conjunction with other medical countermeasures to curtail the spread of highly contagious diseases. There are limited evidence-based data on effectiveness. Recommendations for further research must focus on realistically achievable results. The following identify critical areas of study that would contribute to the adoption of effective strategies.

- Improved modeling is necessary in the context of operational challenges for managing large numbers of displaced individuals. The basic elements of delivery of food and water, and medical support are missing. Additional needs for financial support and family integrity have not been addressed.
- Timelines must be developed to reflect the duration of optimal separation to reduce contagion. Criteria must be developed to determine whether the potentially infected population can be identified soon enough to achieve physical separation and limit transmission.
- Metrics must be developed to measure quarantine as an effective strategy within a society that has rapid global movement opportunities.

- Reporting and communication algorithms are required to assist clinicians in recognizing who to report and when, where, and how to report suspicious activity.
- Clearly delineated authorities must be developed that enable clinicians to act and political figures (e.g., governors, mayors) to make decisions.
- Other containment strategies should be assessed for efficacy with or without a state of quarantine.
- A realistic assessment should be developed regarding the impact of school closure and other activities initiated to facilitate separation on the population. Researchers should model the second- and third-order effects.
- Enforcement options in different societies should be identified.
- Jurisdictional authority issues when federal enclaves or other jurisdictions exist within a state should be deconflicted. This would include determining how a country would manage travel of embassy personnel when no authority exists over those sovereign entities.

In summary, quarantine is an important tool in the armamentarium for protection of the public health from contagious infectious diseases. Its efficacy, the legal authorities, and the logistical and ethical challenges in its implementation require more study to optimize the probability that quarantine will decrease morbidity and mortality in the global environment.

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16

Mass Dispensing of Antibiotics and Vaccines

Susan E. Gorman and Nicki T. Pesik

The findings and conclusions in this chapter are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention (CDC).

OVERVIEW

Following a terrorist event or other large-scale public health emergency, the need to distribute rapidly antibiotic prophylaxis or vaccinations to a large population may be necessary. To accomplish this task successfully a significant amount of planning and preparation must occur in advance of such an event. The ability to respond in the initial phase of an infectious event at the local, regional, state, national or international levels is a key component of public health preparedness. This was demonstrated in the U.S. in 2001, when more than 30,000 people were advised to take antibiotics during the anthrax event.[1] Although the need to plan for mass dispensing is essential, many areas have not engaged in the process. A survey in one U.S. state showed that less than half of 138 community health centers polled in 2004 had begun to address bioterrorism issues in their planning efforts; only 19% surveyed were included in their county's mass prophylaxis plan.[2] In the same survey, only 46% had sufficient space to create a mass immunization or vaccination area, and 23% had plans to communicate bioterrorism events with the public and media.[2] Results such as these emphasize the need for enhanced planning. The inability of a community to dispense needed pharmaceuticals efficiently and effectively to its population may result in the loss of lives. Therefore, the development of mass dispensing clinics and mass vaccination clinics should be incorporated into community disaster plans.

HISTORICAL PERSPECTIVES

Information gathered from past experiences can be applied to future preparations for mass vaccinations and prophylaxis. Those past mass vaccination campaigns that have been considered successful in halting outbreaks have each demonstrated areas for improvement. In 1947, New York City conducted a mass smallpox vaccination campaign that successfully halted an outbreak of smallpox (Figure 16.1). Vaccine tracking and recordkeeping make it difficult to establish the exact number of individuals vaccinated in April 1947. It is estimated that more than 2.5 million persons received smallpox vaccine. This vaccination campaign also dealt with vaccine shortages; little public health information such as vaccine side effects was provided to the public.[3]

In an effort to halt a smallpox outbreak that began with an infected person returning from a pilgrimage to Mecca, the Federal Epidemiologic Commission organized a larger mass vaccination campaign in Yugoslavia in 1972. In a period of 3 weeks, they vaccinated 18 million persons out of a population of 20.8 million persons. The epidemic included 175 cases and 35 deaths and was declared under control in 6 weeks. This mass vaccination campaign noted unsuccessful vaccination uptakes and included the use of strict isolation and quarantine as well as declaration of martial law to include the mandatory restriction of population movement in affected areas.[4]

Considerations for current preparation for mass vaccination or mass prophylaxis can also be gleaned from a historical review of the 1976 Swine Flu vaccination program. In February 1976, serological studies of personnel at Fort Dix, New Jersey suggested that more than 200 persons had been infected with a strain of virus similar to the one that caused the 1918 influenza pandemic. By March of that year, public health authorities decided to launch a mass vaccination program to prevent the effects of a possible pandemic. Information gathered from this campaign applies to current mass dispensing and mass vaccination planning. This includes addressing the following issues: 1) inclusion of special populations when considering formulation of vaccines or antimicrobials, 2) liability issues related to medical countermeasures, 3) interagency cooperation at various levels of government, 4) establishment of surveillance systems for adverse events, and 5) appropriate and timely public health messaging.[5]

Figure 16.1. 1947 smallpox vaccine line. Used with permission: AP.

CURRENT STATE OF THE ART

Examples of International Efforts

Given the ease of international travel and the possibility for rapid spread of disease, a public health emergency in one country has the potential to become an international issue. Many countries are preparing for the need to undertake mass vaccination or mass dispensing campaigns. For example, Israel has stockpiled enough smallpox vaccine for its population and visitors. Supervision of mass vaccination occurs under the direction of the Public Health Services of the Ministry of Health. The Ministry of Health anticipates operating vaccination clinics 24 hours a day. District health officers would determine the locations of these clinics.[6] Clinic sites might include schools, large existing clinics, or other appropriate community buildings.

The United Kingdom anticipates using response teams (SMART teams), whose members have been vaccinated prior to the event, to assist with the initial management of a smallpox incident. In the event of an outbreak, initial cases and contacts would be vaccinated; however, it is planned that sufficient vaccine will be available to vaccinate the entire country's population should it be deemed necessary. Mass vaccination would be considered in the event of multiple attacks if new cases are identified without epidemiological link to previously identified cases, or in overwhelming public demand in the face of increasing threat. Regional epidemiologists are responsible for identifying, training, and vaccinating individuals for regional response teams. In addition, regional epidemiologists are responsible for identifying vaccination centers and training vaccinators.[7] Vaccinia Immune Globulin would be delivered along with vaccine to local authorities within 48 hours of the decision to begin a mass vaccination campaign.[8]

The Canadian national antiviral stockpile for pandemic influenza was established in 2004 as the result of a joint federal, provincial, and territorial purchase. The Canadian federal, provincial, and territorial governments have a goal to provide a stockpile of 55 million regimens of antivirals. The national stockpile is distributed on a per capita basis to each of the provinces and territories. Delivery of antivirals is primarily the responsibility of the respective province and territory and the local governments. Canada plans to address in its preparedness efforts: development of public health and clinical information regarding the use of antivirals, guidelines for the delivery of antivirals including tracking delivery of antivirals, and monitoring antiviral resistance.[9]

The World Health Organization (WHO) recognizes the need for developing countries to have access to certain medical countermeasures that may be part of a mass dispensing or mass vaccination campaign. In 2005, Roche donated 3 million treatment courses of antiviral medication for use in containment strategies against human cases of avian influenza, to be used to preempt a possible influenza pandemic. Logistical considerations for the WHO stockpile include the ability to deliver a portion of this stockpile within 24 hours to countries where assistance will most likely be needed.[10] Through the Global Outbreak Alert and Response Network, WHO can also provide rapid technical assistance in managing an outbreak including clinical guidelines for the use of antiviral prophylaxis or disease treatment. As part of the containment strategy, WHO estimates that the amount of antivirals needed includes approximately enough treatment courses for 25% of the population and prophylaxis courses for the remaining 75% of the population.[11] WHO is developing procedures for the distribution of antivirals within the outbreak area.

At the time of this writing, WHO is also in the process of developing a smallpox vaccine stockpile. WHO will build its strategic stockpile of smallpox vaccine in Geneva. Countries are invited to donate and maintain additional stocks pledged to WHO that would be dispatched to where they are most needed in the event of an emergency. Progress on this reserve has already begun, with 2.5 million doses in Geneva, and an additional 31 million doses donated by various countries, including 20 million doses from the United States, 5 million from France, and 4 million from the United Kingdom.

EXAMPLES OF FEDERAL ASSISTANCE FROM THE UNITED STATES MODEL: STRATEGIC NATIONAL STOCKPILE AND CITIES READINESS INITIATIVE PROGRAMS

Federal assistance in the event of a large-scale public health emergency requiring mass antibiotic prophylaxis or vaccination may include obtaining necessary medications from several sources. In the United States, the Strategic National Stockpile (SNS) is a federally managed supply of antibiotics, vaccines, antitoxins, antivirals, medical supplies, and equipment that is available to affected areas once local, state, or regional supplies are depleted or systems are overwhelmed. The U.S. CDC, a part of the U.S. Department of Health and Human Services (HHS), manages this program. The SNS maintains its inventory in 12-Hour Push Packages and in Managed Inventory. The 12-Hour Push Packages are dispatched when the threat is unknown or speed is critical. Each 12-Hour Push Package weighs approximately 50 tons and is made up of more than 100 different line items. One 12-Hour Push Package is designed to be moved without repackaging either on eight semitractor trailers or on one wide-body cargo jet. The 12-Hour Push Packages are packaged in specialized cargo containers prior to the event and are strategically placed across the United States with the goal to reach any state within 12 hours of the federal decision to deploy assets. Managed Inventory in the SNS consists of large amounts of palletized material and is generally used as follow-on to the 12-Hour Push Package. Managed Inventory can also be used as an initial response when the type of threat is known. Managed inventory may be tailored for a specific known event. The delivery timeframe for Managed Inventory may vary but for most events is estimated to be 24–36 hours after the federal decision to deploy assets. SNS personnel determine the method of transportation for both the 12-Hour Push Package and Managed Inventory based on weather, safety, security, and other incident-specific factors at the time of the event. Included in the SNS are antibiotics in 10-day unit of use bottles that can be dispensed directly to patients, thereby saving time by eliminating the need to break down bulk bottles of antibiotics into individual regimens. Vaccines for smallpox and anthrax are also included in the SNS, but would be shipped only when clinically indicated, such as in the event of a smallpox case or a large exposure to aerosolized anthrax. Federal planning and response efforts continue to evolve as more scientific data are collected, and inventory levels in the SNS continue to expand.

Within the United States, SNS assets may be requested by the governor, or a designee, of an affected state by contacting the CDC. A Presidential Disaster Declaration is not required to request assets, and the activation of the National Response Plan is not necessary; however, procedures for requesting assets may change when they are in effect. Assets requested from the SNS will be shipped either by air or ground to the nearest safe Receipt, Storing, and Staging (RSS) location designated by the State Health Department. RSS sites are designated warehouses where the 12-Hour Push Package or other assets will be delivered, off-loaded, and organized for further distribution. From the RSS location, the distribution of assets to individual hospitals, clinics, or points of dispensing (PODs) is the responsibility of the state or city. It is therefore recommended that contingency plans be made with shipping companies or other partners to provide local transportation. The SNS has program consultants who collaborate on a regular basis with state planners to address issues regarding how they will receive, store, stage, distribute, and dispense assets from the SNS.

Other resources for antibiotics and vaccines should also be explored at the local and state level, as federal assets will only be activated once other resources are depleted. Potential suppliers can include the normal supply chain, wholesale distributors, manufacturers, local or state stockpiles, or other vendors. Memorandums of agreement with neighboring communities and states should also be established prior to the event. Local planners such consider factors such as immediate availability, timeliness and security when developing these agreements. Additionally, neighboring regions or countries may enter into agreements to share products and provide assistance. Disaster planners should be aware of what inventories are available to them domestically and internationally before an emergency occurs. Some medical countermeasures may be in short supply and will require difficult allocation decisions as to who will receive them. Three broad ethical issues related to handling public health emergencies include rationing, restrictions, and responsibilities.[12] Policymakers may benefit from including ethicists in their discussions regarding allocation of scarce resources. A triage or tiered process should be developed to determine the order of need for such supplies.[13]

Once antibiotics, vaccines, or other assets are received by the affected area, they must be dispensed to the patient population in a timely manner. Assets from the SNS are signed over to the receiving authority and it becomes the responsibility of the affected area to distribute the medical materiel to hospitals or PODs. Depending on the type of event, the time frame to provide effective prophylaxis or vaccination may vary. The Cities Readiness Initiative (CRI) is a federal program established by the U.S. HHS and the Department of Homeland Security (DHS) to assist cities with their ability to deliver or dispense medications during a large-scale public health emergency. The CRI is in alignment with the U.S. Homeland Security Presidential Directive 8, the National Preparedness Goal, and is directly related to one of the top four national priorities – to strengthen medical surge and mass prophylaxis capabilities. The goal of the CRI is to enhance preparedness at federal, state, and local levels of government by using a consistent national approach and response to a catastrophic event requiring mass antibiotic prophylaxis with assets from the SNS. Federal funding is provided to participating cities, which were chosen based on population and location. In 2004, the original program included 21 cities and in 2006 expanded to encompass 72 cities and their metropolitan statistical areas. Approximately 56% of the U.S. population resides in a CRI jurisdiction (Stephanie Dulin, CDC, personal communication, March 20, 2007).

The planning scenario for the CRI is to initiate prophylaxis for the entire population of the city within 48 hours of an anthrax event. To accomplish this, three different mechanisms could be used individually or in combination: methods developed and created by the city or state; delivery of medicines and supplies by the U.S. Postal Service, or setting up and running PODs. The U.S. HHS along with the DHS has negotiated with the U.S. Postal Service to provide home delivery at any time of initial doses of antibiotics as a stopgap measure while states or cities initiate PODs. This would permit the use of an existing and reliable delivery mechanism while allowing people to shelter-in-place after an event. Not all U.S. states have chosen to use the postal service option in their planning.

POINTS OF DISPENSING PLANNING

A POD operation is one of the most likely mechanisms available for dispensing medication or administering vaccines to a large population after a catastrophic event. These have also been called dispensing/vaccination clinics by some authors.[14] PODs and points of distribution may or may not mean the same thing. A point of distribution may be a holding area from which assets are further distributed before they are dispensed. The goals for a mass dispensing program include reducing risk of the population becoming ill, and providing public health information to the general public and healthcare providers.[15] Mass vaccination is usually performed to rapidly increase population immunity in the setting of an outbreak.[16] During a smallpox outbreak or that of another contagious infectious disease, surveillance and containment may be implemented. If multiple cities experience widespread simultaneous cases of a contagious disease or multiple near-simultaneous releases of a biological agent, it is possible that voluntary mass vaccination may be implemented.[17] In the United States, dispensing or distributing medications or vaccinating patients is mainly a responsibility at the local level. It will be important for state disaster planners to provide assistance and guidance for local planners regarding state dispensing laws and other applicable policies and procedures or expectations to maintain consistency throughout the state.

Planning for PODs should take into account design-related and operational issues, staffing and volunteers, and activation and deactivation.[18] The time necessary to implement effective prophylaxis or vaccination strategies and the number of persons needing prophylaxis or vaccination will help determine how many PODs are required for the event. Using the 48-hour window of time for providing prophylaxis to the entire population will allow for the worst-case scenario. Plans can then be adjusted to fit the size and scope of the emergency. This flexibility is important because it is impossible to have a set of throughput measurements for every possible scenario.[19] Throughput is defined as the number of persons receiving prophylaxis per unit of time.

The number of PODs required can be determined with the formula:

$$\text{TP} \div (\text{HPP} - \text{S}) \div \text{PPH} = \text{PODs}$$

where TP is the total population needing prophylaxis, HPP is the number of hours to provide prophylaxis to the population (i.e., 48 hours), S is the amount of time needed to set up the POD once the decision is made to do so, and PPH is the number of persons per hour who are provided prophylaxis (i.e., throughput). This equation has limitations in that it makes several assumptions that may not be correct, including: a 24-hour-a-day operation, an equal distribution of population among the PODs, equivalent types of PODs within a jurisdiction, POD performance at 100% capacity, adequate staffing, and a constant flow of people in and out of the POD.[14,18]

To ensure adequate facilities are available, it would be prudent to identify the facilities ahead of the emergency and establish written agreements (i.e., memoranda of agreement). Such agreements should address immediate use of the facility during an event, periodic access for building inspections, 24-hour contact information, security, and compensation or liability/indemnification agreements (if applicable) and authority to use the facility for exercises or drills. The memorandum of agreement may also clarify which entity has the responsibility and authority for running the operation.

POINTS OF DISPENSING SITE SELECTION

Facility site selection will be critical. Publicly owned facilities such as schools, universities, community recreation centers, firehouses, polling places, and armories are usually well known to the community, easy to find, have adequate parking, and are accessible by public transportation or private vehicle. The downside to use of these locations is that it may disrupt their regular functions and associate (potentially enduring) stigmatization due to the gathering of "exposed" people. Alternate locations may include aircraft hangers and shuttered public areas such as hospitals that are no longer in use. Although military installations may have available space, heightened security during a terrorist event or other public health emergency may result in restricted access to these sites. Facilities such as hospitals, commercial pharmacies, or other healthcare institutions may be overwhelmed with additional patient loads created by the event and may not be the best choice to locate PODs. Although a recent survey indicated the willingness of private industries to partner with public health entities for administration of medications or vaccines,[20] there were concerns regarding liability. In the United States, liability protection is provided to covered persons who administer a covered countermeasure through the *Public Readiness and*

Emergency Preparedness Act, part of the *Department of Defense Appropriations Act of 2006*.[21] This takes effect after the U.S. Secretary of Health and Human Services declares a public health emergency that requires administration of such countermeasures as identified by the Secretary.[21] Section 224(p) of the *Public Health Service Act* also specifically addresses the liability concerns associated with administration of smallpox countermeasures.[22] Fewer liability protections exist for institutions responding to emergencies compared with available protection for individuals.[23]

Although there could be concerns on the part of the owners for negative effects on their future business after being used as a site, commercial facilities such as grocery stores, wholesale clubs, or retail stores may be more useful vaccine administration settings because many of these organizations host annual influenza vaccination clinics. Such nontraditional settings for influenza vaccination campaigns have been increasingly utilized.[24] Nontraditional settings have positive cost/utility ratios and their convenience and locations may make them an important choice of vaccination site. Ninety-five percent of the population is within 5 miles of a retail pharmacy in the United States.[25] Retail stores and other nonclinical community settings along with third-party logistics or health service providers in the United States have administered approximately 30 million influenza vaccinations annually.[20] Because of the increased use of these settings, guidelines have been established to define quality standards for immunizations in nontraditional settings.[26] Although there have been some concerns about safety, one study assessed 542,445 persons vaccinated in nontraditional settings and found that adverse events were extremely low, with a total of 112 events, most of which resolved within minutes.[24]

Physical characteristics of the POD location should include the ability to handle hundreds or thousands of people at one time, while keeping them protected from adverse weather conditions. Communities have used a varying range of POD sizes, ranging from 1,670 to 5,500 m^2. Desirable features include heat and air conditioning, adequate bathrooms, water and electricity, handicap access with minimum stairs, public address or speaker system, unloading area for receipt of supplies, parking, helicopter landing, a break room/canteen, and good security, including the ability to control access. These physical characteristics will provide the security team sufficient space to coordinate traffic, manage parking, maintain crowd control, and protect staff and assets.

POINTS OF DISPENSING EQUIPMENT

Adequate equipment and supplies will be useful at the POD. Table 16.1 describes equipment and supplies that should be considered. This is not a comprehensive list and each city or state may find additional items that are useful. Some areas have developed a "go-kit" of items that can be easily transported to POD locations, have multiple uses during different types of disasters, are easily stored at room temperature, and are pre-event packaged according to different POD functions.[27]

POINTS OF DISPENSING OPERATIONS

All PODs within an affected area should be uniform in their medication delivery system, patient flow process, staff roles, operating procedures, projected throughput, hours of operation, information, products, and policies. Uniformity of PODS will make it easier to share personnel between PODs if needed and will avoid the public perception of better service at one location versus another.[15,28] To optimize the success of distributing the population evenly among the PODs, a robust public information campaign will be necessary. This can include population distribution by first letter of last name, postal code, census tract, school district, or neighborhood. POD sites should be prepared for greater than anticipated numbers of people because the population may be unable or unwilling to follow instructions despite an aggressive public information campaign.

Each POD must designate an on-site director (incident commander) who is capable of managing large numbers of people under difficult circumstances and who is familiar with the specific needs of the community. Although POD management is a local responsibility, POD locations, sizes, operations, and leaders are often chosen after collaboration between local, state, and regional health agencies. The Incident Command System and the National Incident Management System are both well-recognized command and control systems in the U.S. that may be used in POD management.[14,28,29] Using these command and control systems allows for clear leadership roles and chain of command, delegation of duties, reporting systems, and recordkeeping.

PODs may be organized in a variety of ways. The type of POD will have a direct impact on transportation and traffic management surrounding the POD. For example, greeting/information, triage, or registration could be performed in a central location with dispensing at another location. This is an example of a segmented POD. PODs that operate entirely in one location are called nonsegmented PODs. Segmented PODs allow the public to gather at a staging site that is accessible by public transportation and also has adequate parking available. Examples would include stadiums, convention centers or shopping malls. At the initial site, the exposed population could be screened, triaged, and given information before being transported to the actual dispensing location (POD). Symptomatic patients could be transported or directed to treatment facilities. Advantages to a segmented POD include a reduction in traffic congestion and parking at the actual POD location; improved security at the POD; a potential decrease in the number of people presenting to the POD who do not need prophylaxis; a regulated flow of people to the POD and the ability to triage symptomatic patients away from the POD. Disadvantages include the need for large parking facilities at the staging site, utilizing transportation assets to shuttle people to the POD, a potential lack of understanding by the public of where to go, more difficult Just-In-Time training for staff in two locations, a greater burden of security, and an increase in staffing requirements. Figures 16.2 and 16.3 depict segmented POD operations.

A nonsegmented POD allows all operations to be conducted at one location. Advantages to this type of operation include a reduction in the amount of staffing and security. Disadvantages may include the need for increased parking requirements, the risk of having symptomatic patients in proximity to those who were exposed but are not yet symptomatic, and the potential for secondary disease transmission (i.e., pneumonic plague) from the resultant crowded conditions. Figure 16.4 depicts a nonsegmented POD operation.

There are four basic functional areas to a POD: intake, screening, dispensing, and exit. Intake includes the processes, procedures, stations, and personnel involved in introducing people

Table 16.1: POD Equipment and Supplies

Name badges	Batteries	Large trash bags
Badge strap clips	Calculators	Waste cans
Badge neck straps	Clipboards	Regular trash bags
Vests	Dry-erase boards	White copy paper
Whistles	Dry-erase markers	Scotch tape
Bullhorns	Adult scales	Paper towels
Red barrier tape	Bike flags	Facial tissues
Traffic cones	Red ink pens	Duct tape
Portable copy machines	Black ink pens	Accordion folders
Emergency alert radios	Walkie-talkies	Colored paper
Extension cords	Blankets	Biohazard bags
Power strips	Hand sanitizers	Sharps containers
Flashlights	Surgical masks or N-95 respirators	Disposable cups
Sign easels	Label makers	Labels
Thermometers	Candy (simulated medicine)	Staplers
Paper clips	Permanent markers	Highlighters
Post-it notes	Lanterns	Gloves
Trash cans with wheels	Toilet paper	Pencils

into the POD. Paperwork such as the medical history can be completed at this stage, with patients being routed to the appropriate station to receive the correct medication. The patient information collected at this time can be used for monitoring medication compliance and adverse events, as well as tracking dispensed medication in case of a drug recall. The amount of information collected is a decision made by the state and local planners but should be concise and useful. In certain circumstances there may be federal requirements as well. Such data can be collected on paper forms, computer databases, telephones, or faxes.[30] Throughput of the POD will slow down as the amount of paperwork or data increases; therefore, forms should be short, simple, and specific. Many U.S. states have developed templates for information collection, both for individuals and for heads of household.[31–34] It is important to have adequate patient information sheets on hand at the POD. This may be accomplished by holding a small inventory of user-ready sheets or electronic master templates that can be used initially, followed by additional information sheets that may be generated through contingency contracts with local printing or photocopy businesses. Other functions that may be necessary at this step include traffic management, security, greeting, registration, and triage.

Screening encompasses sorting and classifying patients to optimize resources and maximize survival of patients. This step may include greeters, screeners, roamers, first aid, medical transport, and clinical resources or mental health counseling.

Dispensing includes the process and procedures for preparing and distributing medications to the public. Various methods of dispensing may be used. There will be certain populations that may not be able to utilize PODs and will therefore require different dispensing methods. These groups include prison inmates, nursing home patients or other long-term care

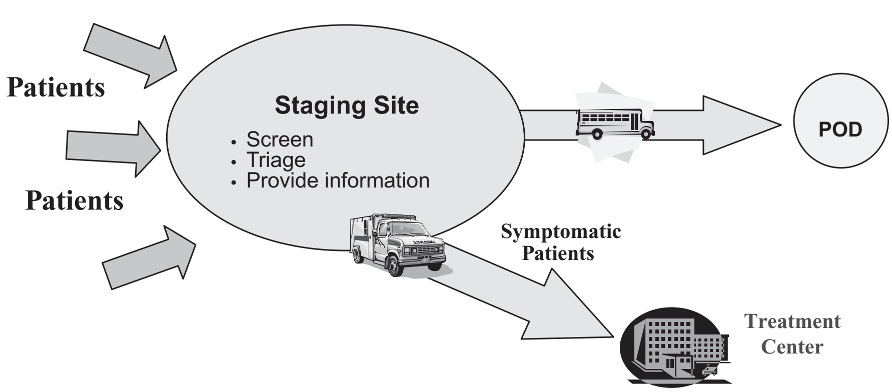

Figure 16.2. Segmented POD.

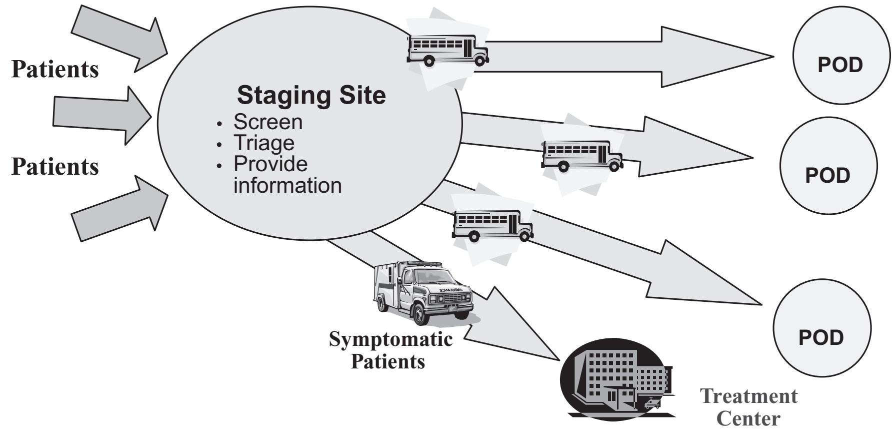

Figure 16.3. Segmented POD with one staging area feeding multiple PODs.

institution patients, workers at large industries operating 24-hours-a-day, hospitalized or home-bound patients, homeless persons, and undocumented immigrants. Alternate dispensing methods may include: deliveries to large corporations or universities that have occupational health clinics or medical staff on site; mobile dispensing clinics; "drive through clinics;" or the U.S. Postal Service delivery previously described.[15] Drive through clinics have been tested in some states and although advantages such as alleviation of crowding and less possibility for disease transmission were noted, there were pitfalls such as confusing traffic flow, long processing times, and limited access to parking or restrooms.[35] Pushing drugs out to these special populations could be faster and may cover a larger area, but does not allow for the medical evaluation of patients for adjustment of medication dosing or addressing drug contraindications. Also, the push method is not feasible for mass vaccinations.[14] Pulling people into PODs for prophylaxis or vaccination could more efficiently use healthcare workers and resources and would allow for medical evaluation and centralized data collection. Logistical delays and setting up multiple PODs are the downsides of pulling people into POD locations. A combination of both pushing and pulling methods may be most useful.

Decisions such as whether one person can pick up medications for an entire household should be made in advance. Allowing one person to pick up medications for the entire family would decrease the number of people at the POD and increase the throughput. If regimens are for children, individuals collecting the medications must provide their weights. Other information regarding family members, such as allergies, current medications, or existing disease states may also be vital. The type of information or evidence required to justify the number of regimens should be decided before an event and should be made known to the public so they can provide appropriate documentation for other family members at the POD. POD staff should be prepared to answer questions about the risk of disease transmission between humans, and the risk to pets and whether prophylaxis would be provided for pets. It is unlikely that prophylaxis would be provided to pets with the exception of service animals. The U.S. Department of Agriculture maintains a National Veterinary Stockpile that may have applicability to certain animal diseases in the event of an impending economic disaster involving cattle or livestock.[36]

Exiting includes moving the public out of the POD and providing any necessary follow-up information. Follow-up methods such as providing hotlines through the local or state health department, poison control center or nurse advice line, implementing a community phone bank, setting up a website, and giving information to primary care physicians can all be useful avenues for providing additional information to patients regarding compliance, adverse effects, or other questions.

Security and patient education are two issues that permeate all four phases of a POD operation and should be addressed throughout. Every step of the POD process may be used to provide patient education. At the intake step, fact sheets, handouts, or videotapes may be used to provide information. Such information should be prepared in multiple languages as appropriate to the community. During screening or dispensing, drug information sheets and individual patient-specific information may be shared. At the exit, follow-up information can be provided. Security should be present at each step of the POD as well as outside of the POD. Security should address crowd and traffic control inside and outside of the POD, and protection of staff and assets. All staff should wear badges identifying them as such.

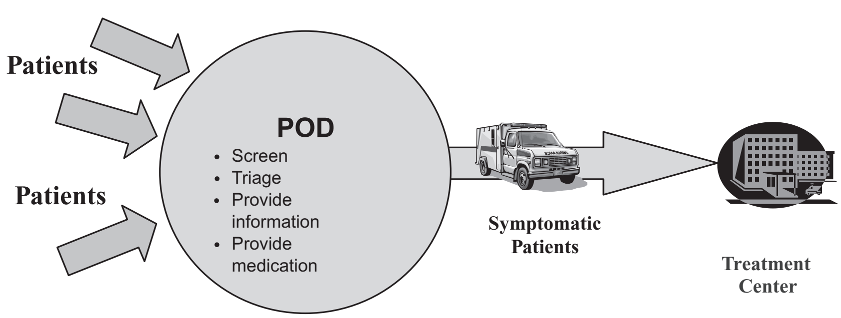

Figure 16.4. Nonsegmented POD.

Plans for security should be addressed in preparation for an event, because local law enforcement will likely be performing other duties related to the event. This is especially important as the POD could be a high-risk site if resources are limited. Also, PODs could be sites of secondary terrorist attacks. All POD workers should be made aware of security concerns and know how to report suspicious individuals or activities. POD locations with controllable entry and exit points will assist security with traffic flow. An evacuation route for patients and personnel should be part of the disaster plan of the POD itself.

In streamlining POD operations, a simple assembly line concept may help improve efficiency and increase throughput. If standing in lines is culturally feasible, using multiple, parallel lines rather than a single line is likely to increase throughput. In a mass casualty situation requiring mass dispensing, a thorough individual-based medical practice approach will not be practical. The focus shifts from individual patient medical care to population healthcare. Ensuring continual movement of patients through the system to eliminate bottlenecks or "balancing the line" will allow for a more effective mass-dispensing POD model. If necessary, a high throughput rate (increased persons per hour) may be achievable by shortening or foregoing orientation, simplifying medical forms, and eliminating secondary medical screening and a final quality assurance check. Also, patients who require specialized attention for any reason could be moved to remote stations outside of the POD. This could include patients with specific medical, safety, mobility, psychiatric, or communication needs including children, unaccompanied minors, travelers, the medically fragile, physically disabled, migratory, homeless, those with language, culture or literacy barriers, or disruptive persons.[37] These groups may require additional attention for them to understand public information messages. Messages and fact sheets can be translated; translators may be useful as could color coding or pictograms. Identifying bottlenecks and adding additional resources to relieve these areas may also be helpful.[38] Bottlenecks at PODs may occur when too many patients are allowed into the POD at one time, too many patients arrive at one particular station, too few staff are operating a station, or staff have too many things to do for each patient. This can be alleviated by having "express lanes" for those with no complications, estimating the number of staff and patients at each POD, and having a flexible command and control system in place that allows for modification of staff and type of PODs.[14,15] Prophylaxis of POD workers should be addressed before the POD is open to the general public.

POINTS OF DISPENSING STAFFING AND TRAINING

It is the responsibility of each public health jurisdiction to develop and maintain the ability to conduct first response and ongoing, federally assisted, community-wide mass antibiotic dispensing and vaccination campaigns.[14] Local mass prophylaxis activities will likely be underway before any federal assets arrive, and federal or state assistance will not likely have sufficient personnel to provide staffing to POD locations, particularly if the event encompasses a wide geographical region such as multiple states or countries. Even after federal assets arrive, POD operations will likely remain under local control, and POD operations may continue well after the departure of state or federal assistance.[14]

Adequate staffing is of paramount importance in running a successful POD and will require people with the correct skill sets who can be trained for their specific tasks. The trained staff will then be able to quickly set up the POD and ensure its operation at maximal efficiency with the highest possible throughput. Staffing the PODs has been accomplished in many different ways depending on historical successes for a particular city or state.[19,30,39–41] A general rule of thumb would be to require various types of staff, such as professionals (physicians, nurses, pharmacists, public health workers, and social workers), volunteers (trained and untrained) and management support staff such as those familiar with the facility or general POD operating tasks. Volunteers or nonclinical staff should be used for any appropriate jobs to free up professional staff and maximize efficiency of POD operations. Volunteers may be recruited before an event; however, expect that they will also present unannounced at the time of an event. The enormous task of training volunteers should be conducted to the extent possible before an event occurs. This task is easier if roles and responsibilities are kept consistent throughout the state or region.[15] It could also be helpful to maintain a statewide registry of trained volunteers. Trained volunteers with special skill sets such as translation and sign language abilities, and those from the Red Cross, can provide invaluable assistance.[28] Untrained volunteers may be found in community civic or fraternal organizations, as walk-ins or as spontaneous volunteers.

When planning for staffing, considerations should also include having enough people to staff two or three shifts per day. Some exercises conducted by states and cities have shown a rapid onset of staff burnout, so planning for additional shifts or rotation of staff among duties may be useful.[39]

Professionals will be in high demand for other jobs or tasks during an emergency; however, some potential sources for accessing professional services include commercial pharmacies, state licensing agencies, professional associations, nursing, pharmacy, or medical students, the U.S. DHS Emergency Coordinator for the region, the U.S. HHS regional health administrator, and via programs such as the U.S. Medical Reserve Corps.[42] Federal staff support for dispensing efforts may be obtained through the U.S. Public Health Service, National Pharmacy Response Teams, National Nursing Response Teams, and Disaster Medical Assistance Teams. These federal personnel assets may be available depending on the situation, such as when a Federal Disaster Declaration is in effect.Table 16.2 lists possible roles for healthcare professionals and volunteers.

Training of POD staff will help shape the success of the POD operation. Training should include orientation to their particular tasks or roles, the physical layout and flow of the POD, other team members on the shift, and familiarity with forms and other paperwork. It may be helpful for planners to maintain a database of those who have received training. Ideally, training would be conducted before an event; however, due to staff turnover, skill degradation, and updates or changes in procedures, this would require periodic refresher training and eventually may be too costly or time consuming. Another option would be to provide Just-In-Time training, where staff would not be trained until they were needed. New people could be trained in the POD at their own workstations with a straightforward job action sheet. This method has been used successfully in a number of exercises.[34,39,43] A third option would be to train enough staff ahead of time (along with refresher training) to

Table 16.2: Suggested Roles for Healthcare Professionals and Volunteers

Assignment	*Staffing*	*Task*
Intake		
Greeting/Entry	Volunteer with standardized script	Greet, direct, answer nonmedical questions
		Assist disabled persons
		Orient the public
Forms Distribution	Volunteer	Distribute medical history forms
		Explain form completion using a script
		Check completion of forms
Briefing	Trained volunteer	Translate dispensing-site procedures and policies to persons who do not understand local language, are hearing impaired, or illiterate
	Volunteer with task-specific training	Hand out medical record forms and provide instructions on completing them
	Volunteer with script	Educate and orient people standing in line
	Health professional or video	Provide information about drugs, including pediatric medicines
	Volunteer with script	Advise about importance of adhering to regimen instructions
		Warn about danger of overmedicating
		Confirm date to return for additional medication if needed
Screening		
Triage	Professional	Perform initial health screen
		Redirect symptomatic people to treatment facility
	Volunteer	Assist seriously ill persons to transport vehicles
Mental Health Screening and Counseling	Health professional and social worker	Watch for signs of anxiety, fear, impatience
		Provide counseling
Medical Evaluation	Professional	Perform health examination and assessment
Healthcare Center Transport	Volunteer	Drive ambulance or other transport vehicle
Drug Triage	Professional	Screen for contraindications for drugs or medical conditions
		Answer questions or prescribe alternate drugs
Dispensing		
Express Drug Dispensing	Pharmacist supervisor	Oversee dispensing process
	Volunteer	Weigh children younger than 5
	Volunteer	Dispense regimens depending on state regulations
	Pharmacist or Pharmacy Technician	Dispense regimens
Assisted Drug Dispensing	Pediatrician or Pediatric Nurse Practitioner	Examine infants and small children
		Dispense proper medication
Exit		
Collection and Review of Medical Data	Volunteer with professional supervision	Check for completeness of forms
		Distribute patient information sheets
		Explain importance of compliance with regimen
		Stress danger of overmedicating
		Note date to return for additional medications if needed

Adapted from receiving, distributing, and dispensing SNS assets: a guide for preparedness – version 10. U.S. Centers for Disease Control and Prevention, Division of Strategic National Stockpile.

Table 16.3: Software and Programming for POD Modeling

BERM, the Weill-Cornell Bioterrorism and Epidemic Response Model	http://www.ahrq.gov/research/biomodel.html
Clinic Planning Model Generator	http://www.isr.umd.edu/Labs/CIM/projects/clinic/
Maxi-Vac software program	http://www.bt.cdc.gov/agent/smallpox/vaccination/maxi-vac/index.asp
MEDS/POD	[44]
RealOpt ©	[48]

comprise the first shift of a POD and provide Just-In-Time training for subsequent shifts. Just-In-Time training should include the person's role, forms or paperwork that will be used, physical layout and flow of the POD, shift hours, information about related POD functions and where the trainee fits into the process, to whom to report any problems, and emergency evacuation procedures. A POD manager can address issues such as staff shortages, medication shortages, or other problems that arise.

Drills and exercises will be the most beneficial way to determine whether the POD will be successful. A number of dispensing campaign and POD-specific tasks, objectives, and performance metrics can be evaluated including unlocking and opening the facilities; location of lights, circuit breakers and alarms; how to set up the facilities with chairs, tables, rope lanes, and portable toilets; how food and water will be provided; and how the facility will be set up and staffed. After drills or exercises have taken place, after-action reports or briefings can help identify areas of improvement for future focus. Although more research is needed to develop models that will ensure high throughput to meet the 48-hour goal for dispensing, several computer-generated modeling programs have been established to help with POD planning efforts for both antibiotic distribution and vaccinations.[14,18,44–48] The U.S. CDC has also published guidance for setting up large-scale smallpox vaccination clinics.[49] In addition, a number of Webcasts are available to assist planners with POD operations.[15,37,38,50]

Using these tools will allow for the formulation of realistic plans. POD staffing levels for entry screening, triage, medical evaluation, and drug dispensing stations may be determined using various bioterrorism response scenarios.[45] The number of staff needed to provide prophylaxis for the entire population within 48 hours can also be determined.[15] Other approaches allow for simulation and decision support for planning large-scale emergency dispensing clinics by offering clinic design and staffing models, including scenarios for smallpox or influenza vaccination and antibiotic dispensing.[45–48] Most of the software or programming is free to planners and access links can be found in Table 16.3.

Many states and cities have conducted exercises and drills to test their preparedness plans and their dispensing or vaccination capabilities.[19,29,34,39–41,43,51–56] Vaccination clinics were also tested beginning in 2002, when President George W. Bush instituted a smallpox vaccination program for military and civilian medical first responders.[57] Bush's two-pronged program called for HHS to immunize a cohort of healthcare workers and first responders, and for the Department of Defense to vaccinate the military population.[58] Military administration of anthrax vaccine has also followed the vaccination clinic model.[59] Annual influenza vaccination clinics are another good source of testing mass vaccination protocols.[28,60] Additionally, testing mass vaccination programs with influenza vaccine provides the opportunity to enhance pandemic preparedness while achieving annual prevention goals.[28] These exercises have produced similar information; some of the most important guidelines are highlighted in Table 16.4.

To be effective, POD operations must address the needs of different patient groups, including otherwise healthy people with no complications who require prophylaxis, people with existing medical conditions who require prophylaxis, or those already suffering from illness as a result of the exposure.[15] The goal for those with symptoms is to get them to a healthcare facility quickly, for those exposed with no complications to get them appropriate prophylaxis medications quickly, and for those exposed with complicated medical histories to determine any contraindications or dosage adjustments and provide rapid prophylaxis. Some patients may be directed to an alternate care site, particularly if they are less ill than others. In some scenarios, healthcare facilities could not handle all patients with symptoms. Secondary goals may include crisis or mental health counseling, recordkeeping, or patient tracking. PODs should have direct communications channels with hospitals and other facilities where symptomatic patients or those who experience adverse reactions can be evaluated. Successful operation of PODs may decrease the number of patients who initially present to a healthcare facility; successful

Table 16.4: Important Guidelines for Effective POD Management

■ Limit medical histories	■ Defined responsibilities
■ Clear signage	■ Clarity of mission
■ Collaboration with law enforcement	■ Defined lines of authority
■ Hotline/phone bank	■ Partnerships
■ Good communication	■ Liability
■ Redistribution of resources	■ Just-In-Time training
■ Transportation arrangements	■ Chain of custody
■ Streamlined triage	■ Regulate entrance/exit to limit flow
■ Multiple language/translators	■ Limit distractions
■ Patient education	■ How to obtain refills
■ Directions for leftover medication	■ Procedures for special cases

Table 16.5: Four Phases of POD Activation

Phase 1	Notify and recall all staff necessary to initiate dispensing campaign
Phase 2	Provide prophylaxis or vaccination to critical infrastructure personnel and their families
Phase 3	Set up POD network – obtain staff, set up the PODs, print forms, unpack inventory
Phase 4	Public notification and opening of PODs

vaccination or mass antibiotic dispensing may reduce the number of patients who become ill and require subsequent treatment.

Once POD sites are selected, staffing is determined, training is provided, and exercises are conducted, the PODs should be ready for use in the event of an emergency. In the activation of a dispensing campaign, implementation of the PODs could occur in four phases as listed in Table 16.5.[15,18] Providing prophylaxis or vaccination to critical infrastructure personnel and their families may result in responders being more willing to come to work because they and their families have been protected. Critical infrastructure personnel may include healthcare workers, first responders, law enforcement personnel, government leaders, and others who are necessary to support the essential infrastructure of the affected area. Local supplies may be available to accomplish this while SNS or other assets are being delivered.

POINTS OF DISPENSING PUBLIC INFORMATION

Public information is one of the most critical elements of a successful dispensing campaign. One key factor is to address the information needs of the public, healthcare workers, and other stakeholders in an effective manner concerning the risks they face and actions they can take to protect themselves and others.[37] Messages should be designed to instill trust as well as provide the motivation and reassurance to do what is recommended. Once the PODs are ready to open, the public should be informed. If feasible, planners should wait until all PODs within a region are ready for opening before notifying the public so as to not overwhelm one site. If information regarding PODs is released too far in advance, people may form long lines well before PODs are open or functional. The media may be used as a first level of triage in addition to public address systems outside of the POD, with announcements telling those who have recently become ill to go to the nearest hospital or other designated healthcare site.[38] A variety of media outlets may be used to disburse messages to the community, including newspaper, radio, television, Internet, telephone hotlines such as poison control centers or nurse advice lines, and press conferences. The Public Broadcast System or other emergency broadcast systems may also be implemented. Local media outlets should be alerted regarding the potential for opening PODs to ensure consistent messages across all levels of government. The media can be helpful during an event and they should have a designated area at the POD location. A media kit prepared before an event occurs will be a useful tool and should discuss background information on threat agents, signs and symptoms, information about the medical products that may be used, as well as information about the communications plan that would be utilized during a disaster along with contact information. Monitoring of media reports will be essential to make sure that critical information is being relayed accurately and to determine if changes, corrections, or updates are necessary.[15]

POINTS OF DISPENSING DEACTIVATION

Once the emergency is entering the recovery phase, implementing a plan for deactivation of PODs will be important. PODs may be deactivated individually or in groups, but should not be simultaneously deactivated. This allows the community to retain some capability while people continue to receive medications, in case renewed activity is warranted. Sites most needed for the community, such as businesses or schools should be deactivated first. Information and data from the PODs, including throughput figures, staffing hours, expenses, and comments from staff for improvements as well as what went well, should be gathered. Some people may have difficulty adjusting after this event so counseling should be provided for staff as well as the public.

SPECIAL CONSIDERATIONS

Drug Formulations for Patients at Extremes of Age

Small children or elderly persons may have difficulty swallowing tablets or capsules as part of a postexposure prophylaxis campaign. The U.S. National Advisory Committee on Children and Terrorism recommends that suspension formulations be available for children aged 9 and younger.[61] The SNS contains a limited quantity of pediatric suspensions. The quantity of suspensions under recommendation that may be required to fulfill a 60-day prophylactic antibiotic course (i.e., for anthrax) greatly exceeds the manufacturing capacity and storage capabilities of most countries. Additionally, suspension formulations have a relatively short shelf life, may be costly, and may have a small annual usage. For these reasons, alternative methods for creating suitable formulations for children have been explored. One potential avenue is to pharmaceutically compound the needed suspension from pills that are triturated, wetted, and suspended with flavoring agents added, as could be accomplished in a pharmacy setting. This method is very time consuming, and when performed on a large scale, pharmacies may be subject to regulatory implications imposed by the U.S. Food and Drug Administration (FDA) such as those applying to a manufacturer. Another option is the potential to crush tablets in the home setting and add the crushed medications to a food or liquid which would then be administered to the child. Informal testing of the initial guidelines provided by the FDA revealed that they were too difficult for some parents to follow. In addition, some of the oral dosage forms have an extremely bitter taste that is difficult to conceal. At the time of this writing, the FDA has updated the guidelines for crushing doxycycline tablets to make them easier to understand and execute. The doxycycline guidelines are available on the FDA website at http://www.fda.gov; others are under consideration and will be made available upon completion.

DISPENSING LAWS – THE U.S. SYSTEM

The label of a drug must have certain information according to U.S. federal law (*Food Drug and Cosmetic Act* (FDCA)

Section 502 (21 U.S.C. § 352) and the Code of Federal Regulations (CFR) (21 C.F.R. Part 201). These laws state that the label of a drug should include (but is not limited to): established name of drug; name and address of manufacturer, packer, or distributor; quantity of contents (weight, measure, or numerical count); lot number; expiration date; and adequate directions for use. Additionally, under federal law (FDCA Section 503(b)(2) and (21 U.S.C. § 353(b)(2)), the label of a dispensed prescription drug must include: name and address of the dispenser, serial number, date of prescription or of its filling, name of prescriber, name of patient if stated on prescription, directions for use, and cautionary statements if contained in the prescription. State laws may also impose further requirements on the label of a dispensed drug.

The labeling regulations were originally developed to support the day-to-day needs of medication dispensing. Planners may want to explore options for attaining regulatory relief (from state and federal regulations) on the labeling requirements for pharmaceutical medications dispensed during an emergency event.

There are also dispensing requirements for prescription drugs. Under U.S. federal law (FDCA Section 503(b) (1) and (21 U.S.C. § 353(b) (1)), prescription drugs must be dispensed only upon a written prescription, an oral prescription (which is reduced promptly to writing), or by refilling a prescription. State laws also impose requirements on the dispensing of prescription drugs.

The size and scope of an emergency may dictate that personnel other than pharmacists or physicians must dispense medication to the public. Disaster planners may need to investigate existing legislative authorities such as the *Emergency Powers Act* and possibly regulatory relief that would allow individuals other than pharmacists to dispense prescription drugs during an emergency. It is also recommended that disaster planners become familiar with state laws surrounding these issues. Currently, 44 states allow pharmacists to administer vaccines. Although it would require authorization for an expanded scope of practice in some states, trained paramedics may be an untapped source for vaccine administration and may provide the benefit of having access to underserved populations.[62]

INVESTIGATIONAL NEW DRUGS

In the instance that a pharmaceutical or biological product is approved by the U.S. FDA but not for a particular indication, or the product itself has not yet been approved by the FDA, its use may require an Investigational New Drug (IND) protocol. Drugs that are used under an IND process can only be administered to patients according to an Institutional Review Board (Ethics Committee) approved protocol, which is maintained by the principal investigator and approved by the FDA. The principal investigator may have coinvestigators who are also able to administer the protocol. Pharmaceuticals or biological agents used under IND protocols require informed consent from each patient.

A few examples of such products integrated into the SNS include the use of smallpox vaccine diluted in a 1:5 ratio, the use of colony-stimulating factors for the treatment of radiation-induced neutropenia, and the use of anthrax immune globulin to treat symptomatic anthrax patients. Obtaining informed consent can be a tedious process especially during a disaster involving mass casualties. To better serve the population in a time of disaster, the U.S. Project BioShield law was enacted in 2004 to help provide new tools to assist with protecting Americans against terrorist threats involving chemical, biological, radiological, or nuclear materials.[63] Oversight of the program lies with the U.S. Secretaries of HHS and DHS. One of the key aspects of the legislation is to give the FDA the ability to rapidly offer promising treatments in emergency situations.[64] Project BioShield amended section 564 of the Federal Food Drug and Cosmetic Act to permit the FDA Commissioner, upon official declaration of an emergency by either the Secretary of HHS, the Secretary of Defense, or the Secretary of Homeland Security, to authorize the use of medical countermeasures for the diagnosis, treatment, or prevention of serious or life-threatening diseases or conditions for which there are no adequate, approved, or available alternatives. This process is known as an Emergency Use Authorization (EUA). The EUA is an authorization by the FDA to allow the use of medical products during a real or potential emergency. This may include either unapproved products (products that have not yet been approved under sections 505, 510(k) and 515 of the *Federal Food Drug and Cosmetic Act* or section 351 of the *Public Health Service Act*), or unapproved uses of approved products (drugs, biological agents, or devices). An EUA is authorized for a specific time frame, not to exceed 1 year.

One example of an unapproved use for an approved product may be administration of an antibiotic for post-exposure prophylaxis to a bacterium that is not included on approved labeling for the drug. It may also encompass dispensing of prescription drugs by a unlicensed healthcare provider. The following criteria must be met before the FDA Commissioner may issue an EUA:

- A serious or life-threatening condition could result from the agent specified in the emergency declaration
- It is reasonable to believe the product may be effective in diagnosing, treating, or preventing the serious or life-threatening disease or condition based on the total scientific evidence available
- The known and potential benefits outweigh the known and potential risks of the product when used to diagnose, prevent, or treat the serious or life-threatening disease or condition
- There is no adequate, approved, available alternative to the product

Informed consent is not required for products used under an EUA; however, recipients must still be informed and provided with general information regarding the risks and benefits. The use of an EUA, granted by the FDA at the time of the emergency, may be a more expeditious way of dispensing investigational countermeasures than an IND approach. Not all investigational or IND products will qualify or be approved for use under an EUA. Additional information on EUA may be found on the FDA website at http://www.fda.gov/oc/bioterrorism/emergency_use.html.

ADVERSE EVENTS

Medication-related adverse events may be seen in varying numbers in a mass dispensing or mass vaccination campaign. Using medical products under an IND or an EUA may require the capturing of medication-related adverse events data. This could be accomplished using existing mechanisms available for passive reporting of adverse events such as the Vaccine Adverse Event Reporting System hosted by the U.S. CDC, or MedWatch, which is sponsored by the FDA. Further research, however, is needed to determine the capabilities of these systems to manage events of large magnitude. Additionally, the details of who is responsible for adverse event reporting during a mass casualty require further definition. The timing and peak number of clinically significant medication-related adverse events will likely be related to the duration of the mass prophylaxis campaign, with short campaigns having the greatest potential to overwhelm the capacity of emergency departments, clinics, or PODs.[65] States may also have their own reporting mechanisms in place such as toll free numbers that patients may call to report medication-related adverse events.

COLD CHAIN MANAGEMENT

Cold chain management is defined as maintaining the quality of temperature-sensitive pharmaceuticals throughout transportation, product handling, and storage. Dispensing sites must be able to maintain the temperature of the drugs or vaccines they provide to the public, in accordance with the package insert of the products. In some cases, vaccines may be frozen at temperatures of −20°C or may be refrigerated at 2–8°C. Some vaccines have strict thawing guidelines. Deliveries of assets to the POD locations should not be left outside both for security and proper storage reasons. Each POD location should have the appropriate equipment such as forklifts or pallet jacks to move deliveries as well as sufficient equipment to provide cold chain storage as needed.

ANCILLARY SUPPLIES

For successful mass vaccination and dispensing, the necessary supplies to administer assets must be available. Ancillary supplies (alcohol swabs, bandages, syringes, and needles) should be procured in advance to ensure that vaccines may be administered when necessary. These supplies may not automatically be provided with the vaccines when ordered from vendors or requested from stockpiles. Planners need to consider other additional supplies that may be critical to dispensing, including water for reconstitution of pediatric medications.

RECOMMENDATIONS FOR FURTHER RESEARCH

Although advances in the area of mass dispensing and mass vaccination continue to accumulate, progress has been slow.[66] Opportunities for future research include the development of standardized policies governing the use of businesses (partnerships and agreements) during a public health response; clarifying potential liability issues and solutions that may differ from state to state and may not be well explained in the U.S. December 2005 Public Readiness and Emergency Preparedness Act; providing guidance and funding for inclusion of public and private organizations to partner with public health entities; improving communication to local communities regarding partnerships and plans between public health and private industry; and encouraging state authorities to establish legal authorization and regulatory guidelines (i.e., to allow pharmacists in all states to vaccinate, and provision of guidance on who can dispense).[66] Additional guidance at the federal level is needed to allow for easier dispensing of products under an IND or EUA and identifying data collection requirements for products distributed under an EUA. In addition, more research is required to obtain licensed indications for pediatric or other special populations in product labeling. Creation of alternative dosage forms for pediatrics would help relieve the shortage and storage costs associated with antibiotic suspensions and may also increase compliance. Development of alternative vaccination forms such as a transdermal patch would simplify administration and decrease storage needs.[67] Additional work is needed on mass dispensing models for vaccinations and medication distribution to help communities streamline their operations and provide prophylaxis to their populations in a timely manner. Standardization of data collection forms for gathering patient information before dispensing or vaccination should be considered. More innovation is required to meet the challenge of providing prophylaxis or vaccination to large populations in a short time while maintaining adherence to appropriate regulations. Mass dispensing and vaccination must be tailored to the available local, regional, national, and global resources. Given the rapidity with which a public health emergency could become a national or international event, it is imperative that preparedness, training, and exercise implementation continue at every level. There is a need for continued funding to maintain an acceptable level of readiness. Building a more robust basic public health infrastructure would not only benefit the national and international communities on a daily basis, but would also provide the foundation for conducting a response to a large-scale public health emergency.

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17

Management of Mass Gatherings

Michael S. Molloy, Zane Sherif, Stan Natin, and John McDonnell

> Some people think football is a matter of life and death. I don't like that attitude. I can assure them it is much more serious than that.
>
> Bill Shankly, Liverpool Football Club Manager,
> In *Sunday Times* (UK) 1981

OVERVIEW

Introduction

Globally, the management of mass gatherings encompasses a wide range of activities because of varying types of events and baseline medical and health infrastructures. Mass gathering medical care can be challenging because it is provided in unfamiliar environments without access to standard hospital resources.

The material in this chapter will assist Event Medical Officers/ Command Physicians/Medical Directors, team physicians, and other medical and health personnel to plan for and provide medical services at mass gatherings. In many countries routine prehospital care is the domain of emergency medical technicians and paramedics. In others there is a mixed model with physician involvement and occasionally physician direction. Although nomenclature is inconsistent across countries, this chapter will use the term "medical director" to denote the physician in charge of medical management at a mass gathering. Mass gathering medicine involves a spectrum ranging from additional prehospital resources being directed to a specific area for a defined time period to more sophisticated models in which resources remain in place over a prolonged time. This can include temporary field hospitals and the conversion of fixed facilities into sites where many medical, nursing, and paramedical staff provide care for one hundred thousand or more persons for periods lasting from 6 hours to 4 weeks.

In addition to the medical director, community public health plays an important role in mass gathering medicine, for example, sanitation, water supply, and food safety. In 2004 Levett described the growing awareness of public health issues that had developed in the Olympic time frame between the Atlanta and Sydney games.[1] He noted, "prevention and preparation more than ever are necessary for organized society, and effective planning demonstrates that future uncertainty can be reduced." He further stated that public health should be an integral part of the planning process for the Athens games and that a dual strategy of supporting a successful event and also improving the quality of life of the Greek population would be desirable.

Emergency physicians are ideally trained to provide direct services at mass gatherings and also to provide leadership in planning the organization of routine medical care and potential disaster response to these events. The American College of Emergency Physicians (ACEP) published a position paper in 1976 on the role of emergency physicians in mass casualty/ disaster management, recognizing that their training prepares them for these unique roles.[2] In 1998 the Council of the European Society for Emergency Medicine suggested, "specific training in preparedness for disasters is required for all emergency physicians" and that members of the specialty should participate in disaster planning at local, regional, national, and international levels.[3] Mass gatherings are in essence a form of organized potential disasters in that a large group of patrons are in a defined area where an adverse event would affect a significant number of attendees and require activation of the region's emergency management plan. Because mass gatherings occur sporadically, they are not routinely included in local authority or regional disaster plans. Event-specific planning and appropriate training at the local and regional levels are important. Hsu, in a review of the effectiveness of mass casualty incident training, highlighted that preparedness at the hospital level has increased; however, the effectiveness of training still requires evaluation.[4]

The mass gathering event site may be a temporary facility or a modified fixed facility where the standard emergency plan is insufficient. The standard event plan focuses on event logistics and not on managing a major incident. For this reason planned mass gatherings should have emergency management plans of their own separate from the event plan. Mass gathering medical care is likely to become increasingly important in the current world climate as governments and other statutory authorities place more emphasis on emergency planning.

Medical textbooks that describe illnesses and novel treatments generally transcend borders and will provide useful information for clinicians treating patients irrespective of their locations. Conversely, although basic principles apply globally, mass gathering medicine varies according to applicable laws and variable health systems. In a career focus article in the *BMJ*, Hearns outlines the qualities, training, and benefits associated with event medicine or mass gathering medical care.[5] Many physicians provide mass gathering medical care on a voluntary basis for sports clubs or societies for which they are also the team physician, thereby mixing roles. Some sport rules specify that there be a physician present prior to the game starting, others specify that there must be a separate "crowd" doctor in addition to the team physician when the crowd is over a certain size. Whether the physician is paid or acting as a volunteer does not change the "duty to care" or "standard of care" for the patients. Physicians must be appropriately trained prior to serving as medical directors for mass gatherings. The Gibson report in the United Kingdom published in 1990 made recommendations about medical care at football matches. Gibson emphasized that the specific requirements should include communication skills and command and control procedure training for major incident management. In the *British Journal of Sports Medicine* in 1999, Kerr noted that 9 years after the Gibson report was published, 44% of doctors providing medical services at sports events remained unaware of the major incident plan for their stadium.[6] Nearly three-quarters (72%) of the doctors Kerr questioned had received no training in major incident management and 61% indicated they had not attended Advanced Cardiac Life Support (ACLS)/Advanced Trauma Life Support (ATLS)/Pediatric Advanced Life Support or other British Association for Immediate Care (BASICS) resuscitation courses. These results are for a country that has placed considerable emphasis on major incident training and mass gathering medical care as a result of football match incidents and therefore may underestimate training deficits in other countries.

Some events that should be considered "mass gatherings" for the purposes of medical management have not traditionally been considered as such. For example, certain religious events are some of the biggest regular mass gatherings, such as the papal gatherings for the Catholic church and the Hajj for Muslims.[7–11] It is not unusual for half a million people or more to participate in papal gatherings. Medical planners may underestimate the numbers who will require medical attention at such events.[12] In a descriptive study of the 1982 papal visit to Coventry, Avery suggests that for any gathering of up to 350,000 people significant planning will be required.[7] Earlier, in 1979 Pope John Paul II held a papal audience in Phoenix Park, Dublin, Ireland that was attended by more than 1 million people (approximately one third of the population), one of the highest percentages of a nation's population in attendance in a confined area for a single event. Although data are incomplete, there was only a single fatality recorded at the event that night, a security guard on patrol. Millions travel to Mecca for the Hajj annually. Every able bodied Muslim who can afford to do so is obliged to make the pilgrimage to Mecca at least once. Up to 2 million persons participate annually and there are excellent data on the various medical aspects of the pilgrims and the additional impact on hospital admissions during the Hajj.[11,13,14] Over the years there have been significant numbers of deaths associated with crushing injuries as the crowd surges across the bridge. Planners have redesigned the bridge as a mitigation strategy.

Definition

There is no standard definition of a mass gathering. In addition, mass gathering medical management has only recently received attention, possibly because physicians have not historically had full time roles. Ordinances dating from 1974 in North Carolina, U.S. recognized that

> The mass gatherings of people for an extended period of time at one place within Union County, without proper care being taken for the protection of said persons and the public, can create conditions which are detrimental to the health, safety and welfare of the citizens of this County and the peace and dignity of this County.[15]

To provide for the protection of public health, property, public welfare, and safety the Union County Board of Commissioners, North Carolina adopted ordinances that 1) define mass gatherings and specify that permits are required; 2) specify creation of detailed maps showing the general location, emergency ingress and egress routes, and emergency medical facilities; and 3) mandate services need to be organized in advance.

The ordinance states

> Mass Gathering means the congregation or assembly in which admission is charged or other contributions are solicited, accepted or received, all in reasonable contemplation of profit, of more than 200 people in an open space, or open air for a continuous period of at least six hours.

Alleghany County, also in North Carolina, enacted similar ordinances in 1975 that increased the number of people required to define a mass gathering to 300.[16] The Arkansas State Board of Health also within the United States defined 1,000 persons in one place for more than 12 hours as a mass gathering.[17] Most authors when discussing mass gatherings in a modern setting refer to gatherings of more than 1,000 people, although others define a mass gathering as being greater than 25,000 persons.[18,19] In determining the types and amount of medical care that should be available on site, important elements to consider include duration of the event, spectator type, participant size, demographics, geographies, and access to definitive medical care. In 1999, Jaslow published a review of U.S. state legislation and found that only six states had specific emergency medical services (EMS) legislation governing mass gathering medical care, namely Connecticut, Iowa, New York, Oregon, Pennsylvania, and Wisconsin.[20]

For this chapter a mass gathering will be defined as an event that requires special planning to ensure capacity and capability for the provision of appropriate medical care to attendees without adversely affecting medical care in the host community. The nature of the event including its size and duration, the numbers and demographics of participants, and its geographical location are important considerations. In contradistinction to the sample ordinances, this definition deliberately avoids using numbers to classify a mass gathering. Consistent with the philosophy of this book, the key consideration is the functional impact of the event rather than the absolute number of people involved.

To determine effects on baseline medical services, events must be considered within the context of the involved community. Medical resources must be planned to mitigate any

Class	Subclass	Numbers Involved	Resources Required	Example	Planning Process
Mass gathering	Small	200-1500	Local district	Local Fair	1-2 months
	Medium	1500-10,000	Local district	Local sports game	1-2 months
	Large	10,000-100,000	Local + County	Concert/sports game	6-12 months
Major Mass Gathering		100,000 - 250,000	Regional +/- National	Large music festivals	>12 months
Super Mass Gathering		250,000-500,000	National	Motor sports events	>12 months
Extreme Mass Gathering		500,000-1,000,000	National +/- International	Religious festivals	12-24 months
Mega Mass Gathering		1,000,000	National + International	Papal visits, Hajj	12-24 months

Figure 17.1. Mass gathering classification scheme as proposed by Molloy.

potential negative effects on routine medical care during the mass gathering.

Classification of Mass Gatherings

A classification system for mass gatherings can aid in the planning process internationally and also achieve a commonality of language for describing future events. Although using numbers of participants alone has limitations, some authors have suggested this approach to determine the resources required for planning (Figure 17.1).

Some mass gatherings reduce emergency department (ED) visits, probably due to spectators remaining in their homes watching the event on television.[21,22] Events that are recurring (e.g., local annual fairs, the Hajj) yield historical data that can be used for planning future iterations. Planners can estimate resource needs for major sports events such as American football, NASCAR, baseball, golf, rugby, or soccer that recur regularly in the same location.[23–27] Team members should be cross-trained so that they can fill alternate roles if necessary (e.g., administrative roles if the regular director and deputy are unavailable). Using the same team for each recurrence of the event reduces training requirements.

This cycle of event, analysis, training, planning, and new event should be the goal for those involved in organizing mass gathering medical care. One drawback of such frequent events is that they can lead to complacency. A varied training program emphasizing elements of trauma, cardiac, pediatric, major incident care, and specific hazards will help mass gathering staff to remain vigilant to potential threats.

History of Mass Gathering Medicine

Mass gathering medicine is a relatively new concept. The first mention in the U.K. literature was a short piece entitled the "Price of Pop" in the *Lancet* in 1971.[28] The author describes the effect of a pop festival on a small island community with a population of approximately 120,000. Attendance at the festival was estimated to be 250,000 people at maximum. This temporarily more than doubled the population, created traffic, noise, feeding, and sanitation problems. The authors suggest

> Open-air pop festivals lasting two or three days may be a passing phase, but other fashions may encourage similar gatherings and conditions.

Mass gatherings have grown in frequency and size since this initial description.

Provision of organized mass gathering medical care in the United States dates back to at least the 1960s. After the death of two spectators at a university football stadium in Nebraska, organizers instituted a system whereby staff and equipment were strategically placed within the stadium ready to respond to emergencies.[29] As a result of historic disasters, in the United Kingdom and Ireland, procedures for treating urgent casualties have been in place for almost a century in many sports venues (Figure 17.2).

Year	Stadium	Cause	Deaths	Injuries
1888	Valley Parade, Bradford	Railings collapse	1	3
1902	Ibrox Park, Glasgow	Terrace collapse	26	550
1939	Rochdale Athletic Ground	Roof collapse	1	17
1946	Burnden Park, Bolton	Crushing	33	400
1957	Shawfield, Glasgow	Barrier collapse	1	50
1961	Ibrox Park, Glasgow	Crush on staircase	2	50
1968	Dunfermline	Barriers collapse	1	49
1971	Ibrox Park, Glasgow	Crushing	66	145
1985	St Andrews, Birmingham	Wall collapse	1	20
1985	Valley Parade, Bradford	Fire	56	Hundreds
1989	Hillsborough, Sheffield	Crushing	96	400+
1993	Cardiff Arms Park	Distress rocket	1	0

Figure 17.2. Deaths in U.K. football stadia.

Initially the focus was on protecting participants rather than spectators. In the 1960s disaster planners created the forerunner to the U.K. BASICS with the goal to provide medical assistance to ambulance services at scenes of localized emergencies or major incidents such as mass casualty events. In 1977 healthcare leaders founded BASICS, a system that provides regional teams to respond to disasters throughout the United Kingdom.[30] Many of its members provide mass gathering medical care at stadia.

The Hillsborough disaster in Sheffield, England in 1989 is a well-known example of an incident at a mass gathering. At the Football Association Cup semifinal a large gate had to be opened to allow late comers entrance.[31] This resulted in a rapid build up of supporters on a terrace that was already crowded. There was no escape at the front because of a crowd control ring fence. Large numbers of the crowd suffered asphyxia.[32,33] Ninety-six people lost their lives, 81 on site and 15 more subsequently in the hospital.[34] The two local emergency departments received 159 casualties, 155 of these in the first 90 minutes after the incident. All the severely injured were received within 45 minutes: 81 patients were subsequently admitted to the hospital. DeAngeles described a similar incident in the United States that resulted in 80 persons being injured by crushing or trampling during a crowd surge at a college football game.[35] On this occasion 86 people were transported to the hospital, 10 were admitted for traumatic asphyxia, two had musculoskeletal injuries requiring admission, one patient had a liver injury, and six others were admitted for observation. Several stadium factors were identified that resulted in crush-related injury. Appropriate changes in crowd control policies were implemented.

Another famous historic event is the Bradford City fire disaster in 1985 resulting from a flash fire that consumed one side of the Valley Parade football stadium in Bradford, England. The fire engulfed old wooden stands in less than 4 minutes and 53 people died with more than 250 additional people injured.[36–38] Some of the crowd were so badly burned that they could only be identified from dental records as described.[39] Sharpe in 1985 wrote about the treatment and triage of multiple burns victims arriving almost simultaneously at the local hospital and the sequence of internal coincidences that ultimately minimized the consequences.[40] He subsequently coined the mnemonic COMMUNICATION to help educate other plastic surgeons who may be faced with a similar mass gathering disaster.[41]

C = Chaos
O = Order
M = Most experienced plastic surgeon
M = Make available adequate resources
U = Update casualty figures at regular intervals
N = No points for economizing
I = Inpatient needs
C = Capitalize on goodwill
A = Accommodation
T = Team leader
I = Invite outside help
O = Outpatients
N = Nursing officer

Although this mnemonic was directed at plastic surgeons working in a burn unit, the principles could be adapted to other settings.

Internationally, football-related mass gathering disasters (or soccer as it is known in the United States) have resulted in more morbidity and mortality than most other sports (Figure 17.3). Data are derived from multiple sources and in many cases it is difficult to determine exact numbers of casualties and deaths. One reason for this is that less seriously injured persons were evaluated by their general practitioners rather than assessed at the site of the event. In some instances officials blocked media coverage of the disasters and, as was the case in 1982 when dozens of sport spectators were crushed to death in Moscow, the true magnitude of the disaster did not become evident until many years later, even to those on site. Morbidity and mortality numbers have been substantial and have prompted major changes in the way events are planned and organized. Some of these disasters have occurred in older stadia where walls, ceilings, or roofs have collapsed. Football authorities have instituted a team licensing system to help prevent this from recurring.

In the 1970s and 1980s football hooliganism was widespread throughout Europe. During the last 15 years, law enforcement communities have successfully cooperated to minimize such activities. Nevertheless, civil unrest before, during, and after games still contributes to significant numbers of deaths (Figure 17.3).

Types and Sites of Mass Gathering Events

> I went to a fight the other night, and a hockey game broke out.
>
> Rodney Dangerfield

Mass gathering events may take many formats. Researchers have described event-specific aspects of medical care for the following

- Local fairs[42]
- Music events[28,43–50]
- School and university gatherings[51]
- Stadium sports events[6,52–56]
- Summer and winter Olympics[57–60]
- Major football championships (World Cup, Union of European Football Associations [UEFA] Championship)[6,27,40,61,62]
- Marathons[63]
- Rugby and cricket world cups
- Motor sports[25,64]
- Water sports
- Political demonstrations[42,65]
- Religious events[7,9,66]

Modern arenas or stadia are equipped with medical facilities built to be compliant with community health and safety standards. In many countries local governments build municipal stadia that are licensed to various sporting bodies to use for their particular events. These stadia are frequently used to host rock concerts and some religious gatherings. Because they are designed as multipurpose stadia there are standard basic medical kits and facilities. For contact sporting events, large rock concerts, or long-duration mass gatherings, additional temporary facilities generally need to be constructed to meet the increased medical and health needs.[63]

Figure 17.4 shows an example of a well-bounded stadium with wide access and egress routes to prevent crushing at entrance or exits. From this aerial shot one can see the access roads, free space in the venue, the local town, and the "back stage"

Year	Stadium/City	Country	Cause	Deaths	Injuries
1961	Ibague	Colombia	Stand collapse	11	15
1955	Santiago	Chile	Crushing	5	300 approx
1964	Lima	Peru	Riot	318	1000+
1967	Kayseri	Turkey	Riot	48	602
1968	Buenos Aires	Argentina	Crushing	74	150 approx
1971	Salvador	Brazil	Fighting	4	1500
1974	Cairo	Egypt	Crushing	49	50
1976	Port au Prince	Haiti	Firecracker/crush/Shooting	6	
1978		Ghana	Wall collapsed	15	35
1979	Hamburg	Germany		1	15
1979	Lagos	Nigeria	Riot	24	27
1980	Calcutta	India	Riot	16	100
1981	Karaiskaki Stadium, Athens	Greece	Exit Crushing	21	54
1982	San Luis	Brazil	Shot in riot	3	25
1982	Cali	Colombia	Stampede	24	250 approx
1982	Algiers	Algeria	Roof collapse	10	600 approx
1982	Luzhniki, Moscow	Russia	Crushing	340+	
1985	Heysel, Brussels	Belgium	Riot / wall collapse	38	437
1985	Mexico City	Mexico	Crushing	10	100+
1987	Tripoli	Libya	Riot/Wall collapse	20	
1988	Katmandu	Nepal	Stampede in hailstorm	93	700 approx
1989	Lagos	Nigeria	Crushing	5 ?	
1990	Mogadishu	Somalia	Shot in riot	7	18
1991	Orkney, Johannesburg	South Africa	Crushing/fighting	42	50
1991	Nairobi	Kenya	Stampede	1	24
1992	Marcana, Rio de Janeiro	Brazil	Fence collapse		50
1992	Armand Cesari Stadium, Bastia, Corsica	France	Stand collapse	17	1300 approx
1996	Lusaka	Zambia	Crushing	9	78
1996	Guatemala City	Guatemala	Crushing	78	180
1997	Lagos	Nigeria	Locked exits-crushing	5	
1997	Ciudad del Este	Paraguay	Roof collapse	30+	200 approx
1998	Kinshasa	Democratic Republic of the Congo	Troops fire on crowd	4	
1999	Alexandria	Egypt	Crushing	8	14
2000	Harare	Zimbabwe	Crowd fleeing teargas	13	
2000	Sao Januario, Rio de Janeiro	Brazil	Crushing		>150
2001	Ellis Park, Johannesburg	South Africa	Crushing	43	250
2001	Seville	Spain	Fence collapse	28	
2001	Lubumbashi	Zaire	Crowd fleeing teargas	10	51
2001	Sari	Iran	Roof collapse	2	284
2001		Ivory Coast	Riot	1	39
2001	Accra	Ghana	Crowd fleeing teargas	126	93
2001	Labe, Guinea	Guinea	Crushing	2	
2002	Bulawayo	Zimbabwe	Riot	2	?
2003		Poland	Riot	1	
2004	Qamishi	Syria	Riot	25	
2007	Sicily	Italy	Riot	1	
2007	Salvador	Brazil	Stand collapse	7	40

Figure 17.3. Deaths and injuries during international football disasters.

area (distant from the stage) in the foreground. This venue accommodates an attendance of approximately 25,000. There are standard first aid areas in all such facilities in Ireland and in many other locations in Europe.

UEFA, the European football regulatory authority, has requirements specifying what facilities must exist for clubs to be licensed to compete nationally and throughout Europe, such as in the Champions league. These regulations are available at UEFA.com or from the national football governing body of the specific country.[67] More commonly, a large event takes place in a venue without planned medical facilities and these will have to be created de novo (Figure 17.5).

Figure 17.5 shows an aerial view of Slane Castle, the site of the U2 homecoming concert in 2001 and also the qualifying event for the 2002 World Cup soccer game. Slane Castle is one of Europe's most scenic natural amphitheaters. De novo facilities were created to manage all aspects of the event, from sanitation to medical care. One of the access roads and one of the gates is visible in the foreground. At this late time of day, the lines are short; however, it would not be unusual to have a 1.5 km-long queue of people outside the stadium waiting for gates to open. The castle itself is in the midground and has been site to many of Ireland's most memorable rock concerts since 1981. Evident in the photograph is the natural slope from

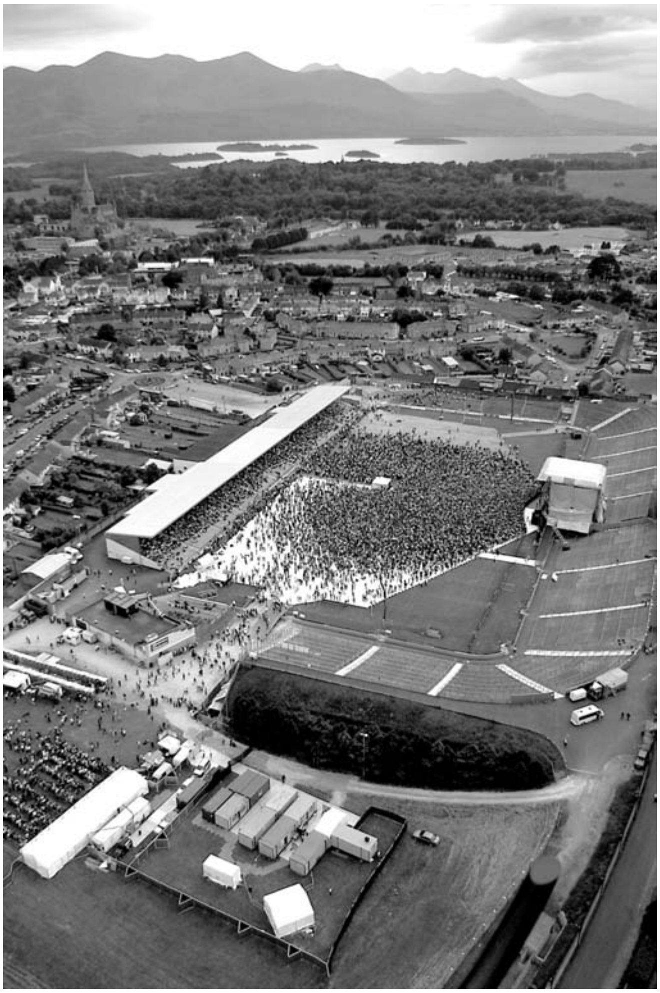

Figure 17.4. Killarney GAA Stadium: Summerfest 2006 credit: macmonagle.com.

entrance on the road to the river more than 150 m gradient below. This particular slope can result in significant numbers of traumatic injuries on challenging underfoot conditions in inclement weather. Murphy described the effects on regional hospitals after an event when 88 patients presented to the two local emergency departments with 13 fractures, six requiring manipulation after induction of anesthesia or formal open reduction and internal fixation.[68] The river in the background is another hazard. It is deceptively fast and has claimed lives over the years as concert goers attempted to swim its course and gain entry for free. In this photograph there are more than 84,000 people in a very confined space with identifiable access and egress routes. Thus, crowd density would be another potential hazard. This example illustrates the types of challenges that are encountered globally due to geography, topography, and insufficient local medical infrastructure.

Tuas maith, leath na hoibre

An old Irish phrase meaning a good start is half the work.

CURRENT STATE OF THE ART

Mass Gathering Event Planning

International guidelines for mass gathering event planning are lacking. Countries with well-developed emergency medical systems such as the United States and the United Kingdom have national guidelines that could be applied in other jurisdictions. In most countries the demand for medical resources at mass gatherings is sporadic and fulfilled on an ad hoc basis. Requests to physicians and other medical workers are increasing in frequency.[54] An ad hoc request the evening before an event indicating "the need for a doctor for insurance purposes" leaves the physician unprepared. This may be the first time the physician will have been asked to provide medical services and there may

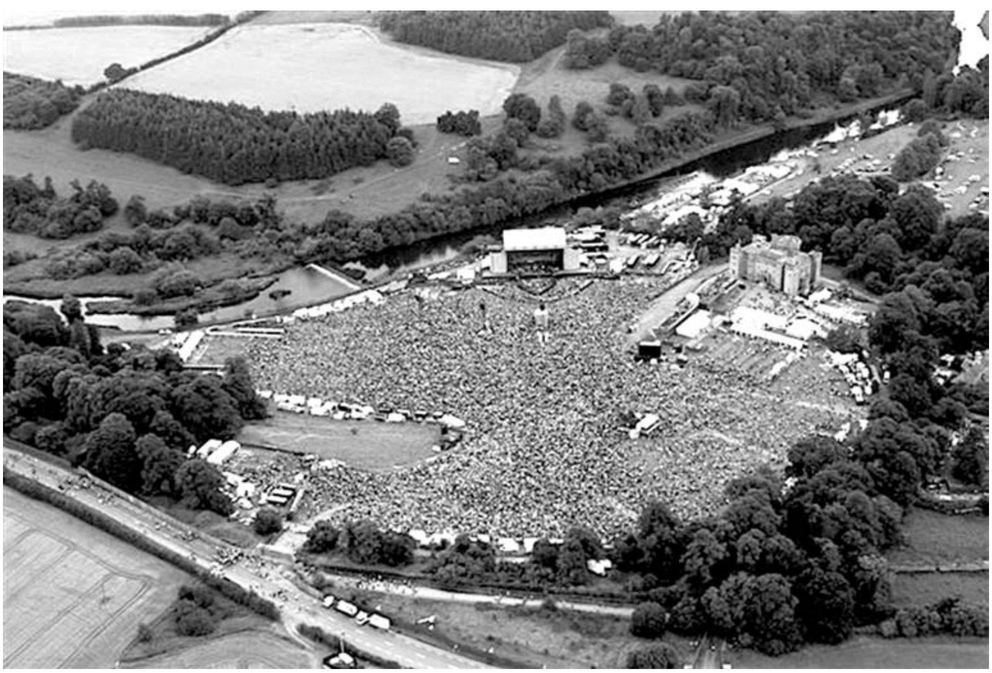

Figure 17.5. Slane Castle 2001: U2 concert.

be no information provided on the layout of the venue, the size of the crowd or number of event employees, what medical facilities will be present, or the standard of training and degree of equipment carried by the EMS service (which may be a voluntary provider) on the day. Other important elements to know in advance include historical information such as how many patrons needed medical attention, have there been any fatalities, what were the crowd demographics, and how many patients were transferred to hospitals?[69–73]

For large venues, mass gathering event planning may begin up to 2 years prior and should occur no later than 1 year before the expected start date. In some jurisdictions the event may require licensing by the local authorities or formal planning permissions when the event involves significant change of use for the venue. Examples include a race course transformed to host a large pop festival for 100,000 patrons with on-site camping for 70,000 for 3 days. Considerations include how many medical practitioners would normally work in a town of that size and how many would be on call at any specific time. The U.K. Event Safety Guide has staffing guidelines.[74] The tables estimate a minimum number of staff who should be on site at all times; when considering staffing levels over a 24-hour period this is paramount. For example, if 14 physicians are required on site at all times and they rotate in 12-hour shifts, a total of 28 physicians per day must be rostered. A Medical Director should be identified at the planning stage and remain involved in the process to ensure that medical matters are addressed and to mitigate any predicted medical risks.

Event planning for a specific mass gathering begins within the organizing body. Once the basic plan is complete, relevant statutory and voluntary agencies are folded into the planning process. Agencies that should be involved early in the planning process include but are not limited to those named in Table 17.1. Nations, states, and smaller jurisdictions such as counties may have different requirements for planning and varying processes for appeals when an application for an event license is refused. As a result timelines for planning must be tailored to local circumstances. In 1996, the ACEP EMS Committee produced guidelines for the provision of emergency medical care for crowds.[75] These can be applied in most countries. The National Association of EMS Physicians (NAEMSP) also promulgated guidelines.[76] One key NAEMSP planning document is Jaslow's Medical Directors checklist.[77]

Table 17.1: Agencies to Involve in Event Planning

- Event promoter
- Local planning authorities
- Local public service transport companies
- Police
- Fire services
- Ambulance services (public and private)
- Voluntary services (e.g., fire and ambulance)
- Civil defense
- Local health services
- Emergency planning/management agency
- Local hospitals
- Site owners
- Event Medical Officer/Command Physician and Deputy
- Public relations/Media

Event-planning Timeline

Local Planning Authority

> Plans are only good intentions unless they immediately degenerate into hard work.
>
> Peter Drucker (1909–2005)

Calabro and colleagues produced a precise event-planning schedule for ACEP in Provision of Emergency Medical Care for Crowds.[75] A sample event timeline modified for Ireland is shown in Figure 17.6. A new template is used for each event and planners provide periodic reports to the director. To allow flexibility to account for unanticipated delays earlier on the timeline, some index times have few or no specific tasks assigned to them, such as at 14 days, 4 days, and 3 days in this model.

The event-planning schedule illustrates the intensity of resources needed and the complexity of organizing a successful mass gathering event from the medical perspective. For regular events such as weekly or biweekly football games, planning may become routine. The event-planning timetable for such regular mass gathering events can be further modified by designating index games such as first pre-season, first in-season, and a mid-season game as full detailed planning events and using a shortened 2-week time scale for the others. For regular events, a yearlong time scale is impractical prior to the first event in the series. Rather, a permanent stadium back room management team for the professional club can be formed to assist in the planning stages, compress time scales, and serve as part of the overall event medical team. When the event is annual, each task takes more time and the medical director will have a more time consuming role. Effects on the routine work schedules in the weeks leading up to each mass gathering event for both the director and the team members should be considered.

Modified from *Provision of Emergency Medical Care for Crowds*, American College of Emergency Physicians.[75]

The following section provides additional detail for each step in event planning as outlined in Figure 17.6.

Define event including

- Agencies involved
- Type of event
- Duration
- Dry or wet event (alcohol or not), age policy for alcohol sale
- Screening for drugs at entrances
- Attendance levels
- Demographics of attendees (minors admitted? elderly or disabled expected?)
- Expected transport modes of attendees
- Event history if applicable with specific details of
    - medical usage rates
    - patient presentations per thousand attendees
    - number of hospital transports
    - names and locations of hospitals
    - outcomes of those transferred
    - numbers of medical, paramedical, and nursing staff
    - reports from voluntary aid societies
    - after action reports
- Provide site map/local area map for event planning team

Walk event site

- Identify topography
- Estimate site diameters/circumference

Task	1yr	6mth	3mth	1mth	14dy	7dy	4dy	3dy	2dy	1dy	EVENT	Post Event	1dy	3dy	5dy
Define Event	X	X		X		X			X	X	X				X
Visit site + Walk	X			X		X			X	X					
Event Planning meetings	X	X	X	X	X	X			X	X					
Get Site Plans	X	X		X		X			X						
Designate + agree responsibilities	X	X		X		X			X		X				
Designate medical/Admin controllers	X			X		X				X	X				
Develop Event Medical Plan	X	X		X	X	X				X	X	X			X
Develop site emergency Plan	X	X		X	X	X				X	X	X			X
Liaise local ED/EMS/Trauma units	X			X					X	X	X	X		X	
Ride alongs to local ED/venue				X		X			X		X				
Obtain indemnity/Malpractice/insurance	X	X		X											
Confirm financial arrangements	X	X		X					X		X				X
Confirm attendance figures	X			X					X		X				
Confirm camping arrangements	X			X		X			X		X				
Confirm VIP Arrangements				X		X			X	X	X	X			X
Recruit Staff + check experience	X	X	X	X		X			X						
Generate outline rosters				X		X			X	X	X				X
Procure + check communications	X			X		X			X	X	X				
Develop medical protocols/SOPs	X		X	X		X			X	X	X	X			X
Medical Staff meeting + agency heads	X		X	X		X				X	X	X			X
Develop + agree event documentation standard		X	X	X		X				X	X	X			X
Credential Staff				X		X			X		X	X			X
Top Up Training		X	X	X					X						X
Procure + check clothing	X		X	X		X			X						X
Procure + check Equipment	X	X	X	X		X		X	X	X	X	X			X
Check adequate siting of medical facilities				X		X		X	X	X	X				X
Assign staff roles	X		X	X		X				X	X	X			X
Procure Site passes/credentials	X			X	X	X			X	X	X	X			X
Set Up event + begin build of facilities						X			X	X	X				X
Pre event briefing						X				X	X				X
Debrief												X			X
Break Up event												X	X		
Post event Audit													X		X

Figure 17.6. Event-planning schedule.

- Plan location of access/egress routes (use Google Earth or equivalent for aerial maps)
- Identify likely location of main and secondary stages for multistage events
- Based on above, plan location for first aid posts and on-site hospitals
- Identify potential hazards and mitigate them
- Identify likely location of campsites if applicable
- Repeat site visit during adverse weather conditions

Event-planning Meetings/Get Site Plans

Regular meetings will take place prior to the event. Some entities like the local emergency planning unit, government health service, and fire and police services will assign a full-time person to this role. For medical personnel, event-planning activities will likely represent extra duties. Medical professionals seeking compensation for these additional activities may find it useful to review the planning timeline and calculate a projected time commitment.

Early review of the event site plan allows an analysis of the potential roles for existing medical facilities and ambulance services. Event planners must advocate for using assets that are the most likely to provide necessary medical resources to support the event and not simply use resources that may be more convenient for existing entities.

Designate and Agree on Responsibilities

- Traffic management
- Site management
- Health and safety
- Voluntary aid
- Communications
- Transport to site
- Transport within site
- Campsite (if present)

Occupational health and safety is an important responsibility for the duration of the event. For large gatherings there may be 5,000 staff on site and even larger numbers with mega events. In some jurisdictions medical personnel are required to inform the statutory authorities of industry-related accidents. Thus a process should be in place to clearly identify medical records specific to staff presentations for work-related injuries. It is important to liaise with the command structures of voluntary aid organizations prior to the event to determine their roles, duties, responsibilities, and reporting relationships. Specific policies and procedures requiring clarification include 1) Under what authority do accompanying physicians work? 2) Who is responsible for the medical actions of nonphysicians? and 3) If a major medical incident occurs during the event, how will volunteer workers receive direction from the event medical director?

Designate Medical and Administrative Controllers

The event medical director and deputy should be identified and trained at least 1 year prior to the start of the event. A person without hospital-based responsibilities during a major disaster should be selected to avoid competing priorities at event and hospital sites.

On-site management follows similar principles to the incident command system. For large events the administration section is a key component. Appropriate types and numbers of records must be provided and distributed to the various venue posts. An administrator ensures that required paperwork is completed at all levels and that essential data are seamlessly communicated between various medical facilities. Patient tracking is important and a system should be in place that enables workers to provide information to friends and relatives with inquiries on victims' locations. Privacy of medical records must be maintained at all times.

Develop Event Medical Plan

Few people have real life experience with mass gathering event planning. For personnel new to the process, communicating with others who have managed similar events and observation of the planning process if feasible are useful approaches. Specific planning needs vary by jurisdiction; however, there are several basic areas that should be addressed.

- Event and audience demographics
- Event medical history
- Proximity to definitive care
- Contact details of medical staff/event managers/safety officers
- Contact details of local hospitals/ambulance services
- Event medical command structure
- Proposed location of field hospital(s) and level of care to be offered
- Proposed location of satellite units and level of care to be offered
- Proposed location of ambulances and level of care to be offered
- Proposed location of staff facilities and parking facilities
- Duties and responsibilities of medical staff
- Duties and responsibilities of medical director/site medical officer
- Communications chain/structure/contact details/procedures
- Documentation and chain for documentation
- Procedure for hospital referrals
- Stand down (return to baseline operational level) details

Develop Site Emergency Plan

The site emergency plan differs from the routine medical plan in that this is the procedure to be followed in the event of a disaster. A standard agreed phrase should be determined that would communicate to all staff that an incident has occurred. Event staff should be prepared to accomplish the following in case a disaster is declared.

- Identify staging points
- Establish triage protocols
- Delineate roles and responsibilities for
  - Medical incident officer
  - Triage officer
  - Casualty clearing station officer
  - Nursing incident officer
  - Ambulance incident officer
- Identify designated hospitals and liaisons
- Establish casualty clearing stations
- Find and liaise with other commanders/incident officers (unified command)
- Gather data for METHANE message
  - Major incident
  - Exact location
  - Type of incident
  - Hazards involved (if any)
  - Access to site
  - Number of casualties
  - Emergency services required
- Log events carefully
- Identify resource requirements

Liaise with Local Emergency Departments/Emergency Medical Services/Trauma Units

Many EMS systems have designated specialty receiving hospitals for patients meeting certain criteria, for example, trauma, burn, cardiac, and stroke centers. Protocols in other systems direct that patients be transported to the closest ED or to the hospital of patient choice. Advanced coordination with ambulance services and local emergency departments will help ensure integration with nonevent-related emergency resource needs and appropriate distribution of patients if a disaster occurs.

Ride-Alongs to Local Emergency Departments/Venues

The event medical director should be familiar with local EMS transport times to be able to make an assessment of needed transport resources. Site visits to local ED leaders are also important to meet key personnel and understand respective responsibilities and resources prior to an event. Local hospitals may provide information critical to event planning.

Obtain Indemnity/Malpractice/Insurance

Liability is a key concern for physicians and other providers working at a mass gathering. Although some countries have no fault compensation systems, most general insurers are reluctant to provide coverage for mass gathering events. In some countries physicians have malpractice insurance and in others they possess medical indemnity (discussed in more detail later). For maximal legal protection, medical workers should inform their primary employers and insurers ahead of the event about their expected activities and qualifications.

Confirm Financial Arrangements/Attendance/Camping/VIP Arrangements

Providing financial compensation for event workers will make recruitment easier. Budget calculations and work agreements must be prepared ahead of time.

Projected attendance estimates, including camping numbers, are necessary to determine medical workforce requirements. Staffing projections should account for changes in attendees over day of week and time of day (e.g., campsite overnight).

If significant numbers of VIPs are expected, the medical director needs to know in advance. Some categories of VIPs have special security requirements, such as, presidents or their families, high-profile politicians, royal families, or other nonperforming rock celebrities. Plans must be in place to manage illnesses and injuries if they occur among this group. This is particularly relevant for presidents as access to services in specific hospitals may be blocked for other patients if a president is being treated.

Recruit Staff and Check Experience/Train and Credential Staff

Staff recruitment, training, and credentialing is extremely time consuming. It is important to ensure that event personnel do not have higher priority competing obligations such as a duty to report to the hospital after a major incident. Community-wide planning is essential to confirm that hospital resources and other portions of the healthcare system are not depleted so they can provide staff to the event site. If identified staff are not sufficiently trained and certified, the event medical director may need to arrange specific training for the event team. Depending on the jurisdiction hospital-based physicians may be required to obtain medical licensure for prehospital events. The director should consult with local medical licensing authorities to ensure that requirements are met in a timely manner.

Develop Medical Protocols and Standard Operating Procedures

The director, deputy, and medical team should develop, publish, and distribute medical protocols for medical staff in advance of the event. Standard operating procedures should also be promulgated for first aid and voluntary aid that delineate levels of care and when additional medical help should be requested.

Procure Clothing

Safety clothing is essential for mass gathering events. Team members should provide professional gear including safety boots, gloves, and high-visibility clothing. The event organizers should provide event-specific items such as high-visibility vests/caps/light rain jackets and so forth. Logistical arrangements like sizing for all team members must be made in advance to ensure timely delivery of specific seasonally appropriate clothing.

Procure Equipment

The medical director should consult with staff who will be on site for the event and organizers of prior similar events to determine what type and quantity of equipment will be needed. Once requirements are determined, the medical director should develop a budget and make a request to the event organizer to provide funds for purchase or lease of the equipment for the duration of the event.

Generate Outline Rosters/Assign Roles/Procure Passes and Credentials

After calculating the expected number of attendees and the expected variations over time, staff scheduling by area should begin. The U.K. Event Safety Guide is a valuable resource for estimating staff requirements.[74] Numbers of physicians needed on site will depend on the level of training of volunteers and EMS personnel. Event insurers may also impose requirements distinct from individual physicians' medical liability providers.

Photographic identification is required at most mass gathering events and will need to be collected 7 days in advance of the event to ensure distribution to individual team members (unless the team is traveling together to the venue). Identification should allow access to all areas. If team members are traveling separately they will need parking passes and route-access passes for any roads that are closed to the public.

Set Up Event/Begin Build/Check Medical Facilities

The first phase of "set up" for the event begins 7 days prior with staging equipment in containers that are ready to be moved on site. The day prior to the event, equipment should be moved to the site and secured overnight. Controlled substances must be kept in double-locked containers, preferably off site until medical staff are present to receive them. A system should be in place to account for restricted drugs and secure them with a responsible worker at shift change. Most events start early in the morning. The medical team should be on site and prepared 2 hours before the event. The team should take a walk-through tour of the site to familiarize themselves with the locations of their duty stations and their access route to the next higher level of care.

Pre-event Briefing

On the day of the event, the medical director should organize a briefing to the on-site team that includes information on

- Use of radios and channel numbers for communications
- Channels for communications to other services
- Individual cell phone numbers
- Roles and responsibilities
- Chains of command
- Top medical priorities
- Identifying transferring physicians if required to accompany patients
- Interaction with other service providers
- Importance of documentation
- Site orientation
- On-site transport possibilities
- Site of main medical facility and satellites
- Break periods with meals

The briefing should also give instructions on procedures in the event of a disaster/major incident to include

- Assembly point for retasking
- Triage protocols
- Communications channels
- Roles of individual physicians and assigned posts

Debriefing

Mass gathering medical care regulations vary by country and individual locality. In Ireland and the United Kingdom legislation requires medical teams to remain on site at their posts for a minimum of 1 hour after the event has finished. For music events the end time would be when the band has left the stage whereas for sports events the event is defined to end when the teams have left the field. The intent of this requirement is to ensure that there is an appropriate level of medical care available for patrons who may suffer a medical event in the process of exiting the mass gathering. In large events, 1 hour may be insufficient for complete egress of patrons, particularly if they must drive from a remote parking facility under crowded conditions. In other confined stadiums 1 hour may be ample time as patrons walk away from the stadium and board public transport.

During this period there is generally ample time for a roving medical director and deputy to perform a quick debriefing of the medical teams at their posts. Key areas of assessment should include

- What went particularly well?
- Were there any areas of concern?
- Were the facilities appropriate?

- Was the provided equipment appropriate?
- What are the areas for improvement?
- Were there any patient safety issues?
- Were there any staff safety issues?

By visiting staff posts, the medical director can determine whether there are any structural issues that need correction before the next day of the event or for future events. Photographic reminders are useful to document recommendations. Following the debriefing, the director or designee should prepare a written summary of the event that includes patient demographics for the day.

For prolonged events with on-site camping some staff will be on night shifts. An overlap period with the day shift is helpful to assist night staff with understanding event operations. The director or deputy should be available for debriefing when overnight staff are going off duty. This allows overnight staff to highlight any issues that need to be addressed during the day and to report on the patients treated overnight. Patterns of injury or illness that may be related to recreational drug use, sanitation facilities, or food-borne pathogens should be sought and the public health services alerted in a timely fashion. In June 2008, the World Health Organization published a comprehensive "key considerations" document in relation to communicable diseases and response for mass gatherings detailing risk assessment and management, surveillance and alert systems, outbreak alert and response systems, and cross discipline considerations such as training, logistics, and communication systems.[78]

Break Down Event

Break down procedures should mirror the set up phase. Transport containers need to be repacked, inventoried, locked, and prepared for transport. A detailed inventory of stock used will assist with planning for similar events in the future and will also highlight what additions may be needed for the following day at multiple day events. Any supplies or equipment left on site at the conclusion of the event (or day for prolonged events) must be appropriately secured. Procedures should be in place to maintain accountability for controlled medications.

The medical director should collate and secure all medical records. Some jurisdictions require a copy of the medical records to be submitted to the regional health service authority. Local ordinances or the permit issued for the mass gathering will clarify requirements. For events with camping at locations remote from the main medical facility, additional medical posts may need to be established over night. Depending on the flow of patrons these posts may not be in operation during the day when few patrons are expected to remain on campsites.

Medical Reconnaissance

It is a bad plan that admits of no modification.

Publilius Syrus (~100 BC)

A site visit by the medical director and deputy can reveal a number of details that may not be evident from reviewing planning applications, architect drawings, or aerial photographs. Venue location, access routes, and topography should all be assessed. Google Earth is a useful tool for generating aerial maps for the majority of locations worldwide. Maps can show access routes overlain with rail networks. It is useful to drive to the event site during peak traffic to estimate transport times to the venue. Per licensing requirements, the event start may be delayed until the medical team arrives. Extra time should be allowed because police and other authorities may alter access routes and change normal traffic flow on event days. For example, roads that may have been two-way may only be one-way. The medical director and deputy should remain informed about planned traffic routes to ensure that their team has priority access to routes if such exists. Special parking passes may be required for vehicles and would need to be secured in advance.

Pre-event visits will also allow the director and deputy to plan ambulance transports from the venue. For large venues there may be a significant period of on-site travel from the various first aid posts to an ambulance and then another period of travel on site before the ambulance gets to the access road. At a venue with remote parking or a town nearby there may be large numbers of attendees walking along the roads to the venue, which may further increase ambulance transport times. These factors affect overall transport times to hospital. The Event Safety Guide has a useful model for predicting resource requirements including a scoring system for proximity to definitive care.[74]

Planning should account for the fact that the transport times may increase dramatically from baseline during mass gathering events. In addition, some mass gatherings take place in remote venues where the nearest ED may be small and have few resources. Even in a moderate-sized setting with an annual ED volume of approximately 36,000 (fewer than 100 patients per day), a requirement to transport 100 patients over a 24-hour period would likely exceed surge capacity in that institution. Nix and Ryan in their papers from Ireland in 2004 and 1992, respectively, describe the effect on attendances at local and regional emergency departments for a 3-day festival and a large single-day rock concert.[47,79] In Nix's case there were 1,355 attendances for medical attention on site over a 2-day festival (3 nights camping on site). This represented 1.7% of those in attendance at the event. Milsten in 2003 discussing variables influencing medical usage rates (MURs) describes the term MUR as being a number of presentations per 10,000 attendances.[80] For the Nix event this would then result in an MUR of 171, a significant number when compared with Milsten's own average figures of 4.85 for baseball games, 6.75 for football games, and 30 for rock concerts. Ryan's MUR of 10 is still significant but it was a much shorter event than Nix's and resulted in only 18 patients being transported. Nix reported 72 transports during a 3-day event. This represented a 45% increase in workload for the local ED. What is not clear from either report is the number of secondary transfers that occurred from the local ED to a regional trauma center or for higher levels of care due to the need for intensive care services.

The numbers of physicians in the field at the event may be significantly more than that staffing the local ED. What may seem like a small number of referrals from the venue taking the crowd size into account may actually overwhelm the local ED, forcing them to go on ambulance diversion. This would significantly increase transport and turnaround times with the consequent loss of on-site physicians for longer periods when they accompany patients during transport to more distant hospitals. In some settings, the local ED may also not be able to accept intubated or other types of critical patients. To guide transport decisions, the site medical director needs to know the current capacity and capability of the local healthcare resources throughout the duration of the event. Historical information as described by Arbon is useful for repeat events.[19] This complex model predicts the requirements for patient transports. Requirements for a physician to accompany transported patients must be clearly understood in advance so that staffing levels can be adjusted accordingly. Air evacuation procedures should also be delineated if applicable.

The medical director needs to talk to the venue owner or facility manager regarding the site itself, its current usage, drainage patterns, whether the fields have been rolled or not, internal access routes, and use of chemicals on the land. Rolled fields will help prevent ankle injuries. Facilities that have been sprayed with chemicals may result in allergic-type ophthalmological presentations especially in summer. Hay fever exacerbations may increase in number when large open fields have recently been cut in advance of the event. Some facility managers may cover the playing surface in a stadium with a temporary surface to protect it from damage. This procedure can create inversion effects with microclimates of increased temperature over specific areas and result in increased demands on medical services. In a review article, Milsten described this phenomenon at a rock concert in Denver, Colorado where a black tarp caused a local rise in temperature of 17°C.[81]

Additional considerations include the drainage capacity of the land and the locations of internal walkways. If there are areas where water is likely to pool, these should be highlighted on event maps and campsites; access routes and medical facilities should not be located there. Thousands of patrons could potentially be stranded when attempting to leave the event if parking is situated in an area prone to water logging. If this parking location is unavoidable, contingency plans should be in place for this possibility.

Both director and deputy should walk the site to assess timing of foot transport between the clinical areas, around the circumference of the site, and between the campsites (if present) and the main arenas. In a football stadium this may be a simple task; however, in a large open-site race course where there may be multiple venues and campsites accommodating more than 50,000 people, there may be a need for medical personnel to have on site transport. Such transport should be season and weather appropriate, for example, golf carts are unlikely to be useful in muddy, marshy conditions.

VIP care including access and evacuation plans needs to be discussed in the planning stages. At the time of this writing, Ireland has the highest proportion of helicopters per capita in the world and these are used frequently for VIPs to attend mass gatherings. The event medical plan should address potential hazards from helicopters if they are to be used. If the VIP area is distant from the on-site medical facility, a separate VIP medical area may need to be established.

Local authorities and law enforcement are good sources of information regarding the potential for violence or issues related to drugs misuse. They may require the presence of a physician at "pat down" entry to the venue to verify that tablets/medicine are for legitimate medical use, particularly if they are not in their original dispensed containers. Posters that display the common drugs of abuse can be a useful reference aid at this location.

A reconnaissance visit to the local hospitals and potential referral sites in advance may help to ease the referral process during the event. The local ED may be small and the addition of 80,000 event attendees may result in significant increases in attendances.[47,68] In some areas there may be a local referral hospital, in others there may be protocols for bypassing local facilities and transporting certain types of patients to specialty receiving hospitals such as trauma centers. On-site physicians must be familiar with these policies.

Negotiations

The medical director should ensure that negotiations take place at an early stage. Issues for discussion include

- Liability coverage
- Compensation
- Site access
- Required resources
- Command and control issues
- Safety
- Communications
- Transportation
- Housing on site (if applicable)
- Media issues
- VIP medical care
- Documentation
- Postevent debriefing and reporting requirements

The medical director should negotiate compensation for all staff providing medical services and also appropriate compensation for the director and deputy for the planning, preparatory work, and medical direction during the event. Recruiting additional appropriately trained medical staff for the event will be easier if the compensation package is understood. In systems where mass gathering medical care is provided by the local health authority, hospital staff may be offered additional compensation to provide medical services to the event. This arrangement can be advantageous for the event organizer as many of the employment and liability issues will be covered by the hospital.

Site access will also need to be negotiated in advance. On large event sites, patron access levels vary from highly restrictive to an "Access All Areas Pass." Even the highest level of patron pass may not include access to certain secure areas of the site. Medical personnel should be granted access to all areas needed for responding to patient care needs, even if this includes the ability to traverse a restricted area. On-site security workers must be educated to allow healthcare workers access when they are responding to medical emergencies. Other important access issues are car parking and route access. If special venue route access passes exist, medical teams need them to ensure that they are able to transport medical equipment to the site.

A system of identifying medical, nursing, and paramedical personnel is required and should be coordinated with other event workers. Identifying clothing such as polo shirts, T-shirts, sweatshirts, and rain jackets with pockets to store medical items should be provided. Team members should provide their own personal protective equipment such as safety boots, trousers, gloves, and high visibility jackets with appropriate identification for overnight work. Shift duration should be no longer than 12 hours for very high-intensity work or 16 hours for low-intensity work. For events that are multiple days in duration, on-site lodging may be the most practical and time efficient arrangement for the team. This would reduce the risk of motor vehicle collisions driving home from the event late at night. For overnight work accommodation may also be required for on-call staff to allow for short rest periods and sleep if possible. Even small amounts of anchor sleep have been shown to improve performance.

VIP medical care procedures need to be negotiated in advance. At some large events there is a specific VIP area that may be back stage or otherwise separated from the rest of the attendees. Placing a dedicated physician in this area may prevent problems related to patrons or the media trying to access the medical tent where a VIP is being treated. If the promoters request a separate physician dedicated to VIPs this should be added to the numbers required to staff the event itself as per the local template used to estimate staffing levels or the U.K. Event Safety Guide.[74]

Airway problems represent some of the most sensitive issues related to mass gathering medical care. Although anyone with emergency airway experience (e.g., an emergency physician) can fulfill the role of airway management, in some countries, event promoters often specify that an anesthesiologist be among the medical team in attendance. Staffing levels as suggested in the Event Safety Guide refer to the number of generic physicians required to staff an event in the United Kingdom.[74] If physicians with specific training and experience are required, they should be in addition to the generic number of physicians calculated. The medical director, and deputy for large events, should focus on administrative aspects of event management and will therefore not be available to provide direct medical care.

On-site transport issues should be addressed during the advance negotiations. For bounded sports stadia and indoor venues it is unlikely that on-site transport will be required; however, for large unbounded events on sites such as city parks, race courses, marathons, or music festivals with large campsites on-site transport is essential. With very large events promoters may have to identify a significant number of golf carts or quad bikes in advance. The medical director should ensure that adequate types and numbers of transportation vehicles are dedicated to medical staff. Vehicle type should be appropriate to the terrain and weather conditions. Some event sites are only accessible by foot, for example, at the Glastonbury Festival of Contemporary Performing Arts in England, patrons hiked through mud baths every day to reach the concert venue from the campsite. For flat venues with long transport distances it may be necessary to secure carts that can accommodate spinal boards for transporting patients with suspected spinal injuries.

Level of Care

Level of care provided on site will depend on a number of factors including

- Local legislation, ordinances, and licensing rules
- Event size
- Presence of on-site camping
- Estimated effects on local EMS infrastructure
- Whether the site is remote from local hospitals
- Whether the local area is urban or rural
- The capacity of the local ED to treat trauma patients and admit intubated patients

Local designations of provider level may include emergency first responder, first aid personnel, and emergency medical technician. Patients should be assessed by the most appropriate person based on their medical needs. In the setting of mass gatherings, significant numbers of internal transports of patients from satellite facilities to stations where there are nurses and physicians or to the site hospital facility may be required. The level of care plan should address early defibrillation goals and how these will be achieved on a dispersed site. In generic terms the level of care provided should mimic what is available in the community and should not drain community resources needed for nonevent-related emergency care.

The level of care plan should address the ABCDEs of mass gathering management as follows

- Airway – assessment of compromise and management
- Allergic reactions/anaphylaxis/altered mental status
- Breathing assessment and management
- Bites/burns/bones/back pain
- Circulatory problems – assessment and management, including chest pain
- Disability assessment – strokes, headaches
- Drug ingestions/drug exposures/drug overdoses/diabetic emergencies/drowning
- Electrocution/environmental emergencies/eye and ear, nose, and throat presentations
- Soft tissue injuries/psychiatric emergencies/syncope/seizures/spinal assessments in trauma

Airway management is one of the issues of greatest concern for event promoters. The medical team on site at mass gatherings should be skilled in emergency airway management. All members of the medical team should be aware of the location of the nearest equipment (if it is not carried on the person). At least some types of rescue airway devices such as the bougie, laryngeal mask airway, intubating laryngeal mask airway, and Airtraq single-use intubation assistant should be available.[82–84]

Medical Oversight

The event plan, not the medical plan, defines requirements for medical oversight. In many jurisdictions, this is the document submitted for licensing or permits. It should contain specific roles and responsibilities for both the medical director and deputy and indicate which position will have the primary medical command officer role in the event of a major incident. The event plan may also specify the various training requirements, certifications, and indemnity/malpractice or insurance required of the medical director and deputy. The medical team provides both indirect and direct medical control. The medical director's indirect role refers to designing the site medical plan and ensuring that standardized levels of care are present throughout the site. There must also be a mechanism for medical supervision of all activity on site either directly in the same vicinity or indirectly by protocol or standard operating procedure.

Direct medical oversight refers to the director's supervisory role during the event. The director should be easily recognizable by uniform. Jaslow outlines these roles in detail in the United States context in the *Mass Gathering Medical Directors Care: The Medical Directors Checklist.*[77]

Medical Staff Selection

Because significant orientation and training is necessary for personnel without prior experience in mass gathering medicine, medical staff selection should take place as early as possible. On-site providers should not be given the false expectation that they will have the opportunity to enjoy a free sporting or music event. Rather, their primary mission will be to support medical care for the event.

The director should identify the numbers and types of staff needed, using appropriate tools. Depending on crowd numbers there may be a requirement for first aid or more advanced medical tents to be spread over a large area. Thus some practitioners will be expected to work alone at times and must know the indications and procedures for accessing more advanced medical care. If possible, staff recruitment should begin 1 year prior to the event, particularly in rural locations where resources may need to be drawn from outside the local area.

Medical Staff Training

All those providing medical care at the event should be qualified to provide appropriate levels of life support. A board-certified physician with regular experience during routine duties probably does not need additional clinical training but may need training in incident command systems. For certain levels of providers, additional certifications may be desirable or required. Depending on roles and responsibilities, these could include Basic or Advanced Cardiac Life Support, ATLS, Prehospital Trauma Life Support, International Trauma Life Support, Advanced Disaster Life Support, Major Incident Medical Management and Support (MIMMS), Safe Transport and Retrieval, Advanced Life Support in Obstetrics, Neonatal Resuscitation Program, Hazardous Incident Medical Management, and Advanced Pediatric Life Support.

Completion of the stadium or Advanced MIMMS courses is desirable for event medical directors. Advanced degree programs (e.g., MSc, MPH, MBA, PhD) that focus on disaster and emergency management are becoming increasingly available and would be useful for physicians pursuing a career in this field. One unique program conceived in 1998 is the European Master in Disaster Medicine, a second-level masters degree awarded jointly by the Free University of Brussels and The University of Eastern Piedmont in Italy (http://www.dismedmaster.com/). This is a 1-year interactive distance-learning program in which students from around the world complete course work, online examinations, a publishable thesis and a concentrated 2-week residential program that includes a full-scale major disaster exercise.

The Royal College of Surgeons in Edinburgh, Scotland offers a diploma (DipIMC) and Fellowship examination (FIMC) in immediate medical care. The training provides a solid framework for medical practitioners and advanced paramedics in many of the skills needed for mass gathering medical care. Sporting bodies such as the Football Association in the United Kingdom sponsor a course in rapid emergency management on field called REMO. The Football Association also offers a stadium management course, "Crowd Doctors Course" that addresses all aspects of crowd medical care. The Rugby Football League, based in Leeds, England provides a course entitled immediate medical management of the field of play designed for doctors who are providing medical care to teams and in stadia at rugby league events. Physicians providing on-field services to rugby league teams are mandated to be current in their certification or their team will face a hefty fine.

If the event is likely to recur, the director should consider developing a training schedule for a pool of dedicated staff. This can provide training opportunities in mass gathering medical care for resident physicians and disaster medicine fellows, practical experience as a team member, and the ability of those with an interest to train as a deputy medical director.

Triage

Triage has existed since the days of the Napoleonic wars as a method to ration medical resources when demand exceeds supply (see Chapter 12). Most systems have an initial filter for ambulatory wounded patients (termed "minor" or "green"). The remaining patients are then categorized according to reproducible scales. Several dozen triage systems exist and use various tools, labels, and even colored hair bands or clothes pegs to sort patients in priority of either medical need or order for transport to definitive care sites. Separate systems exist for pediatric triage and should be considered if applicable to the event demographics. Because few data exist that validate any of the multiple triage systems, choosing a system familiar to local providers may be the best option.

Medical staff at all levels should be trained on the chosen triage system. For those with no prior triage experience for this setting, exercises should take place. Some experts recommend that the triage method be published in team member guidelines and that there be an early practice session for all team members on the opening day of the event. Another suggestion is that posters explaining the triage system be developed and distributed to medical facilities (including receiving hospitals), casualty clearing stations, and each first aid post.

Required Resources

Management of a mass gathering from the medical perspective requires human resources, medical equipment, pharmaceuticals, and medical facilities with sufficient examination rooms on site. For very large events a dedicated logistician would be useful. In 2000, Jaslow, on behalf of the NAEMSP, produced a document entitled Mass Gathering Medical Care: The Medical Directors Checklist.[77] This is a comprehensive resource for anyone involved in directing medical care at mass gatherings. It contains great detail regarding medical equipment needs, including essential and desirable components for basic and advanced medical interventions.

Estimating Medical Resources

> Don't live in a town where there are no doctors.
>
> Jewish Proverb

There are no international standards for the numbers of physicians, training requirements, or level of care that should be provided at mass gatherings. Although not necessarily evidence-based, event licensing regulations or local statutes and ordinances may specify required numbers of medical personnel. If they exist, such ordinances or statutes specify minimum levels of physician coverage and have usually not been updated to account for increased duties and medical developments locally, nationally, or internationally. Estimating medical resources required for any mass gathering is an inexact science and may involve real-time adjustments to ensure that sufficient resources are present on site. For the first iteration of an event, it is better to overestimate staffing and equipment requirements than to risk the consequences of understaffing or underresourcing. Once experience is gained from the same or similar events on multiple occasions, patterns will emerge that allow for a more valid estimate of the true requirements for human resources, equipment, and transportation assets. Even when good data are available, it is prudent to provide more than just the minimum numbers of staff and a system for surge capacity in case of a sudden increase in health and medical demands.

Organized planning for mass gatherings at stadia is relatively new, beginning over the last two decades. Retrospective analysis of attendance rates on site for medical treatment, medication and equipment use, transport to hospitals, and audit of medical records provides planning guidance for minimum requirements for an event of similar size in the same jurisdiction. Although generic planning elements are similar, no two mass gatherings have identical requirements even when planned for the same site, crowd number, and activities. Resources requirements are dependent on a variety of factors including

- Jurisdiction and legal safety standards
- Level of care in local EMS system
- Distance to definitive medical care
- Time period before outside assistance arrives (i.e., how long stadium needs to be self-sufficient)

The total medical resources required to manage medical services at a mass gathering include but are not limited to

- Ambulance personnel and on-site ambulance officer
- Communications officer(s)
- EMS director
- Paramedics
- First aid workers/Volunteers/First responders
- Nurses
- Physicians, including medical director and deputy director(s)
- Ambulance service managers
- Support units
- Ambulances
- On-site transport vehicles
- Event safety officer/Event controller (provided by event organizer)

Since health systems vary widely there is no universal matrix to calculate staff numbers, grades, or types of services required to provide medical coverage at a mass gathering. In some countries voluntary first aid organizations such as the Red Cross, the St. Johns Ambulance, or the Order of Malta may provide medical services without an on-site physician. In other regions local referral hospitals operate temporary facilities on site in an attempt to prevent unmanageable patient volumes from being transported to their existing fixed facilities.

The U.K. Health Services Executive in conjunction with the Home Office and Scottish Office published *The Guide to Health, Safety and Welfare at Pop Concerts and Other Similar Events* in 1993. This was updated in 1999 to reflect changes in U.K. health and safety law and to update best practices. The Event Safety Guide was developed in consultation with an event industry working group and is the standard for managing health and safety at such events.[74] Although it has no legal basis in Ireland, it is regularly referenced in planning meetings in conjunction with the Codes of Practice for Safety at Sports Grounds, Safety at Outdoor Pop Concerts and Safety at Indoor Concerts, which are government-sponsored documents.[85–87] These are examples of country specific documents that outline basic levels of care

Table 17.2: Event Nature

		Score
(A) Nature of Event	Classical performance	2
	Public exhibition	3
	Pop/rock concert	5
	Dance event	8
	Agricultural/country show	2
	Marine event	3
	Motorcycle display	3
	Aviation	3
	Motor sport	4
	State occasions	2
	VIP visits/summit	3
	Music festival	3
	Bonfire/pyrotechnic display	4
	New Year's celebrations	7
	Demonstrations/marches/ political events low-risk disorder	2
	Medium-risk disorder	5
	High-risk disorder	7
	Opposing factions involved	9
(B) Venue	Indoor	1
	Stadium	2
	Outdoor, confined location, e.g., park	2
	Other outdoor, e.g., festival	3
	Widespread public locations in streets	4
	Temporary outdoor structures	4
	Includes camping	5
(C) Standing/Seated	Seated	1
	Mixed	2
	Standing	3
(D) Audience Profile	Full mix in family groups	2
	Full mix, not in family groups	3
	Predominantly young adults	3
	Predominantly children, teenagers	4
	Predominantly elderly	4
	Full mix, rival factions	5
Add (A) + (B) + (C) + (D)	Total Score for table 1	

Source: From the Event Safety Guide, published by Her Majesty's Stationery Office.

Table 17.3: Event Intelligence, Event Safety Guide

		Score
(E) History	Good data low casualty rate previously (less than 1%)	−1
	Good data medium casualty rate previously (1%–2%)	1
	Good data high casualty rate previously (more than 2%)	2
	First event, no data	3
(F) Expected Numbers	<1,000	1
	<3,000	2
	<5,000	8
	<10,000	12
	<20,000	16
	<30,000	20
	<40,000	24
	<60,000	28
	<80,000	34
	<100,000	42
	<200,000	50
	<300,000	58
Add (E) + (F)	Total Score for table 2	–

Source: From the Event Safety Guide, published by Her Majesty's Stationery Office.

and resources that attendees can expect to receive at music and sports events.

The Event Safety Guide contains tables that are helpful for estimating a reasonable level of resources that should be provided at events. These guidelines provide a good framework; however, they were developed based on the levels of care available in a particular jurisdiction and may not be applicable in all countries. Data from Tables 17.2–17.4 can be combined to provide a scoring system that can be applied to Table 17.5 to calculate recommended resource requirements.

Equipment

A useful approach in determining the equipment needed for a mass gathering is to coordinate with the local ambulance services. Many ambulance services have disaster/major incident–specific equipment in significant quantities with procedures for rapid restocking when necessary. This equipment can be staged directly on site or in proximity.

Planners should be prepared for unanticipated changes in requirements and develop flexible command and control systems that can accommodate unexpected events. For example, at a mass gathering in Ireland, cloudy weather was predicted. A heat wave occurred unexpectedly on the second day of the event and resulted in large numbers of patients seeking treatment for sunburns. Patrons from out of town and members of the on-site medical team rapidly depleted supplies of sunscreen and "after sun" products from stores and pharmacies within a 32-km radius of the event.[88] This illustrates the need to be creative in obtaining unanticipated resources.

Table 17.4: Sample Additional Considerations, Modified from the Event Safety Guide

		Score
(G) Expected Queuing	<4 h	1
	>4 h	2
	>12 h	3
(H) Time of Year (Outdoor events)	Summer	2
	Autumn	1
	Winter	2
	Spring	1
(I) Proximity to Definitive Care (closest suitable emergency department)	<30 min by road >30 min by road	0 2
(J) Profile of Definitive Care	Choice of EDs	1
	Large volume ED	2
	Small Volume ED	3
(K) Additional Hazards	Carnival	1
	Helicopters	1
	Motor Sport	1
	Parachute Display	1
	Street Theater	1
(L) Additional On-site Facilities	Suturing	2
	X-ray	2
	Minor surgery	2
	Plastering	2
	Psychiatric/Primary care facilities	2
Add (G) + (H) + (I) + (J) + (K) + (L)	Total Score for table 3	–

Source: Modified from the Event Safety Guide, published by Her Majesty's Stationery Office.

It is difficult to estimate the exact quantity of pharmaceuticals that will be required. Planners should develop a restocking agreement with a local pharmacy or the local health service. Some medications require refrigeration. Controlled substances will need to be appropriately secured. One approach would be to designate one of the medical teams as being responsible for sign out of controlled drugs with signature policies on a named patient basis.

Additional field hospital supplies and resources include

- Beds/cots/trolleys
- Tables and chairs
- Sinks
- Access to electrical power
- Sheets
- Blankets
- Pillows
- Towels
- Drapes
- Patient identification bracelets
- Refrigerators
- Safety pins

Table 17.5: Suggested Resource Requirements, from the Event Safety Guide

Score	*Ambulance*	*First Aid Worker*	*Ambulance Personnel*	*Doctor*	*Nurse*	*National Health Service Ambulance Manager*	*Support Unit*
<20	0	4	0	0	0	0	0
21–25	1	6	2	0	0	visit	0
26–30	1	8	2	0	0	visit	0
31–35	2	12	8	1	2	1	0
36–40	3	20	10	2	4	1	0
41–50	4	40	12	3	6	2	1
51–60	4	60	12	4	8	2	1
61–65	5	80	14	5	10	3	1
66–70	6	100	16	6	12	4	2
71–75	10	150	24	9	18	6	3
>75	15+	200+	35+	12+	24+	8+	3

Source: From the Event Safety Guide, published by Her Majesty's Stationery Office.

- Pen and paper
- Patient report forms
- Nonhazardous waste bins
- Hazardous waste bins
- Head lamps
- Floor lamps
- Phones
- Fax machines
- Printers
- Laptop computers
- Lock boxes for pharmaceuticals
- Spare batteries (multiple sizes)
- Flashlights: large and small for examination
- Access to bathroom

Medical equipment includes

- 12-lead EKG machine, paper stock, skin razors
- Airway equipment (Ambu bags, laryngoscopes, blades/batteries/airways endotracheal and nasal/oropharyngeal and laryngeal masks, Airtraq devices, saturation probes, portable pulse oximeters, portable face masks, oxygen masks)
- Automated blood pressure monitors
- Bandages/gauze pads/band aids and elastoplast/adhesive tapes
- Betadine
- Blankets
- Blood glucose strips, monitors, ketone measuring strips
- Broselow tapes (to estimate pediatric weights and drug doses)
- Burn dressings
- Cotton balls
- Defibrillator – AED (Numbers dependent on-site layout)
- Delivery packs for obstetrics
- End-tidal CO_2 monitors
- EZ IO intraosseous access devices
- Face masks

Gloves: sterile/nonsterile, latex/nonlatex, multiple sizes

- Intravenous fluid infusers
- Intravenous fluids
- Intravenous devices and tubing
- Multiple cervical collars – adult and pediatric (or universal) sizes
- Nasogastric tubes
- Needle cricothyroidotomy kits and supplies
- Needle thoracostomy kit/portable chest tube kit
- Neonatal resuscitators
- Thermometers
- Observation monitors
- Ophthalmoscopes
- Otoscopes
- Oxygen tanks, regulators, masks, and nasal cannulae
- Portable ventilators
- Prescription pads
- Ring cutters
- Skin closure devices (steri strips, tissue adhesive, skin clips, suture kits, and sutures)
- Snellen charts
- Spinal boards
- Splints: multiple sizes/slings/dynacast/crutches
- Stethoscopes (electronic with volume control at rock concerts)
- Suction devices (with chargers), suction catheters
- Trauma scissors
- Urinalysis strips
- Vaseline gauze and tubs

Pharmaceuticals

Drugs can be categorized according to the ABCDEs of mass gatherings as described previously. Even with this comprehensive approach, it is likely that medical needs will occasionally exceed immediate resources. For this reason, planners should develop policies for medication restocking, for example, with local pharmacists. The following represents the classes of drugs that should be available on site.

Airway

- Bronchodilators
- Induction agents
- Nebulized and oral steroids
- Paralytic agents

Allergic reactions/Anaphylaxis

- Epinephrine
- Oral and topical steroids
- Oral and topical antihistamines

Analgesics

- Aspirin (also for chest pain)
- Acetaminophen
- Antacids (proton pump inhibitors, H_2 blockers)
- Antiinflammatory medications
- Nonsteroidal antiinflammatory agents
- Opioid analgesics
- Other nonnarcotic analgesics

Breathing

- Antibiotics
- Bronchodilators

Bites/Burns/Bones/Back pain

- Point of care tests for tetanus immunity (desirable because there is growing evidence that most persons in industrialized societies are immune even though they may think they are not)[89,90]
- Vaccines: Antitetanus/Hepatitis B passive and active immunization (particularly for "fight bites")
- Water gel/Silver sulfadiazine cream or similar
- Analgesics as above
- Local anesthetics

Circulatory problems: ACLS medications

- Adenosine
- Amiodarone
- Atropine
- Beta blockers
- Calcium chloride
- Calcium channel antagonists
- Digoxin
- Epinephrine
- Lidocaine
- Nitroglycerin
- Vasopressor agents
- Sodium bicarbonate
- Thrombolytic agents (consider if delay to definitive care)

Disability assessment: stroke, headaches

- Analgesics
- Antibiotics (if suspect meningitis and delay to lumbar puncture/definitive care)

Drug ingestion/Drug exposure/Drug overdose/Diabetic emergencies/Drowning

- Activated charcoal (efficacy questionable)
- Antidotes to common poisons
- Antiepileptic medications (lorazepam/diazepam/midazolam)
- Antihistamines (topical, oral, and parenteral)
- Dantrolene (for MDMA poisoning with hyperpyrexia)
- 50% dextrose
- Glucagon
- Induction agents
- Insulin
- Steroids (oral and parenteral)

Electrocution/Environmental emergencies/Eye and ENT presentations

- Topical anesthetics
- Topical antibiotics (ophthalmological preparations)
- Topical antibiotics (aural preparations)
- Irrigating solutions
- Mydriatic agents
- Fluorescein dye (strips or drops)
- pH strips

Soft tissue injuries/Skin problems/Psychiatric emergencies/Syncope/Seizures/Spinal assessments in trauma

- Antiepileptics (lorazepam/diazepam/midazolam, including rectal diazepam)
- Anxiolytics
- Skin closure aids (steri strips/tissue adhesive/staples, and sutures)
- Topical antihistamines/steroids/antibiotics/antifungals
- Oral and systemic antibiotics
- Sedatives
- Local anesthetics

Other
Antidiarrheal agents

Transport (On and Off Site)

Transportation vehicles can include golf carts for football stadiums and quadcycles for rougher terrain, particularly when there are large distances over open spaces with a potential for boggy ground with precipitation. In Ireland, St. Johns Ambulance Brigade volunteers use specially designed mountain bikes as personal means of transportation to move around the site.

Mass gatherings can encompass large areas and difficult environments. For example, in the annual Glastonbury festival, the distance from one of the campsites to the main arena is large and could include muddy areas. Without proper vehicles it would be nearly impossible to move patients under such conditions. Standard heavy ambulances will not easily traverse this terrain. Alternate vehicles such as quadcycles or SUV-type ambulances would be needed, especially in very muddy conditions. If not anticipated well ahead of the event, it may be difficult to secure environment appropriate vehicles. Staffing levels should be sufficient to ensure timely responses to critical areas in venues spanning large geographical areas or events with multiple stadia.

The local ambulance service typically organizes transport from the event site to local emergency departments. They may be delays in ambulances returning to the venue, for example, if there are prolonged handovers at the local ED or ambulances are needed for secondary transfer of patients from the closest hospital to a higher level of care. Staffing and transportation resources must account for such situations, particularly if an event physician is accompanying a patient off site or during an interfacility transfer.

Medical Indemnity – Medical Malpractice

Physicians providing medical coverage at mass gathering events need to be sure they are protected from liability. Although event promoters generally have public liability, weather, and "no-show" insurances, they are unlikely to provide medical liability coverage. The system of medical malpractice or medical indemnity as it is termed in Europe is generally based on an individual practitioner's specialty and routine medical practice and not occasional work such as that performed at a mass gathering event.

There is a significant difference between the two terms and it is important that physicians know which variant they possess. Malpractice insurance or liability coverage as it is called in the United States means the physician has an insurance product that covers the financial cost of a malpractice incident or the cost of defending a negligence claim. To obtain such coverage individual physicians detail their work plans including specific information on their involvement in medical activities outside their primary specialty (such as mass gathering medical care). This is then factored in to the cost of the liability coverage. If an event has not been prospectively included in the work plan, the physician must make a separate request to the liability insurer for coverage.

Medical indemnity on the other hand is not an insurance-based product. Physicians become members of mutual medical societies such as the Medical Defense Union and the Medical Protection Society. The organizations were founded in the 19th century as nonprofit bodies that assist members with legal and ethical problems arising from clinical practice. The benefits of membership are discretionary. Although rare, these organizations may elect not to assist with the financial consequences of a claim against a member.

Mass gathering medical care is a new concept and liability insurers and indemnification bodies have little experience with it. Therefore when obtaining liability coverage, it is advisable to carefully define physician roles and responsibilities (including how this might change after a major incident or disaster).

In Ireland one of the bodies involved, Medisec, which now has an insurance policy for its members, specifically states that for general practitioners (family physicians)

> The policy will not indemnify GP's in respect of any liability arising from or directly or indirectly caused by advice and/or treatment not coming within the range of services normally provided by a general practitioner.

The policy specifically excludes acting as an event doctor (medical director) who is responsible for crowd control, ambulance services, provision of appropriate medical equipment, and other related activities. This significantly limits the number of doctors in Ireland who are willing to operate in such roles.

Few if any physicians work full time in mass gathering medical care. More typically, this activity reflects a small portion of a physician's overall medical practice. Thus there is limited case law available to insurers for decision making. In addition, a physician who provides medical services at an event needs different types of liability coverage than a physician in the role of event medical director who is involved in planning and organizing medical care. The level of responsibility for a medical director or Medical Incident Officer in case of a disaster is much greater than for a physician providing direct medical care at the event.

In the United Kingdom and Ireland, large medical indemnity bodies such as The Medical Union and The Medical Protection Society do not generally permit physicians to function at such events in roles not part of their normal practice, e.g., physicians without regular trauma experience who assess patients injured at events, or physicians without toxicology training and experience who manage overdose patients at a mass gathering. In instances in which physicians must perform services outside of their normal scope of practice, it might be advisable to maintain certification in relevant courses such as ATLS, ACLS, MIMMS, or pediatric trauma management.

Medical Protection Society: 10 Best Practice Points for Doctors Providing Services at Sports Events

1) Ensure your skills are up to date and that qualifications are appropriate to those required for a specific event.
2) Acquire sufficient knowledge of the sport being played. You should be aware of the risks involved and the likely nature and severity of possible injuries.
3) Be prepared for all medical emergencies, including those that are not sports related.
4) Ensure that you have access to the appropriate medical equipment and resources that your risk assessment has identified as being required.
5) Know and follow the guidance published by the sport's governing body.
6) Be familiar with the local emergency services and ensure you are aware of and comfortable with the level of support available.
7) Arrange appropriate professional indemnity.
8) Ensure that the extent of your responsibilities is defined and agreed with the event organizer in advance. Specifically, are you responsible for spectators and event staff as well as the participants?
9) You may wish to speak to the referee/umpire regarding arrangements for stopping play if necessary.
10) If you are dissatisfied with the support facilities and resources available, you should bring this to the attention of the event organizer and consider objecting to the event proceeding until the situation has been rectified.

Medical Records

Maintaining medical records is important but can be challenging because mass gatherings are infrequent events. Voluntary bodies such as the Red Cross, the St. John Ambulance Brigade, and the Order of Malta have decades of experience providing medical care at mass gatherings and have produced their own standardized medical records. In general these are single sided A4 pages, occasionally triplicate forms containing basic demographics, nature of the incident, and nature of the treatment given with a record of whether the patient was discharged, referred for more senior opinion, seen by a physician, or transported to a hospital. Although additional detail is desirable for a mass gathering event medical record, on a practical level, documentation will not be as detailed or comprehensive as a hospital chart. At the time of this writing most events use paper records because electronic medical records and Wi-Fi transmission of data on site are not yet fiscally viable options. Records should be kept for 30 years or longer, consistent with local guidelines and regulations.

Four forms of documentation are required: 1) patient medical record (PMR), 2) injured staff medical record (ISMR), 3) patient transfer record (PTR), and 4) running tally of patients treated and transported and the resources used.

Patient Medical Record

The essential data set should include

- Day of week
- Date

- Venue
- Event name
- Medical post location
- Transfer on site – post transferred to
- Transfer off site – destination, hospital name
- Location of incident (if injury)
- Time of incident (if injury)
- Level of healthcare provider (First Aid, EMT, Paramedic, Nurse, Physician)
- Name of healthcare provider
- Name of patient
- Date of birth of patient
- Cell phone number of patient
- Details of transport to venue (arrangements may need to be made for transfer home posthospital treatment)
- Details of illness or injury
- Medical history (if relevant)
- Current medications (if relevant)
- Incident related to alcohol ingestion
- Incident related to illicit drug ingestion, name of drug, quantity taken, description of drug (color/shape/symbols)
- Observations (vital signs, pupil size and response, oxygen saturation, 12-lead EKG, if applicable)
- Physical examination
- Differential diagnosis
- Treatments given, including
  - Airway management required? (yes/no) (type)
  - Intravenous line required? (yes/no)
  - Fluids administered intravenously? (yes/no)
  - Medication names and doses
  - Splint required? (yes/no)

A triplicate form is used by some event planners. The treating physician receives a copy at the end of the event to maintain a record of patients treated. A second copy is given to the voluntary agency involved in treatment if any. The third copy is maintained by the event medical director as an overall record of the patients treated. This allows for record maintenance and audit of medical service requirements to assist in postevent report writing. In the absence of triplicate forms a photocopier should be part of the equipment brought to the event.

In some jurisdictions event promoters provide branded notepaper for use as medical records and argue that because they own the paper they also own the record. They claim they need records to protect against potential future litigation. Although medical record keeping is important for clinicians providing direct medical care, it would be better to provide anonymous summary statistics for the event promoter. If actual records are later required for litigation, the medical director can produce the original. Local medical licensing authorities can assist with ensuring systems are in place to protect confidential patient health information.

Injured Staff Medical Record

In addition to the aforestated elements, the ISMR should include the following

- Nature of the injury
- Was personal protective equipment being used? (yes/no)
- If not, why not?
- Staff title and role
- Able to resume work? (yes/no)

A separate file should be kept on injured staff particularly if there is mandatory reporting of workplace accidents.

Patient Transfer Record

In addition to the information on the basic PMR, the PTR should include

- Reason for transfer
- Details of accompanying persons/cell phone numbers
- Physicians name and contact details

Treatment Facilities

During the planning phase, the medical director, in conjunction with the ambulance service, should determine the number, location, and size of medical facilities including first aid stations to be provided on site. If there is more than one medical facility, the director should designate a field hospital or medical center. A facility should also be designated as a casualty clearing station for field triage in the event of a major incident.

Satellite medical facilities should be highly visible and easily identifiable from a distance to roaming medical staff. The satellite medical facilities and first aid posts should be located on the peripheries of the audiences in the main arenas to enable unrestricted access and egress for ambulances. Maps should be available for all medical and first aid staff to ensure that they know response locations after receiving a radio call. Generally there will be a medical facility at one or both sides of the main stage as this is where the largest crowd concentration will be. Historically the greatest numbers of crowd crushing injuries have occurred at the areas of highest patron density.

At large sites consideration should be given to having mobile response teams with the skill mix to be able to provide initial resuscitation to unconscious patients with unprotected airways. Teams should operate in pairs.

Medical facilities should not permit smoking; however, in the absence of legislation this may be difficult to impose. If oxygen is used in the main medical facility, patrons must be restrained if they are trying to gain entry while smoking. The number of treatment gurneys will depend on the estimated crowd size but a minimum of six ambulance stretchers or examination tables should be provided. Local ordinances may specify exact sizes, materials to be used in construction, and utilities to be provided. For example, in Ireland the minimum size for a main medical facility is 25 m^2 for crowds in excess of 15,000 and 15 m^2 for smaller crowds. Facilities must contain hot and cold running water, a telephone with outside line capability, heating, lighting, ventilation, electrical sockets, and examination couches. They should be staffed by nurses and doctors experienced in emergency work, and first aid workers to assist with patient observation. Emergency vehicles must have ready access. Toilets restricted from general public use must be available proximate to the medical facility.

Doorways should be large enough for wheelchair access. Although equipment lists are not specified, it would be standard to provide defibrillators both in the facility and situated around the venue, usually automated or semiautomated external defibrillators (AEDs). Several experts have suggested mathematical formulae to assist in determining the number of AEDs needed at mass gathering sites. Crucco derived a formula based on stadium area, severity of slopes, stairway distances, and horizontal distances to achieve certain targeted response times.[91] At the University of North Carolina, Motyka completed a similar study in the football stadium (capacity 60,000) and the basketball stadium (capacity 21,444).[92] Multivenue events with pass access restrictions and variable crowd densities along the routes present additional challenges. In these situations, roving teams with portable defibrillators in addition to fixed-site AEDs can decrease time to defibrillation.

Communications

Communications requirements will depend on the event setting and the number of people present. If not already available in the stadium, the event promoter usually provides communications systems. For events situated in remote areas, wireless phone services for voice communications are unreliable because the local cell will likely be overloaded by the volume of cell phones for the duration of the event. There are systems such as Access Overload Control, when in the event of an emergency, the authorities can request the cell in a particular area be shut to all voice traffic except for those on pre-event registered handsets for emergency services. This can be very expensive as the authority has to compensate the communications provider for lost revenue, which is calculated from the average traffic in that cell over a reference period. This may be inexpensive in remote areas with low usage volumes on nonevent days. Text messaging is another possibility. Even with limited bandwidth or weak signals there are protected channels for text communications. This system would ensure that there is an audit trail of communications; however, timely message delivery cannot be guaranteed in an overloaded cell.

The choice of communications technology should be made in conjunction with local authorities (police, fire, medical and health) and should conform to community codes of practice for such systems. There should be a central control area on site for the relevant service commanders where they can regularly update each other on developments. This area should have a good view of the event site, if necessary by using closed circuit television. There should be a capability to communicate on two-way multichannel radio sets to event controllers, security, promoters, medical and ambulance services, first aid workers, welfare personnel, and law enforcement. Two-way communications are preferred from the medical perspective because with one-way communication other users on the same channel cannot hear a colleague's appeal for help; they will only hear the control room response.

Even with very high quality equipment, it can be difficult to hear radio communications within the main arena or close to a noisy stage. Limited communication may be possible by using brief hand signals or alternatively runners may be used to bring messages directly from place to place with requests for supplies or assistance.

Audit

In the aftermath of the event it is important to perform an audit of the on-site medical care to facilitate quality improvement. Specific areas to address include quality issues, whether appropriate skill mix levels existed on site, levels of care, patient demographics, presentations related to alcohol and drugs, and the effects on off-site health service resources. Analysis of these factors will assist with planning for future similar events to include providing data on appropriate staffing levels required to safely manage a mass gathering.

The following represent important data elements that the medical director should collect to facilitate continuous quality improvement.

- Number of patients treated and demographics
- Number of patients treated per post
- Number of patients who received care from the appropriate provider
- Number of patients who were referred to see a more experienced or specialty practitioner
- Number of transfers off site to other medical facilities and reasons for transfer
- Average return to site times for team members accompanying patients off site
- Number of hospital admissions and reasons for admission
- Number of drug-related presentations and drugs involved
- Numbers of alcohol-related presentations
- Number of assaults
- Number of patients treated per hour
- Time first patient seen
- Time last patient seen
- Number of staff seen as patients
- Numbers and types of injuries occurring in staff
- Top 10 medical presentation list
- Medications used and doses
- Medical equipment used
- Time to defibrillation

RECOMMENDATIONS FOR FURTHER RESEARCH

The science of mass gathering medicine is in its infancy. Much of the early academic focus has been on descriptive research including reports of medical involvement at single events.[6,30,46,62,93–97] Publication of the NAEMSP's Medical Director's Checklist provided a valuable resource beyond the previously published descriptive studies.[77]

Several authors have emphasized the importance of drills, exercises, advanced preparation, and education; however, more work is needed on how to improve patient outcomes via training and preparedness of all levels of team members.[4,98–105] A critical review of the efficacy of current physician training for mass gathering medical care would be valuable.

In recent years a number of reviews of mass gathering literature have been published, most notably by Michael and Milsten. Zeitz published a model predicting the workload at a mass gathering.[73] Michael in a 25-year review published in *Prehospital and Disaster Medicine* suggests that a uniform classification scheme is necessary for future prospective studies of mass gatherings.[106] Milsten produced a comprehensive literature review examining the variables that can affect patient presentations at events.[81] He found that weather, environmental factors, event type and duration, crowd mood, attendance, and crowd density, age, alcohol, and drug use were prominent factors.

In 2007, Arbon published a comprehensive review of the evidence and future directions for research.[107] He identifies that there is no consensus definition for mass gathering and suggests using a description that includes nontraditional mass gatherings such as mass transit systems, shopping complexes, airports, and cruise ships. He delineates accepted principal goals of mass gathering medical care, specifically


A

Figure 17.7A. Aerial view of Oxegen music festival 2007 showing main arena, large tents for other concurrent stage performances with multiple campsites in midground and background for up to 70,000 people.

1) Establishing rapid access to ill or injured patients and providing triage
2) Effective and timely stabilization and transportation of seriously injured or acutely ill patients
3) Providing on-site care for minor injuries and illnesses

Arbon argues that there is a lack of uniform standards for the provision of health services at mass gatherings with a foundation based on relatively low levels of evidence. This overreliance on "expert level of evidence" leads to marked variations in standards and legislation. Expert level of evidence is an example of "eminence-based" as opposed to "evidence-based" medicine. Procedures recommended by the eminent "Professor" are followed as no one would dare question the "expert." Arbon recognizes the need for consensus among the "eminence" in creating commonality of language with respect to data collection. Examples include the use of patients presenting per ten thousand attendees (PPTT), transfer to hospital rate (TTHR), patient presentation rate (PPR), and MUR. Until there is an agreed standardized dataset that is collected at mass gathering events there will be no consistency in data collection and it will be impossible to compare similar events (Figure 17.7A and 17.7B).


B

Figure 17.7B. Aerial view of Electric Picnic Festival showing densely packed camping within a well bordered/sheltered site with multiple performance arenas for simultaneous performances.

In summary, there is an immediate need for new research that focuses on

- Appropriate timelines for event planning
- Liability issues
- Education and training of medical personnel without prior mass gathering medicine experience
- Differences in medical attendance rates for similar events
- Appropriate levels of care to be delivered at mass gatherings and benefits of on-site versus off-site treatment
- Alternatives to hospital transports for diagnostic access
- Standardized data sets
- Standardized definitions for events, interventions, and records
- Best practice documentation strategies
- Utilization of Wi-Fi tools and other electronic means for documentation
- GPS/RFID tagging for large unbounded events (e.g., to locate roaming teams with critical patients)
- Mitigation strategies
- Outcomes of care provided at mass gatherings
- Appropriate staffing requirements for medical, nursing, and other paramedical personnel
- Reduction of effects on local health services
- VIP care strategies
- Impact of licensing legislation in different jurisdictions on medical attendances

As mass gatherings become more frequent, more experts need to be trained and more research performed to ensure continued reductions in morbidity and mortality among those attending or managing such events.

> The world is a dangerous place, not because of those who do evil, but because of those who look on and do nothing.
> Albert Einstein

> A goal without a plan is just a wish.
> Antoine de Saint-Exupery

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18

Transportation Disasters

Ulf Björnstig and Rebecca Forsberg

OVERVIEW

The Red Cross defines a disaster as an event causing 10 or more deaths and/or 100 injuries. According to the Red Cross World Disaster Report, transportation-related disasters are a major source of morbidity and mortality, causing 45% of all disaster-related deaths in Africa.[1] During the 1990s, approximately 80,000 people were killed in different disasters in the world each year.[1] This number may be compared with the "low virulent epidemic" of road fatalities that annually kill approximately 1.2 million people (16.1/100,000 inhabitants) and injure 50 million people to such an extent that they require medical attention.[2] In the United States alone, 43,000 are killed annually on the highways.[3]

In commercial aircraft crashes, approximately 1,000 people are killed each year. In sea disasters, the events are more infrequent, but may sometimes engage a few thousand victims each. A few major train incidents are reported annually with sometimes hundreds of fatalities. Bus and coach crashes kill fewer people in each incident than in prior times but apparently are increasing in frequency. A common feature is, however, that many of these incidents occur in rural and remote areas, creating special rescue problems.

In most of these categories, both unintentional and intentional injury events have been reported. More and more frequent suicide attacks have introduced a new dimension of intentional violence, rendering many previous preventive strategies ineffective.

A structure that helps organize the approach to these events is the Haddon Matrix. Originally created to examine road traffic trauma, it is now widely used throughout the transportation industry. Dr. Haddon identified several factors that contribute to injury events and disasters. These are human, vehicle/equipment, physical environment, and socioeconomic environment. These factors contribute in the three phases: 1) pre-event, 2) event, and 3) postevent (Figure 18.1).[4] In referring to the rescue work in the postevent phase, this chapter will use the structure from the British Major Incident Medical Management System (MIMMS).[5] This system is widely used in Europe, Australia, and several other countries in both civilian and military contexts. The MIMMS nomenclature for disaster management includes "preparation" (i.e., planning, equipment, and training) and "onscene command." The command structure is described by the mnemonic CSCATTT (Command, Safety, Communication, Assessment, Triage, Treatment and Transport). In summary, this chapter will use the Haddon Matrix to describe the disasters affecting each mode of transportation and the MIMMS to illustrate how these events are managed.

STATE OF THE ART

The following sections will deal with air disasters, sea (ship and ferry) disasters, rail (train/railway) disasters, and motor vehicle (bus/coach) disasters.

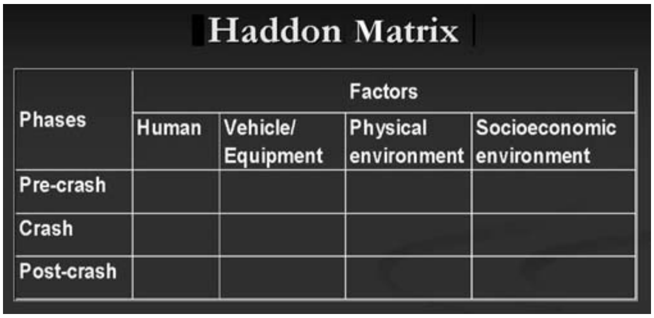
AIR DISASTERS

Incidence Data

During the "Zeppelin" era from 1913 to 1937, the number of fatalities due to dirigible crashes was 14–52 per event. This period ended in 1937 when the Hindenburg exploded, killing 36 of the 97 people on board. In the modern aviation era, from 1970 through 2006, the number of passenger airline crashes has varied from 32 to 73 annually, with a shift toward lower numbers especially after 2002. The fatality rate for this period has been between 517 and 2,556 people killed per year. The number of fatalities per million departures has decreased from approximately 290 fatalities per million departures from 1970 to 1974 to 47 during the years 2000–2004 (excluding the suicide hijack terrorist attacks in the United States on September 11, 2001).[6–8]

Injury Events: Historical Perspective

The track record on fatality rates varies considerably by airline. The following numbers are current as of early 2009. Qantas Airlines is free from fatal injury events since 1952. Cathay Pacific is free from deaths since 1972. All Nippon Airways, British Airways, and Lufthansa are also companies with low fatal injury rates



Haddon Matrix

Phases	Factors			
	Human	Vehicle/ Equipment	Physical environment	Socioeconomic environment
Pre-crash				
Crash				
Post-crash				

Figure 18.1. The Haddon Matrix used to organize the analytic approach to evaluation of an injury event.[4]

per flight. The best crash record among commercial aircraft is the McDonnell Douglas MD-80, a middle-distance aircraft (0.45 events/million flights) and the Boeing 767, a long-distance aircraft (0.6 events/million flights).[7]

Most crashes per time unit occur during takeoffs and landings,[6] but some aircraft have experienced problems during flight, mostly related to technical or weather problems. In this business, most incidents are unintentional, but intentional events are also a real threat to flight safety. During the 1980s, an epidemic of aircraft hijacking initiated new passenger and baggage control systems, which have been developed further during the 21st century due to the terrorist threat.

Injury Events: Current Perspective

The geographical distribution of crashes from different parts of the world for the years 2000 through June 30, 2007 with 10 or more people on board is as follows: Africa (24%), Asia and Middle East countries (19%), South and Central America (17%), Russia and former Soviet Republics (excluding the eastern European Union member states) (15%), Europe plus the eastern European Union member states (14%), North America (10%), and Australia (1%).[7]

The most disastrous incident involving civilian aircraft is the September 11, 2001 terrorist attack in the United States, when four aircrafts were hijacked and crashed into the World Trade Center buildings in New York, the Pentagon in the Washington DC area, and a field in Virginia. The human losses were approximately 3,000 dead. This incident was extreme and is well described elsewhere.[9]

Because prevention is the first choice in disaster mitigation, it may be beneficial to more closely examine factors contributing to air disasters.[1] Following are selected incidents that illustrate typical factors and sequences of events found in airline crashes. Each event was thoroughly investigated and documented in reports published by different countries "Accident Investigating Boards" (e.g., in the United States, this agency is the National Transportation Safety Board[10]).

Errors: Human Factors, Lapses in Job Performance, and Communication during Conditions with Ice

WASHINGTON, DC

During the departure of a Boeing 737 from Washington National Airport after a severe blizzard in January 1982, several significant mistakes were made.[11] Insight into these errors can be gained by examining the captain's previous training and performance records. His experience with winter departures was limited to eight and the first officer had two. A flight check in 1980 revealed poor performance by the captain in several areas: adherence to regulations, checklist usage, flight procedures, and approaches and landings. He was temporarily suspended as a Boeing-737 captain. During a new check in 1981, he demonstrated deficiencies in memory, knowledge of aircraft systems, and aircraft limitations. He later completed necessary tests, and was reinstated. The first officer had completed all checks satisfactorily.

After the blizzard, the airport reopened and a de-icing procedure was performed on the aircraft at 3:10 PM. Due to deep snow, it was difficult to push the aircraft back, and the captain tried to facilitate the maneuver by reversing the engines. While doing this, he sucked large amounts of debris into the engines. During taxi, the captain decided to use exhaust from a preceding DC-9's engines to melt the snow that had accumulated on the wings. This was an unsuccessful maneuver, which only pushed the snow back on the wings where it refroze. The aircraft's de-icing system could not melt snow on this portion of the wing. While running through the takeoff checklist, he responded "off" to the item "engine anti-ice." Having neglected to switch on the engine de-icing equipment, the engine instruments showed erroneously high thrust readings during takeoff because ice had formed on the sensor. Consequently, the crew attempted to take-off with ice on the wings and using only 71% thrust because of the wrong thrust reading. During the takeoff at 4 PM, the first officer probably realized that something was wrong, but he was unable to communicate his concern to the captain.

At rotation speed, (when the aircraft's nose lifts upward) the aircraft pitched up sharply, which was a known behavior of the Boeing 737 with ice on the wings. The first officer's correction of the nose-up attitude failed and the stall warning immediately sounded. The aircraft continued to stall and fell downward.

The aircraft impacted a bridge over the Potomac River, resulting in four deaths and four injured on the bridge. The aircraft then crashed into the icy water (0°C) and went to the bottom, approximately 1 km from the end of the runway. Seventy-four (including three infants) of the 79 on board were killed plus four on the bridge. One died of drowning; all the others suffered fatal injuries, most often head and neck injuries. Five were rescued and survived.

The dramatic rescue efforts were extensively covered by the media. The airport's water rescue equipment was not adapted or tested for winter conditions and was not used. An available U.S. National Park Police helicopter rescued four people between 4:22 and 4:35 PM and ferried them to the shoreline. Two survivors were incapacitated by their injuries and the cold and required hands-on rescue; one by a helicopter crewmember, the other by a civilian bystander who swam out and pulled her ashore.

Errors: Human Factors and Communication during Conditions with Fog

TENERIFE, SPAIN

With regard to number of fatalities, the worst crash in history happened on the island of Tenerife in 1977. Two Boeing 747 jumbo jets (from Pan Am and KLM) collided on the runway in heavy fog. A total of 624 people were involved of whom 583 died and 41 survived.[7,8]

This was the precrash sequence. The Pan Am crew was instructed to taxi behind the KLM jet, but to turn left off the runway and into a taxiway before reaching the end of the runway. As the KLM aircraft turned to depart on runway 12, its captain immediately powered up for takeoff. The first officer corrected him saying, "No, we don't have our air traffic control clearance yet." The captain responded with, "I know that, you call for it." As the first officer was repeating his request for departure clearance, the captain initiated takeoff despite the fact that the control tower did not grant permission for this action. At the same moment, the Pan Am 747 crew was looking through the thick fog for their assigned runway turnoff, and saw the lights of the KLM aircraft approaching at takeoff speed. Just after the nose was lifted the KLM aircraft struck the Pan Am jet just behind the cockpit, climbed to a height of 30 m, and then crashed on the runway. Both aircraft caught fire.

TAIPEI, TAIWAN

Crashes in fog continue in the 21st century in part due to airports that lack ground radar. In the year 2000 in Taipei, a Boeing 747 jumbo jet with 159 passengers and 20 crew initiated takeoff by mistake on closed runway 5R (right) instead of 5L (left), which was open.[7] The tower could not see the aircraft in the fog and they did not have ground radar. The first officer notified the captain about a signal indicating the aircraft position was incorrect on the runway. The captain misunderstood the remark and initiated takeoff. They crashed at high speed into an excavator at a site on the runway where construction work was in progress. The aircraft broke into three pieces. The mid and forward portion of the fuselage sustained extreme fire damage. The airport's 32-person fire brigade responded immediately and arrived at the crash site in 1 minute and 38 seconds. Despite this rapid response, it was impossible to save people from the middle section that was burning heavily. The injury distribution was as follows: fatal 83, serious 39, minor 32, and uninjured 25.

MILAN, ITALY

In 2001, a crash in heavy fog occurred at Linate airport in Milan. An MD-87 was cleared for takeoff on a runway with visibility limited to 225 m. At approximately the same time, a business jet was cleared to taxi, but this plane entered the active runway by mistake and was impacted by the MD-87 during takeoff. Both aircraft skidded along the runway and caught fire before they finally hit a baggage hangar, which partially collapsed and also caught fire. All 118 on board the two aircraft and four people on the ground died. Ironically, ground radar equipment had been in storage at the airport for years but was not installed. Four administrators and controllers at the facility were later sentenced to several years in prison for neglect.

Errors: Aircraft/Equipment Failure

THE BRITISH COMET

Metal fatigue (localized, progressive structural damage that occurs during cyclic loading) is a recognized problem with modern aviation airframes and a difficult issue to resolve. The well-known crashes of the British Comet jet aircrafts in the 1950s first brought this problem to the attention of civil aviation authorities. These aircraft broke up in flight due to a design flaw causing metal fatigue around the aircraft's windows.

CHICAGO, ILLINOIS

A DC-10 lost its left engine during takeoff in Chicago in 1979 due to metal fatigue. When the engine separated from the aircraft, it flew up and over the wing, falling on the runway. When it separated, the hydraulic lines to the rudder and slots systems were disrupted, making the aircraft impossible to steer. All 270 on board were killed.

MANCHESTER, ENGLAND

In 1985, a Boeing 737 crash in Manchester highlighted several important factors.[12] When the aircraft with 137 people onboard passed 125 knots (245 km/h) during takeoff, a burn chamber in the left engine exploded due to metal fatigue. Debris flew through a weak hatch into a fuel tank, which caught fire. The captain abandoned the takeoff immediately and brought the aircraft to a stop to the right of the main runway. A wind of 7 knots (3.5 m/s) blew the flames around the rear fuselage, and the fire quickly penetrated the cabin through melting plastic windows. In a few minutes the aircraft was destroyed and 54 persons on board were rapidly killed, most of them by the effects of toxic gases.

The Manchester experience can be summarized by the following points.

- The wind blowing the flames over the fuselage might have been avoided if the tower had reminded the pilot of the wind direction when confirming the fire.
- Uncoordinated escape attempts began before the aircraft came to a halt, especially among the passengers who were trapped in the rear cabin where the flames had entered. This behavior made evacuation difficult.
- Evacuation problems were also exacerbated by the loss of usable emergency exits on one side of the aircraft due to the fire, temporary jamming of the right forward exit, and by the heavy, black, toxic smoke.

The combination of these factors explained why so many passengers were killed. Pathological examination showed that 48 passengers died as a result of inhalation of hydrogen cyanide and carbon monoxide, and six died from the heat. Most survivors reported incapacitation by the thick, black, and very hot smoke, which affected visual, respiratory and cerebral functions within minutes.

UNITED STATES: JAMMED VALVE

In 1991 the first of three Boeing 737 incidents occurred, caused by the same type of servo valve jam and dysfunction. All 25 on board died in the first violent crash, which happened during approach to an airport. When the pilots turned into their final approach at an altitude of 300 m, the aircraft went out of control and plunged steeply into the ground within 10 seconds. The investigators were confused and could not establish the cause. Another crash of a Boeing 737 in 1994 showed a similar course of events. The aircraft rolled out of control, despite the pilot trying to compensate by opposite rudder deflection. The dive became steeper and the aircraft fragmented into small pieces in the violent crash, killing 132 people. This also made the investigation very difficult, and it threatened to be one of few unsolved crashes. In 1996, a third Boeing 737 suffered similar problems. After having gone out of control two times with the same pattern as in the two previous crashes, the pilots finally managed to gain control of the aircraft and land it. This gave the investigators an undamaged aircraft to investigate. They finally came to the conclusion that a servo valve in the steering system had jammed, causing the problem. The jam came after rapid temperature changes, typically during descent from cold temperature at high

Figure 18.2. The Concorde's last flight in the year 2000. A piece of metal on the runway caused a tire explosion. Debris from the tire punctured the wing fuel tank and the fuel caught fire. Photo from Associated Press. Available at: http://www.airdisaster.com/photos/afsst/2.shtml. See color plate.

Figure 18.3. The 1991 MD-81 crash in Stockholm was caused by engine failure at low altitude when clear ice from the wings was sucked into the engines. During the emergency landing, the aircraft's momentum was reduced by hitting a number of trees before crashing on a snowy field. The snow probably prevented a postcrash fire. See color plate.

altitude. These findings explained the unexpected and reversed movements of the rudders that all three aircraft had suffered. After modifying the servo valve, no further incidents of this type have occurred.[7,8,10]

Errors: Physical Environment, Debris on Runway, and Hostile Weather

PARIS, FRANCE

The Concorde crash in the year 2000 ended the Concorde supersonic era in civil aviation. The aircraft caught fire during takeoff from Charles de Gaulle Airport (Figure 18.2). The pilots lost control and the plane crashed into a hotel killing all 109 on board and an additional 5 people on the ground. The Concorde had run over a metal strip dropped earlier from another aircraft during departure. This metal strip caused a tire explosion and debris punctured the wing fuel tank.[8]

TORONTO, ONTARIO, CANADA

An Airbus 340 crashed in Toronto in 2005 during inclement weather. The aircraft touched down on the 2,700-m-long runway but was unable to stop before reaching the end of the runway. It finally came to rest approximately 180 m from the runway, with its fuselage split into several pieces. Four minutes later, the Airbus was burning furiously; however, all 297 passengers and 12 crewmembers had escaped the aircraft without major injury before the fire started. In this crash, the evacuation procedures worked well, and the 4-minute time period before the aircraft caught fire was sufficient for a successful evacuation.[7]

Errors: Socioeconomic Environment and Failure in the Organization

STOCKHOLM, SWEDEN

A 1991 crash of an MD-81 aircraft in Stockholm was caused by lack of proper ground crew procedures and insufficient information in the pilot's flight manual.[13] After departure from Arlanda airport on a winter day in December, an abnormal noise was heard shortly after the plane became airborne. At 600 m, after 25 seconds of flight, the right engine sucked clear ice from the wing into the engine, which triggered a surge in thrust. The captain throttled back on that engine but the surging did not cease. After 50 seconds, the engine shut down. This same series of events occurred almost simultaneously with the left engine.

As the plane descended to approximately 300 m, the captain found a field where he could land. After impacting a number of tree tops, the aircraft slid along the ground for 110 m before it stopped. The fuselage was broken into three pieces and 17,000 L of jet fuel spilled out. Wet snow on the ground and an air temperature of 0°C prevented a fire.

The energy attenuation was optimally distributed during the crash phase, and all onboard survived. Those few with serious injuries were sitting in the right forward part of the aircraft, or where the fuselage was broken, which was what could be expected with regard to the kinematics of the crash (Figure 18.3).

Despite the short distance to Sweden's busiest airport, the first reconnaissance helicopter did not find the site until 30 minutes after the crash. The alarm was first raised by a passenger calling the dispatch center from a telephone in a house close to the crash site.[14]

The Swedish Board of Accident Investigation concluded that the crash was caused by inadequate company instructions both to the pilots and ground staff. To identify clear ice on the wings, it is mandatory for the ground crew to climb up and inspect the upper wing surface. This was not done. Furthermore, the pilots lacked training in identifying and correcting engine surges in an aircraft equipped with an automatic thrust regulation (ATR) system. In this case, the pilots were unaware the aircraft they were flying contained an ATR system and information on ATR was not included in their flight manuals. The ATR automatically increased the engine thrust, even though the throttles were pulled back to abort the engine surge. As such, the pilots did not anticipate or understand the events as they unfolded.

Crashes Caused by Shootings and Terrorist Attacks

RUSSIA

In 1983 a Korean Boeing 747 jumbo jet was shot down by a Soviet fighter plane over the Russian island of Sakhalin and 269 were killed.

IRAN

In 1988, an Iranian Airbus A300 passenger aircraft was mistakenly shot down by a missile from the American war ship, the USS Vincennes, while patrolling the Persian Gulf. All 290 people on board were killed, making it the eighth deadliest aircraft incident through the year 2006.

IRISH SEA

An Indian Boeing 747 was the victim of a terrorist bomb over the Irish Sea in 1985. All 329 people on board were killed, making it the sixth deadliest incident as of 2006.

LOCKERBIE

The Lockerbie incident in 1988, in which a Libyan terrorist bomb killed 270 people in a Boeing 747, is also a well-known act of terrorism. A Libyan man was later convicted for this action in 2001.

Intentional Crashes: Suicide

Crashing an airliner in an act of suicide is probably a rare event. In a few situations, however, suspicion of such a possibility has been raised, as illustrated by the following case. One-half hour after takeoff from New York, an aircraft with 200 passengers on board steeply descended from approximately 10,000 m into the Atlantic Ocean in 36 seconds. The data flight recorder showed that the autopilot had been disconnected just before the dive and no technical explanation or malfunction was found.[7]

What the Human Body Can Survive

The miraculous survival of the 22-year-old Yugoslavian flight attendant Vesna Volcovic in 1972 is an interesting anecdotal story, indicating what the human body can withstand under advantageous conditions. She was a crewmember on a JAT (Yugoslav Aerotransport) aircraft when it exploded at an altitude of approximately 10,000 m, probably due to a terrorist bomb. During search and rescue operations under the flight path, she was found in the Tjeckian mountain area, in her chair, unconscious with severe spine and lower-extremity injuries but with no memory of the incident or her descent to earth. She had landed in deep snow on a mountain slope. After an 8-month hospitalization, she returned as ground crewmember to JAT Airways where she worked until her retirement. A similar story is reported from South America, in which a 10-year-old girl survived a fall from 4000 m, after a suspected bomb explosion on board her aircraft. She landed in soft marshland, injured but conscious.[14]

Preparation

What are the chances of finding survivors after an aircraft crash? In some cases, the crash is so violent that all on board are obviously killed; however, even a violent crash such as the Boeing 747 crash into a Japanese mountain in 1985 can produce survivors. In that case, the aircraft lost its tail fin (weakness caused by an earlier faulty repair) during flight. It remained airborne for approximately half an hour before it violently crashed into a mountain. Four people survived in the rear section of the cabin, but all the other 520 people on board died, making it the deadliest single aircraft crash on record. This crash put heavy demands on the rescue teams that had to negotiate hostile terrain.

Analyzing airline crashes involving 10 or more people from the year 2000 through June 30, 2007 reveals that a total of 78 crashes resulted in the death of all passengers on board. In 82 crashes, however, survivors were found, and in 24 of these, no person was killed. In 12 of these 82 crashes, only one or two survived. For some of these events, the total losses were measured in hundreds of lives.[7]

A notable exception occurred more recently in January 2009 when a US Airways Airbus A320 with 155 people on board crashed into the Hudson River in New York shortly after take-off, presumably after a flock of geese disabled the engines. The experienced pilot was credited with a safe landing and this, coupled with the rapid actions of the well-trained crew and local rescuers, resulted in all passengers surviving.

PLANNING

Airport rescue resources must adapt to local circumstances. In the Washington DC crash, the airport's water rescue equipment was not tested under winter conditions and so was not utilized. To combat the violent blaze in the Manchester crash, in which the interior of the plane was also involved, fire fighters tried spraying water into the cabin via the emergency doors. This action, however, significantly hindered the evacuation of passengers. These examples argue for better planning and training.

There are few areas in modern society where the planning for an incident is more rigorously regulated than in aviation. Commercial airports should have rescue resources ready for deployment to a crash site so they arrive within 1.5 minutes of the event and they should have the capacity to extinguish a fire within 30 seconds after arrival. An aircraft must be designed to permit complete evacuation within 1.5 minutes by using half of the emergency exits (experience from the Manchester crash). The International Civil Aviation Organization regulates many of these standards.

EQUIPMENT

Substantial emergency equipment such as emergency slides, flotation devices, life rafts, and emergency oxygen are carried onboard. Automatic fire extinguishers for engine fires have been mandatory for decades. Smoke hoods were recommended after the Manchester crash but have not been introduced.

TRAINING

The aviation workforce receives more training and is better prepared for handling emergencies than the workforces in most other industries. The cost effectiveness of the substantial rescue resources assigned to commercial airports might be questioned, but obviously there are cases in which lives have been saved because of this investment in response capability. For example, the rapid response by fire fighters in the Taipei crash indicates extremely well-trained rescue forces, which may have helped victims survive.

Scene Response

COMMAND

Crashes that do not occur at airports often generate debris fields covering large areas, such as the downing of a Pan Am 747 over Lockerbie. This causes significant command and control problems for the incident officers in the different task forces.

SAFETY

Establishing a safe environment at the crash site is sometimes difficult. When the aircraft has crashed in hostile terrain, the safety of rescuers and survivors may be compromised. Spilling fuel and the magnesium–aluminum metal structure may catch fire and burn intensively.

COMMUNICATION

Overload of all types of communication systems has been reported, despite the fact that individuals within the aviation industry are well trained and prepared to manage communication issues. After the Taipei crash, communications failure between the crash site and the dispatch center severely compromised the distribution of injured passengers to different hospitals. As a result, the nearest hospital was overwhelmed with patients, many of whom required transport to the burn hospital in Taipei.[15] In addition, radio signal interference has compromised rescue operations, even near an international airport as in the Stockholm – Arlanda crash.[13] Furthermore, implementation of a well-developed communication plan after an aviation incident facilitates transmission of information to all participating agencies. Because international flights often carry passengers from many countries on a single aircraft, those in charge of communicating information must account for time differences, variations in cultures, and multiple languages.[6]

ASSESSMENT

The number of dead and injured may be difficult to assess after crashes in remote areas or at sea. First, it might be difficult to find the crash site, especially in darkness; second, it may be difficult to reach the site if it is located in hostile terrain. One example of such a situation is the Swissair crash in 1998, when it took 10 hours to identify the crash site in the ocean off Canada's coast, despite the use of two aircraft specially equipped to search for fuel spills and debris.[6] Nonetheless, survivors can be expected in half of all crashes, even when they are catastrophic. This is why the assessment must be done very cautiously, and search and rescue efforts should not be withdrawn prematurely.

TRIAGE

The injury spectrum associated with airline crashes is dominated by trauma and burns. Because postcrash fires are quite common, this mechanism of injury requires special attention. More deaths are caused by smoke inhalation than by the flames (e.g., in the Manchester and Taipei crashes) and this mechanism may complicate the triage process among survivors.

TREATMENT AND TRANSPORT

"Load and go" principles have been used most commonly in takeoff and landing crashes because the transport times are often quite short. Sometimes, this policy can create problems if ambulance dispatch is not well coordinated. In areas without roads, other transport modes must be sought and in these situations, the military might provide support.

SEA DISASTERS

Incidence Data

The number of lives lost when the Titanic sank was approximately 1,500. The worst single ship disaster ever occurred in January 1945, at the end of WW II. Approximately 9,000–10,000 people died when the German cruise ship Wilhelm Gustloff was struck by a Russian torpedo and sank in the Baltic Sea. Many passengers were trapped in the sinking ship. Even those who escaped subsequently perished due to the extremely cold air temperature of −18°C; however, approximately 1,200 survived.

The large losses in sea disasters have often been related to warfare. In the civilian context, significant sea disasters appear infrequently. During the 20th century, incidents with hundred to thousands of victims occurred at a rate of approximately three every decade. In the last 20 years, however, the rate has increased, with five incidents occurring from 1990 to 1999 and five during 2000–2007.[8,14] The world distribution of these incidents has been quite even. In areas such as Indonesia, the Philippines, and Malaysia (with thousands of islands), and in other countries with fast-growing populations and economies, ferry or boating incidents are increasingly reported. In these countries, where millions of often poor people rely on ferries for transportation between their archipelagos, overloading of ferries is a frequently reported factor contributing to ship wrecks. The worst incident in Asian waters with respect to the number killed (1,565–4,300), and the worst ferry incident in the world, was the collision between the Dona Paz and a small oil tanker in Philippine waters in 1987. The Dona Paz, constructed with modern safety equipment on board, was built for 1,518 passengers and was probably heavily overcrowded. It caught fire immediately and sank within minutes. Twenty-one survivors had to swim underwater to escape the flames. No lifeboats were launched. The deadliest maritime disaster in African waters occurred in 2000. The Senegalese ferry Joola, built for 550 passengers, was also overcrowded and sank killing 1,200–1,863 people (64 survived).[16,17] Smuggling migrants on board vessels that are barely seaworthy has also caused hundreds of deaths.[18] In the 21st century, pirate attacks are being reported in places such as Somalia.

Other major events have likely gone unreported. As such, the aforementioned estimates may be conservative and may only represent data for the better-regulated sea transports.

Injury Events: Historical Perspective

From the beginning of the 20th century, the most frequent types of incidents involving vessels were 1) sinking in storms or typhoons; 2) fires and explosions; and 3) collisions with other vessels, icebergs, and submerged structures. Better navigation aids, especially radar and global positioning systems, have reduced collisions and navigational errors on ships equipped with such technology. With modern ship building techniques, ferries and other vessels have become less susceptible to bad weather.

Injury Events: Current Perspective

After 1970, overturning/sinking and fires have been the most frequent types of incidents, with a component of overloading involved in Asian and African ship disasters. Change in ship and ferry design has been one factor in this development. Ferries that permit cars to drive on and drive off in the same direction have an apparent design weakness in that they contain openings in the front and rear. If water flows into the vehicle deck in rough seas, this can change the center of gravity so the ferry becomes unstable, overturns, and sinks. Typical examples are the incidents involving the MS Herald of Free Enterprise (Zeebrugge, Belgium, March 1987) and the MS Estonia (Baltic Sea, September 1994).

The construction of ever-larger cruise ships has increased their vulnerability to fire. With many people on board, not only is the potential for careless acts increased, but these vessels are potential targets for hostile acts. A fire may erupt spontaneously, but may also be intentionally set as in the Scandinavian Star incident (discussed later).

Errors: Human and Design Shortcomings

Below are two incidents caused by the increased risk imposed by bow and stern openings in drive-on/drive-off ferries. The main difference between these two incidents is the environmental circumstances making the rescue operations quite different. The first happened close to a harbor with excellent rescue resources and in great weather. The second occurred during a storm with 6–8-m high waves, in the open sea, far from shore and with long flight distances for the rescue helicopters.

HERALD OF FREE ENTERPRISE – ZEEBRUGGE

On a March evening in 1987, the English ferry "Herald of Free Enterprise" left the harbor of Zeebrugge in Belgium. The weather was fine with an air temperature of 0°C and a water temperature of 3°C. Just outside the harbor, when the ferry turned slightly, water rushed through the bow loading doors, which were left open by mistake, into the two vehicle decks. The ferry's rolling motion, initiated by the course change, increased dramatically because of the moving water inside the ferry. Within minutes, the ferry was lying on its side on a sand bar with the hull two-thirds under water. The port control was immediately notified and activated the disaster plan. Thanks to NATO exercises in the area, military resources contributed to the rescue operation. Thirty vessels, nine helicopters, and 11 medical teams were part of the rescue operation. This event claimed 188 lives but 351 survived. During the inquiry after the incident, individuals expressed the opinion that one contributing factor was a "disease of sloppiness and negligence at every level of the corporation."[16]

ESTONIA – BALTIC SEA

On an evening in the fall of 1994, the ferry Estonia left Tallinn, bound for Stockholm. The weather was bad, with strong winds and waves between 6 and 8 m high.[19] Around midnight a loud noise was reported from the bow opening, and soon thereafter, the ferry rolled heavily 30° when water flushed into the vehicle deck. At 12:20 AM, an emergency call was sent. Ten minutes later the Estonia's radio went silent and the ferry sank at approximately 12:50 AM. The evacuation was not well organized due to the hull's list, the heavy storm surge, and the speed at which events unfolded. It was later estimated that approximately 200 people escaped the ferry before the ship sank. The incident happened in international waters between Finland, Estonia, and Sweden, so the Maritime Rescue Coordination Center (MRCC) in Turku, Finland, was in charge of the rescue operations. Helicopters from Finland and Sweden were dispatched to the incident area, as well as ships and ferries. The captain of the Silja Europa ferry was appointed On-scene Commander. The Swedish MRCC, however, did not receive the first request for assistance until 40 minutes after Estonia's first emergency call.

Ships and ferries arriving at the site found many people in the water; however, most of the vessels were not able to launch lifeboats because of the stormy conditions. Helicopters lifted some victims from the water and placed them on board the vessels, and some were hoisted on board by other means. Of nearly 1,000 people on board, 137 survived and 838 died. The lowest reported core body temperature in a survivor was 26.5°C. Most of the survivors were men. People did not have time to put on clothing and most of those in the sea were not wearing their life jackets properly.

Errors: Ship Wreck and Delayed Rescue

AL SALAM BOCCACCIO 98

This Egyptian drive-on/drive-off ferry, with 1,400 people and 220 vehicles on board, sank during the night in February 2006 in the Red Sea. The ferry caught fire and after only 10 minutes of fire suppression activity, the ferry capsized. One explanation for why the ship capsized was that the seawater used to fight the fire collected in the hull, because the drainage pumps were not working. An emergency call via satellite was received in Scotland, from where it was passed on to the Egyptian authorities. Poor weather conditions hampered the search and rescue operation, and the first rescue vessels did not arrive until 10 hours after the incident. President Mubarak expressed concern that the absence of safety procedures contributed to the loss of 1,000 lives. Rescuers ultimately saved 314 passengers.[16]

Errors: High-speed Vessel and Bad Weather Navigation

SLEIPNER

The cause of this shipwreck was a combination of navigational error, high vessel speed, severe wind, and large waves.[20] The high-speed catamaran MS Sleipner, on its daily route along the Norwegian coast in November 1999, drifted off course and ran aground on a rock in bad weather and rough seas. The rock damaged the bottoms of both hulls extensively, and due to poor design, the water flooding the hulls could not be controlled. Strong winds soon pushed the vessel off the rock and it sank after half an hour with all onboard ending up in the cold water. The crew lost control of the vessel's evacuation. Only one of the vessel's four life rafts was deployed and it landed upside down. Only four passengers managed to get inside the raft, and two managed to remain there until rescued. Many of the vessel's passengers reported difficulty putting on the life jackets. Some of them came loose in the water and some jackets nearly strangled the wearer. A total of 69 people were rescued and 16 died. Hypothermia was a severe problem. These experiences illustrate the following principles.

- Evacuation routes need to be adapted to how people behave in life-threatening situations. Evacuation information must identify alternate routes and be delivered in the local language and in English.
- Life rafts must be designed so they automatically turn right side up in the water. Life jackets must be easy to don, have sufficient buoyancy to keep the victim's head above water, and must also turn an unconscious person into the correct position with the face upward.
- The response time of 1 hour for rescue helicopters during off hours is too long in case of an emergency. Fifteen minutes or less would be ideal. Prioritization principles for managing hypothermic patients must be developed.

Errors: Intentional Incident – Fire on Board

SCANDINAVIAN STAR

One night in 1990, fires were started on board the cruise ship "Scandinavian Star" while traveling between Oslo in Norway and

Fredrikshavn in Denmark.[21] There were 99 crewmembers and 383 passengers on board. The first fire started at 2 AM when the ship reached open water. Bedclothes and carpets in a corridor were set on fire. The fire was discovered and extinguished but a second fire started in another corridor. Within a few minutes, the fire and heavy smoke spread through the corridor and up to the next deck. Only a few of the fireproof doors were activated. A "mayday" message was sent at 2:24 AM. The position was incorrectly given as Norwegian territory, and consequently the Norwegian MRCC was appointed to lead the rescue work. (The correct position was in Swedish territory.) During the first 30 minutes, several helicopters, vessels, and rescue units were dispatched from Norway, Sweden, and Denmark.

At 2:50 AM, the first two ships arrived. By this time, the Scandinavian Star was burning heavily aft. One and one-half hours after the fire began, the captain announced that he and the crew were in a lifeboat and that all people had left the ship, which was completely false. The crew was exhausted and lacked knowledge of the ship, its emergency equipment, and the emergency plan. In addition, they had not made any real attempt to control the fire. These factors contributed to the death of 159 people including a number of children. Sweden has an organization of specialized firefighters (called smoke divers) trained to work in a toxic smoky environment who are ready for deployment to burning ships, but these resources were not dispatched until later. The postincident investigation estimated that these firefighters could have arrived 2 hours earlier if dispatched initially. Ultimately, only six people died from burns; the rest died of a combination of hypoxia, carbon monoxide poisoning, and hydrogen cyanide inhalation. It is probable that rescue coordinators could have saved many more lives had they sent the smoke divers immediately. Two-thirds of the fatalities were found in their cabins, one-fourth of them in the bathroom with a towel over their faces. One-third were found dead in the corridors, many of them near doors they were unable to open.

Preparation

In many incidents at sea, the majority of passengers have been saved, but in a number of the large disasters, most have died. As shown previously, faster and more effective rescue efforts have the potential to improve survival for many victims.

PLANNING

Sea transportation and rescue are tightly regulated areas in many aspects.[22] National authorities standardize the safety of ships, vessel traffic on open waterways, and rescue operations. In addition, the policies of international insurance companies such as Lloyds' of London affect maritime safety. National MRCCs manage emergencies and their planning is often rigorous and well structured. Of course, economical factors influence the availability of rescue resources, such as the number of helicopters and their response times.

EQUIPMENT

It is not unusual that a ship or ferry sinks during bad weather or in rough seas. Therefore, it is critical that safety and rescue equipment function effectively. In the cases referred to previously, the emergency equipment performed poorly. Mistakes were avoidable. Crew members could not launch life boats, life rafts turned upside down when deployed, and life jackets failed to automatically keep the heads of unconscious and hypothermic victims in an upright position to prevent drowning.

Rescue helicopters appropriately equipped and rapidly available are essential for saving people at sea. In the Estonia incident, the helicopters dispatched to the scene had inferior quality winches and rescuers lost potential survivors during the process of lifting them from the water. Several arriving helicopters could not participate at all in the rescue efforts for this reason. This disaster suggests that a revision of the guidelines governing the types and quality of resources used in such rescue operations is indicated.

TRAINING

An incident at sea often happens far from land and from emergency and rescue resources. This is why the ship's crew must fill the critical role of first responder during such events. This necessitates extensive training in managing different emergencies. In addition, the training with rescue equipment such as lifeboats and rafts should include experience using these resources under severe weather conditions.

Participation by cruise ship passengers in emergency training or drills is equally important. Operators of cruise ships in the Caribbean and many other locations require all passengers to learn how to move to their emergency stations and life boats, and also how to find and test their life jackets.

Training of rescue personnel in hostile weather and environmental conditions is also necessary. Use of young inexperienced persons, such as those fulfilling their military commitment, is not appropriate. In the Estonia incident, inexperienced individuals were assigned the demanding position of surface rescuers on some of the helicopters. It was psychologically stressful for these young people to participate in the response to a deadly disaster, attempting to rescue victims in darkness with poorly functioning equipment while enduring extremely high waves.[19]

Scene Response

COMMAND

Effective rescue operations for an incident of this kind involve practically the entire chain of command, from the individual to the government level. All require training specific to their roles to manage the situation properly. Many sea disasters occur in international waters. The MRCC in charge of the rescue effort is normally determined by the rescue zone in which the vessel is located. A rescue mission must be well planned from both the tactical and organizational perspective. Examples include identification of the first suitable ship arriving at the site as the On-scene Commander and automatic dispatch of the appropriate units. The error of not immediately dispatching smoke divers to the site of the Scandinavian Star fire probably caused additional deaths and suggests commanders experienced lapses in judgment during a stressful situation.[21] Air traffic command and control is also essential when many rescue helicopters are in the air.

SAFETY

Safety precautions for response personnel and crew are a first priority during a rescue mission but may be in conflict with the sometimes extremely difficult conditions under which they must work. To minimize the risks, responders systematically review all safety factors under the category of "preparation," including planning, equipment, and training. In addition, emergency drills at the beginning of a voyage may potentially reduce the risk to passengers. Improving the safety of all involved also mandates the use of emergency equipment that is effective under all conditions, including rough seas.

COMMUNICATION

It may be difficult to communicate the status of passengers to relatives and the press in the initial phase of rescue operations because of the huge numbers of victims. The Al Salam Boccaccio 98 incident is one example in which the delayed release of information regarding survivors created a public outcry; similar reactions have been reported in other incidents. It would be wise for the sea transport industry to have a well-prepared communication plan to reduce these problems.

ASSESSMENT

The initial assessments regarding the number of dead and injured in the above referenced incidents contained a large degree of uncertainty.[16,19,21] The final assessments, however, were usually quite accurate. Notable exceptions include some Asian and African ferry incidents, where the number on board was not clearly determined. One seriously incorrect assessment was the message from the captain of Scandinavian Star that all had abandoned the ship. In reality, more than 160 were still on board and this erroneous report may have contributed to the high death toll in the fire.

TRIAGE AND HYPOTHERMIA

Hypothermia may be a complicating factor that is not taken into account in common triage systems. In the aforementioned incidents, hypothermic victims were common. Hypothermia may make it difficult for rescue personnel to know who is truly dead and who is actually alive but profoundly hypothermic. After the Estonia incident, it was observed that the commonly used guidelines regarding survival times in water of different temperatures may be conservative estimates.[23] Young fit men with strong survival instincts seem to survive longer.[19] It is essential to account for these findings when deciding to terminate a search.

TREATMENT

Fire victims and passengers who have ingested or aspirated petroleum products, as in the Dona Paz incident, may need urgent treatment. Hypothermic victims must be handled cautiously (e.g., so as not to induce ventricular fibrillation), and they ideally need to be extricated (or hoisted if a helicopter is involved) in a horizontal position. This is due to cold-induced diuresis and resultant hypovolemia that can cause hypotension if the patient is placed in the vertical position.

TRANSPORT

Helicopter transport to the nearest appropriate facility is indicated for severely ill patients, such as those suffering from burns, serious traumatic injuries, and profound hypothermia. One limiting factor in the rescue operation is the time helicopters can remain airborne, which is often approximately 3 hours, exclusive of reserve fuel. In practical terms, if it takes a helicopter 1 hour to arrive at the incident site and requires 1 hour or more to reach a medical facility, the time to accomplish the rescue mission at the site may be very limited. In these cases, the tactic may be to hoist people to a ship in the vicinity, and in this way save as many as possible, as in the Estonia incident. This would, however, not be optimal for severely ill victims.

RAIL DISASTERS

Traveling by rail is relatively safe but the global railway industry is growing at a rapid pace. Rail traffic and train speed are increasing significantly, as are the numbers of tunnels and bridges. These factors increase the number of rail disasters. Historically, the challenge has been to find ways of controlling the kinetic energy that dissipates through the train structure during a crash and to protect passengers from the destruction it can cause. Considerable progress has been made regarding train structure but insufficient changes have been made to the interior of rail carriages. This is a direct result of the conflicting demands of safety, comfort, economy, and performance.

Large differences are revealed when comparing safety and security issues between the rail sector and aviation. Safety regulations for train travel are limited despite the fact that railway speeds have increased significantly. Furthermore, hostile acts committed against the rail sector are increasing. This raises the question of whether it is necessary to improve safety and security regulations for train travel.

Incidence Data

During the 19th century, the number of major incidents that produced significant fatalities was low because train speeds rarely exceeded 80 km/hour. In the 20th and 21st centuries, the speed and density of rail traffic increased as did the frequency and severity of rail injury incidents[14] (Figures 18.4 and 18.5).

Injury Incidents: Historical Perspective

The first train carriages were made of oak. These designs protected the passengers from the weather, but in a crash they simply disintegrated. A French crash in 1933 demonstrates this reality. In thick fog, a locomotive struck a slow moving wooden passenger express from behind and managed to run through almost its entire length, killing 230 people. In 1937, experts began to examine what happens to wooden carriages during a crash. The investigations showed that the dissipated kinetic energy resulted in complete destruction of the entire rail carriage in a phenomenon called "telescoping"[24] (Figure 18.6).

Telescoping was one of the major causes of death and injury in train crashes at that time. Experts were highly motivated to find a way to prevent this from happening. The French decided to construct a new stable rail carriage out of metal. This rail carriage reflected the kinetic energy and emerged relatively intact, and metal carriages were introduced across the world. By the 1950s, metal rail carriages had more or less replaced wooden ones on the world's railroads and the new design increased the chances of occupants surviving a rail disaster. Although the concept had minimized the telescoping problem, it inadvertently created another dangerous phenomenon, "overriding" (Figure 18.7). This problem cast a shadow over railroad safety for decades. As an example, three morning trains collided in

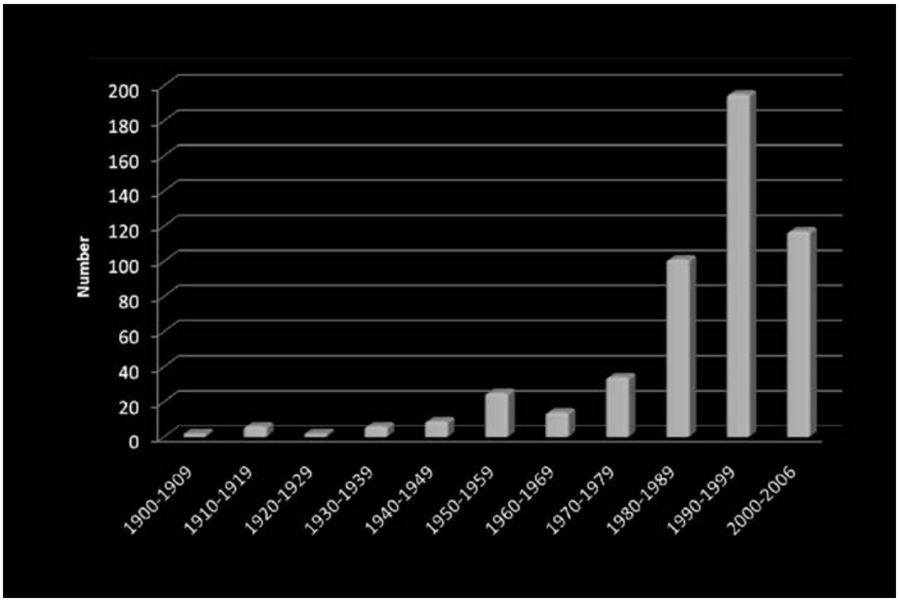


Figure 18.4. Number of rail disasters worldwide with at least 10 or more deceased or 100 or more people injured. (Data from: "EM-DAT: The OFDA/CRED International Disaster Database – www.em-dat.net – Université Catholique de Louvain – Brussels – Belgium").

Clapham, England in 1988. One train overrode the other and crashed down on the passengers below, killing 33 people.[24]

After the rail incident in Clapham, experts worked to develop new approaches to carriage design. They started to encourage deformation zones on trains. Between 1980 and 1990, these crash zones were finally investigated as a possible answer to the "overriding problem." Corrugated metal plates, which make the carriages hook together in a crash, were fitted to the ends of each rail carriage. These designs decreased the risk of vertical movement that could develop into overriding. The corrugated metal plates, known as anticlimb devices, are a standard safety feature today on many trains. In the United Kingdom and the United States, fitting of crash zones and anticlimb devices have become mandatory on all new rail carriages.[24]

One last issue remained with regard to carriage safety and this problem was highlighted by the 1987 crash near Chase, Maryland. Here, 16 people were killed by a crash phenomenon called "jack-knifing" or "lateral buckling" as it is known in technical terms (Figure 18.8). On impact, the train carriages derail and collide into each other's sides. The often-weak sidewalls collapse inward, injuring the passengers inside.[25]

In the Purely train crash in 1989, two trains bound for London collided. Part of the rear train rolled down a steep railway embankment and jack-knifed against a tree. The passengers were thrown forward in the carriage and against the floor, roof, and sides. Most of those seriously injured or killed had been sitting in the carriage that jack-knifed against the tree.[26]

Researchers have continued to find ways to reduce the risk of lateral buckling. One approach is the TGV (*Train à Grande Vitesse*), launched by the French in 1980. At that time, it was the world's fastest train, traveling at 200 km/hour. This speed required a new conceptual design. The vulnerable point where two carriages are linked was made strong and stable to reduce the risk of carriages buckling either sideways or vertically.[24] Nonetheless, it has been difficult to eliminate these problems completely due to increasing train speeds and different carriage designs.

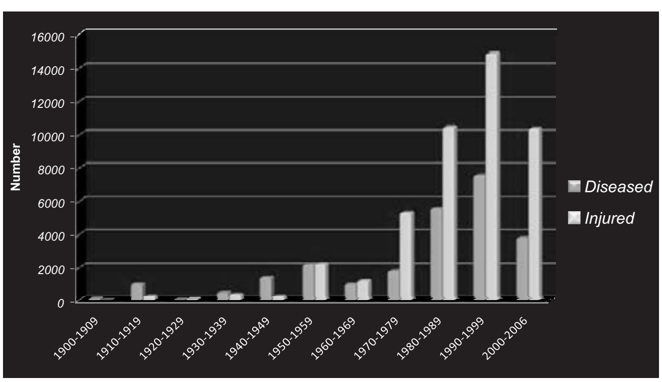


Figure 18.5. Number of injured and deceased in major* rail disasters. *At least one of the following criteria must be fulfilled for inclusion of these data: 1) 10 or more people killed; 2) 100 or more people injured. (Data from: "EM-DAT: The OFDA/CRED International Disaster Database – www.em-dat.net – Université Catholique de Louvain – Brussels – Belgium").

Figure 18.6. Telescoping. Illustrator: Gunilla Guldbrand. See color plate.

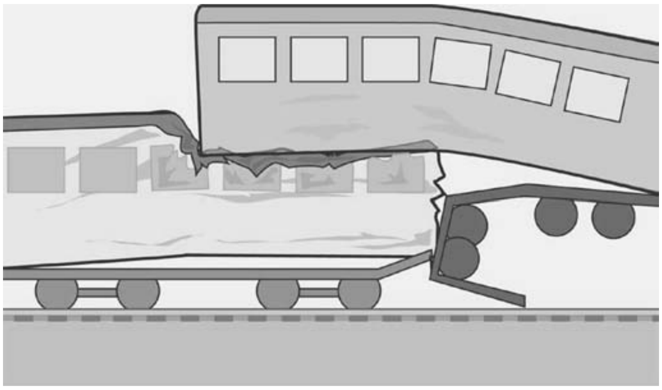


Figure 18.7. Overriding. Illustrator: Gunilla Guldbrand. See color plate.

Injury Incidents: Current Perspective

The train exterior has thus been developed to reduce the consequences of railway incidents; however, what happens inside a rail carriage during a crash is just as critical as what happens on the outside. Published data show that the carriage interior and loose objects have a major impact on passengers' injuries. Unsecured seat cushions, chairs, luggage, and unrestrained passengers are thrown through the carriages in a crash.[26,27] The presence or absence of head restraints also has an impact on the injury panorama. Folding tables significantly increase the risk of facial injuries and tables located between chairs are a risk factor for thoracoabdominal injuries.[27] Findings from the Cannon Street disaster in 1991, when a commuter train collided with the hydraulic buffers at the Cannon Street British Rail station, showed that craniofacial trauma was the most common type of injury in those standing at the moment of impact. These injuries resulted from passengers hitting the luggage racks.[28] In March 1994, a train traveling at 85 km/hour collided with the back of a stationary passenger train, north of Aarhus, Denmark. All of the resulting injuries were related to victims striking structural elements inside the carriages.[27] In October 1999, a passenger train at Ladbroke Grove in London missed a stop signal and collided head on with another at a combined speed of 209 km/hour. Thirty-one people lost their lives and many more were injured. Passengers described how luggage and people were flying around inside the carriage. A collision in Placentia, California in 2002 is another example. A freight train missed a signal and smashed head on into a passenger train. Two people died from hitting the table in front of them.[24] At the Amagasaki train derailment in 2005, which left 107 passengers dead and 549 injured, the most common causes of death were severe head injury (39%), chest injuries (20%), and abdominal hemorrhages (20%).[29] Many of the severe head injuries were probably caused by luggage (S. Nakayama, personal communication, 2006).

After the 2002 collision in Placentia, California, the U.S. Federal Railroad Administration performed tests with the Hybrid III crash test dummy to demonstrate how a body moves in a crash (e.g., how it impacts a table). Such impact may cause rib fractures and lacerations of internal organs, which are pushed against the spine, and broken ribs. These tests resulted in a new design for a safer table and this design has subsequently been tested. On impact, the table collapses and absorbs the passenger's kinetic energy, reducing the level of trauma to the passenger's abdomen. The passengers can also suffer serious head and neck injuries if they impact the seat in front of them. If they fly over the seat in front of them, the final impact will be even more severe.[24] When viewed in conjunction with research data from 1975 indicating the injury reduction potential of restraint devices, these data raise the question of whether seat belts should be introduced on trains.[30] The debate on seat belts continues, and these devices have so far not been installed as a standard safety feature on trains. The tests performed with the crash mannequins also demonstrated that it is safest to sit in rear-facing seats relative to the direction of travel.[24] At the 1989 train crash in London, almost two-thirds of those killed or seriously injured were sitting in forward-facing seats.[26] Experiences from the 1995 train crash in Jelling also demonstrate a significant increase in injury risk when facing forward in a moving train.[31]

Another concern is the threat from crashes between passenger trains and those carrying hazardous materials. These events have the potential to kill more people than any other rail disaster. In Mississauga, Canada, in November 1979, a freight train carrying deadly chlorine gas derailed and exploded. Some 218,000 residents were forced to leave their homes in one of the largest peacetime evacuations in North American history. In the end, there were no fatalities, but the lives of nearly 250,000 people were placed at risk.[24]

Recent history has shown that designers have not yet created a sufficiently safe train and many safety concerns remain. One significant problem is the speed. The Shanghai Magnetic Levitation Train in China is the first magnetic train in commercial

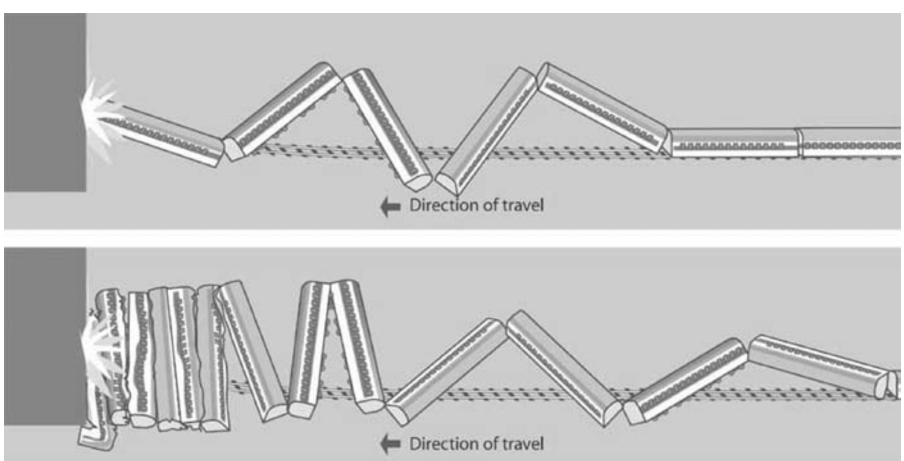


Figure 18.8. Jack-knifing/Lateral buckling. Illustrator: Gunilla Guldbrand. See color plate.

Figure 18.9. The Eschede, Germany, train disaster is one of the world's worst high-speed train disasters. The train disintegrated in the crash and the disaster claimed 101 lives and injured 103. See color plate.

operation with a speed of 430 km/hour. The highest recorded speed of a magnetic levitation train is 581 km/hour, achieved in Japan in 2003.[32] Engineers and designers try to make the trains lighter, smoother, and above all faster. It is a development that increases the risk for major rail disasters. A carriage wheel failure was the probable cause of the crash in Eschede, Germany in 1998, when one of the world's fastest and most technologically advanced trains, the German ICE, ended up in ruins (Figure 18.9). It derailed and crashed at 200 km/hour straight into a concrete bridge, disintegrating on the impact. The crash killed 101 passengers and injured 103.[33]

Increased safety through new design and technology could not improve survival when the world's worst train disaster to that date occurred in Sri Lanka, in December 2004. A train was simply swept off the rails by the South Asia tsunami, killing as many as 1,700.[24]

The public transport system, which has occasionally been exposed to hostile acts, appears to have become a preferred target (Figure 18.10). According to the International Union of Railways, this is because of its vulnerability and the number of people it carries. Public transport systems are open and accessible to all, generally without individual entry controls or passenger identification requirements.[34]

Acts of aggression against the rail transportation system, such as the terrorist attacks that occurred in Madrid in 2004, London in 2005, and Mumbai in 2006 and 2008, indicate a new threat to train security and the potential need for a "bomb proof" train. Of the violent acts directed against railways depicted in Figure 18.10, the most common assault involved the use of explosives. As many as 61% of these attacks resulted from bombings. Data indicate that explosions in confined spaces are associated with a higher incidence of primary blast injuries, with more severe injuries, and with a higher mortality rate (49%), in comparison with explosions in open air (7.8%) (see Chapter 26).[35]

Even before the 1995 incident involving release of the nerve agent sarin in the Tokyo subway, there were growing concerns related to the vulnerability of subways to hostile acts. Due to this threat, security and safety concerns must become a priority and transportation agencies need to address these hazards.[36] Countries that have experience in dealing with acts of aggression are working to decrease their vulnerability to such threats and taking actions to minimize the impact of attacks against the railway sector.[37] Nevertheless, there is a need to be proactive against this growing hazard.

Preparation

PLANNING

Despite the relative low risk for a rail disaster, emergency response organizations must plan for such an incident. A rail disaster involving a high-speed train has the potential to produce mass casualties; the dissipated energy is so large that the expected damage and associated injuries will be severe. The complex nature of responding to such events makes pre-event planning essential.

In Kaprun, Austria, the track, the tunnel through the glacier, and the train itself were considered fireproof. So there was no plan for a fire incident. The train was supposedly built of fire safe material; however, the material was combustible and served as fuel for the fire that started in an overheated fan. The doors could not be opened manually, either from the inside or the outside, and the passengers could not contact the driver when they discovered the fire. The possibility of escape was further diminished because of the narrow tunnel in which the train was located when the fire started. The 3.3-km long tunnel had

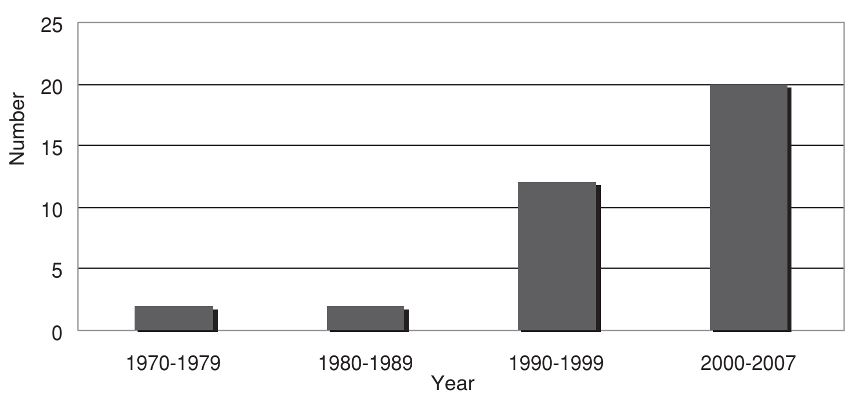


Figure 18.10. Number of hostile acts* against the rail transportation sector in which people have been injured (acts of war are excluded). *Hostile act: Action performed by an individual, group or organized group with intention to injure or kill people. (Data from Wikipedia).

only one emergency exit in the middle with steps 0.7 m wide and without orientation lighting. The incident claimed 155 lives; only 12 passengers survived.[38]

The Japanese believed that the Tokyo subway was the safest transportation system in the world, but the sarin attack uncovered many problems. Authorities now acknowledge a lack of preparedness for a chemical disaster, including the absence of decontamination resources at the scene and personal protective equipment for rescuers. These factors have now radically altered the approach to disaster management.[39] Hostile acts directed against the railways can occur anywhere, as history has shown. In Madrid and London, the police, fire brigades, and ambulance personnel were placed at significant risk due to lack of planning regarding the necessary safety measures for such events[40] (J. Edmondson, personal communication, 2006). Therefore, rescue operations need specific plans that address the extraordinary safety risks that these acts create.

EQUIPMENT

Working at a train crash site exposes rescue personnel to many different hazards. Adequate personal protective equipment is mandatory. Staff must also be provided with communication equipment that operates in tunnels and subways. In addition, it is important to investigate whether current rescue tools are effective against the rugged steel construction of today's high-speed trains. The electrical high-voltage power is another danger. Even if it is disconnected by the rail company, first responders need the skills and equipment to perform the necessary protective grounding. It can be difficult to enter a carriage and even harder to evacuate passengers due to the carriages height. Therefore, it is important to try different solutions such as gangways. At the 2004 train crash in Nosaby, Sweden, a passenger train drove into a truck at a street level motor vehicle railway crossing, killing 2 and injuring 48 passengers. It took approximately 8 hours until the fire brigade could establish that there were no passengers trapped under the derailed train. The reason for that lengthy operation was lack of efficient equipment to lift the carriage (A. Nählstedt, personal communication, 2008).

TRAINING

Prehospital personnel need training to identify and manage potential threats resulting from train incidents including chemical exposure, fires, and risk of electrocution.[41] In addition, all must learn how to control the risk of further explosions and exposure to toxic agents, especially in situations in which the disaster resulted from a hostile act.

It is also important that personnel receive education and training in tactics and techniques that minimize the delay in delivering medical care to injured passengers. Investigation of a train crash in Hamburg, Germany, discovered that the four victims who died were only slightly injured initially, but expired due to traumatic asphyxia and suffocation.[42] A review of the injuries sustained by the 113 people in the Moorgate tube train disaster has also shown the need for early extrication and evacuation of casualties. Those who died of traumatic asphyxia and crush syndrome might have survived if they had been rescued more rapidly.[43]

On the morning of April 25, 2005, a Japan Railway express train derailed and jack-knifed against a parking garage in an urban area of Amagasaki, Japan. The crash left 107 passengers dead and 549 injured (Figure 18.11). The responders used confined-space medicine techniques to aid trapped passengers.

Figure 18.11. A Japan Railway express train derailed in 2005, and jack-knifed against a parking garage in an urban area of Amagasaki, Japan. The crash left 107 passengers dead and injured 549. See color plate. Used with permission from Scanpix.

These techniques allow the rescuer to conduct a medical evaluation and institute appropriate medical therapy while the patient is still entrapped. Such interventions can expedite the victim's safe extrication from the confined space. Confined-space medical techniques can effectively prevent crush syndrome resulting from prolonged entrapment. The critical need for these skills was illustrated earlier during the Kobe earthquake, when hundreds of deaths were caused by crush syndrome. After the Kobe incident, a number of emergency physicians were trained in confined-space medicine, and some of these physicians were present at the Amagasaki crash site. Without this training, it was estimated that at least three of the last survivors rescued would probably have died before reaching the hospital.[29]

Scene Response

COMMAND

Command is not a new problem, but in a rail disaster, it can be particularly problematic. Command and control at the scene of a rail incident with injured victims scattered throughout the site is a challenge. Following the train collision in Eschede, the disaster site encompassed an area over 450 m long, making it difficult to maintain control when the communication lines failed. As a consequence, medical teams had to act independently. This contributed to an overload of the nearest small hospital in Celle, while the nearby trauma hospital in Hannover received only four patients.[44] The 2004 terrorist attack in Madrid involved four different disaster sites and emergency managers also reported command and control difficulties. First responders encountered problems in identifying different emergency support functions within cooperating organizations and difficulty in obtaining a global perspective regarding the disaster.[40]

Lack of a structured command system resulting in poor coordination also existed at the crash in Amagasaki, Japan. The command chain worked well within each agency, but there was no overarching response plan that connected all the responding agencies, which created confusion at the site.[29]

SAFETY

Rescue efforts adjacent to railway tracks expose response personnel to great risks. Electrical, kinetic, thermal, and chemical hazards are the most common dangers encountered when working at a rail incident site. From full speed, a train needs over 2 km to stop. Unless railway supervisors have given clearance, it may be very hazardous to approach the tracks. Bridges, tunnels, and narrow cuttings may contribute further to an unsafe environment on one or both sides of the track. Gaining access to the interior of carriages can be difficult, owing to their height and heavily reinforced construction. Use of ladders and the need to walk on sloped surfaces also contribute to the hazards. Concrete cable ducts are covered by small paving stones. Responders may fall when walking on these stones because they are often unstable. In addition, cross ties are often covered in oil and can be slippery. Another danger is the moving blades of switch tracks because these can be operated remotely and could trap a foot without warning. Old trains still contain chemical substances that can be very toxic if ignited in a fire, and the huge array of chemicals that are transported as freight further complicates the issue. Some parts of trains are extremely hot and it is not uncommon for emergency personnel to receive burns during their rescue work. Finally, the power lines may carry up to 25,000 V of electricity. Maintaining a safe distance of 3 m from live cable is recommended. It is necessary to wait until the power is disconnected and the cables are grounded.[41]

In the Eschede crash, the carriages had a tendency to slide and it was difficult to lift the carriages without causing further damage.[44] Additionally, it is not always possible to use the metal cutters and other rescue equipment due to the high risk of igniting a fire. At the Amagasaki crash, gasoline leaked from vehicles in the garage struck by the train. This precluded the use of these devices and the rescue teams were forced to work with hand-driven tools.[29]

Another major safety issue is emergency evacuation. The stairways within double-decked carriages are small and often destroyed in a crash, trapping passengers on the upper deck. The sliding doors that serve as dividers between the vestibules and seating compartments are also problematic. The doors can jam on impact and prevent passengers from escaping.[30] At the Ladbroke Grove rail incident in 1999, passengers were trapped as a result of these flaws and subsequently died in the fire that followed the collision. What the Ladbroke incident highlighted was how difficult it is to evacuate from an overturned rail carriage. The doors normally used for carriage access are too heavy for many passengers to open, if they can reach them at all in an overturned carriage. Seat cushions, suitcases, and clothes obstruct exit routes and make the evacuation even more difficult. The implementation of airplane-style luggage racks and installation of emergency escape routes would facilitate evacuation. Train companies have been slow to adopt these innovations and, to date, have not implemented them anywhere in the world.[24]

Last, terrorism has also become a hazard. At the 2004 Madrid bombings, the ambulance service established field hospitals close to the railway track, placing themselves and the victims in an area at risk from potential further bomb explosions (Figure 18.12). One of four backpacks containing unexploded bombs was brought to a police station. The bomb was discovered when someone made a call to the telephone in the backpack. The phone was connected to the detonator via the alarm function; however, the timer was incorrectly set to detonate 12 hours later than the others.[40]

After the Tokyo sarin attack, there was no field decontamination of victims on site and rescue workers did not wear personal protective equipment. Of 1,365 emergency medical technicians, 135 (9%) showed acute signs and symptoms of sarin intoxication from secondary contamination and required medical treatment at hospitals. If the sarin had been in its pure form, the resulting situation would have been much worse.[39]

COMMUNICATION

Communication problems are exacerbated when the incident occurs in a tunnel or a subway. This is a situation in which communication is particularly important. In Kaprun, Austria, there were also communication problems due to radio signal interference at the disaster site, and the mobile phone network was overloaded. When the rescue personnel entered the tunnel to secure the scene, they had no contact with the teams located outside.[38]

ASSESSMENT

Making an initial assessment of the number and severity of injuries at the disaster site can be very difficult, especially if the incident is in a tunnel or a subway and communications are not functional. The 2005 London bombings highlighted this problem. It was very difficult for rescue personnel to assess the situation in the subway due to the absence of electricity and ventilation. Explosions incapacitated both systems. At the same time, there were communication problems (J. Edmondson, personal communication, 2006). Moreover, no passenger list existed, which is typical for rail traffic. Therefore, it was difficult to know how people many were onboard. Because it is quite challenging to estimate the number of fatalities or injured passengers trapped in debris, decisions regarding the withdrawal of rescue activities should be made carefully, as evidenced from the Amagasaki train crash.

TRIAGE

In many rail disasters, responding emergency personnel have not had experience with common medical triage protocols and perform triage poorly at the site[40,44,45] (J. Edmondson, personal communication, 2006). In the 2004 Madrid bombings, 191 people were killed and more then 1,500 were injured. Reasons given for a lack of triage in Madrid was, "it was so obvious who had

Figure 18.12. The 2004 attack in Madrid was Spain's worst terrorist event in its history to that date. Ten bombs exploded in four different sites, which killed 101 passengers and injured more than 1,500 survivors. Ambulance services established a field hospital close to the railway track, placing themselves and the injured passengers in an area at risk for further bomb explosions. See color plate. Used with permission from Scanpix.

minor or severe injuries" and "we did not have enough triage tags."[40]

The Amagasaki train derailment marked the first use of on-site mass casualty triage in a Japanese crisis. The quality of triage was high, and preventable deaths were few. Nevertheless, it was logistically impossible to assign green tags to all of the hundreds of victims with minor injuries. One problem that occurred at the Amagasaki incident was that injuries such as traumatic asphyxia and crush syndrome received a low priority. In the future, triage criteria must account for these conditions.[29] In addition, triage of victims from train disasters can be complicated by the presence of chemical substances including nerve agents because symptom onset can be delayed. Ambulance personnel also need training in handling toxic agents and decontamination in these cases.[39] Finally, it remains controversial whether it is a reasonable strategy to perform triage inside a deformed rail carriage.

TREATMENT

In a rail crash, it is common that passengers become trapped by debris. At the crash in Amagasaki, Japanese physician teams used confined-space medical techniques in treating trapped survivors. It took between 14 and 22 hours until the last injured passengers were extricated. During that time, the doctors secured intravenous lines in tight spaces and administered fluids to prevent crush syndrome. Other advanced treatments performed at the site included endotracheal intubation, rapid fluid infusion, and needle decompression of tension pneumothoraces.[29]

TRANSPORT

Transport of victims to medical facilities can be difficult when a rail disaster strikes, especially in rural areas. In 1991, a Shigaraki Railway local train and a Japan Railway express train, both full of passengers, collided head-on after a signal malfunction. Forty-two passengers died and 614 were injured. The rural setting of the crash hampered rescue efforts and during the unorganized response no triage or effective helicopter evacuations were performed.[29] At the 1988 rail disaster in Clapham, England, three trains collided and 33 people were killed. Passengers were trapped in three separate and somewhat isolated areas of the site. Ladders were needed to climb over the carriages to reach the different inaccessible areas. Significant difficulties were encountered extricating the victims and transporting them up the embankment to the road and the waiting ambulances.[46]

It remains controversial whether volunteers are helpful or not in the rescue effort. While convergent volunteers who respond to the scene may actually hinder rescue efforts if they are not well integrated into the on-scene incident management system, bystander volunteers may, in some cases, improve outcomes. One notable experience comes from Mumbai, India. On July 11, 2006, more than 180 people were killed in coordinated terrorist blasts on commuter trains in Mumbai. Mumbai had no formal emergency medical services system, so people did not wait for ambulance personnel to arrive because there were none. Consequently bystanders and other volunteers handled the situation themselves, with the astonishing result that most victims (700) were transported to hospitals within 1.5 hours (R. Nobhojit, personal communication, 2006).

Even in systems with well-developed emergency medical services systems, there is frequently a maldistribution of casualties to area hospitals after a train crash. One reason given for the uneven distribution of injured passengers among hospitals is that the facilities could not provide patient care capacity information to the incident sites. Consequently, medical and fire department commanders had to guess where they should send the victims.[29,40,43,44]

MOTOR VEHICLE DISASTERS

Comprehensive data on highway disasters may be more difficult to find than corresponding data on more regulated sectors such as air, sea, and rail. This is not surprising, considering that even an event with a death toll of 50–100 could be considered small within the overall context of the worldwide total of 1.2 million deaths annually in motor vehicle crashes. It might also be possible that a major incident could be missed in countries with immature systems for collecting road injury data.

Injury Incidents: Historical Perspective

The number of fatal motor vehicle incidents and the number of casualties associated with them varies considerably. There are many incidents with approximately 25 dead, fewer with approximately 50 dead, and incidents with 100 dead do occur but are quite rare. A majority of the events involve buses. Seven road "disasters" with more than 100 killed were reported from 1970 through June 2007.[47] In three of these cases (Afghanistan, Spain, and Nigeria), a gasoline tanker collision and subsequent fire were the factors responsible for the deaths of 120–2,000 people. The other cases (106–127 killed) involved a bridge collapse (Nepal), a bus that crashed into a bridge (Kenya), and a bus that drove into an irrigation canal (Egypt). The worst incident occurred in the Salang tunnel in Afghanistan during the Soviet occupation in 1988. Although details remain obscure, this event is probably the deadliest tunnel fire in history. One hypothesis regarding the incident mechanism is that a fuel tanker crashed into an ammunition truck in a Red Army convoy. The casualty figure is uncertain and varies between 1,000 and 2,000 killed, most of them Afghan civilians. Many died from exposure to toxic gases and smoke. Lethal tunnel fires have also occurred in the Alps. In 1999, some 39 people died when a truck caught fire in the middle of the 12-km-long Mont Blanc tunnel. The fire reached an estimated temperature of 1,300°C, and 53 hours elapsed before it was finally extinguished.[47]

The focus of this section will be on the most probable type of traffic mass casualty event that rescue forces will encounter, that is, a bus or coach crash. As these crashes often occur in rural or remote areas, their management is challenging for ambulance and rescue organizations. The majority of bus incidents are unintentional; however, intentional attacks, such as the suicide bombings experienced in Israel beginning in the year 2000, and the London bombings in 2005, have highlighted the problem of hostile acts directed against public transportation systems.[6]

To simplify terminology, the word "bus" will be used to represent all types of motor vehicles carrying more than nine people. This term includes the following types of buses: commuter, school, intercity, motor, and tour coaches.

Typical Injury Incidents: Current Perspective

Crashes are the most common incidents affecting buses, but these vehicles may also catch fire, either as a consequence of a

Figure 18.13. A timber truck with trailer suffered a front tire blow out and became so difficult to steer that it crashed into an oncoming school bus in rural, northern Sweden in 2001. Timber entered the bus and made the rescue effort extremely difficult. Six of the 42 passengers involved died. See color plate. Used with permission from Scanpix.

collision or spontaneously. These fires can be deadly if passengers are unable to evacuate the bus quickly.

One of the worst bus incidents in the United States with respect to the number killed was the 1988 Carrollton bus disaster, when a tour bus caught fire after a collision and 27 people died.[48] Another crash resulting in many deaths occurred in rural Finland in 2004 when a frontal collision between a heavily loaded tractor trailer and a tour bus claimed 23 lives. Many crashes with 20–60 fatalities each have been reported in the last decade in countries such as Albania, China, India, Iran, Mexico, Nigeria, and Thailand. Most of them have been single vehicle crashes, with a bus plunging into a ravine or down from a bridge. In a 1976 Swedish event, a tour bus caught fire due to overheated brakes. The fire and smoke were so intense that 15 people died within minutes.

The Enhanced Coach and Bus Occupant Safety project published a review of bus-associated trauma in Europe in 2002.[49] The report states that in Sweden (9 million inhabitants), approximately one significant crash with 20–60 injured victims has occurred every year between 1998 and 2007, with a death toll up to nine in the worst crash. Six of these 10 mass casualty incidents resulted from single vehicle crashes; the other four were collisions with other buses or trucks.[50]

Seat belts are mandatory on buses manufactured after 2005 in the European Union. The impact of this change remains difficult to estimate, in part because the presence of seatbelts does not necessarily imply they will be used. Nonetheless, the combined data from actual crashes and simulations of typical single vehicle rollover events indicate that the potential for reducing moderate to severe injuries is approximately 50% with lap belts only and 80% with three-point restraints.[50]

Single bus crashes in Sweden are characterized by several common elements: 1) they involve intercity and tour buses; 2) events occur during winter, in rural areas under windy conditions; and 3) the buses finally come to rest after a 90° rollover to the right, with the door side down and the doors blocked. Arriving ambulance and rescue personnel often discover numerous injured people lying on top of each other inside the bus, as few passengers use their seat belts. Responders often have difficulty managing the scene. Fatalities typically result from two mechanisms of injury: Victims are ejected through the large windows and crushed under the side of the bus as it rolls over, and passengers are crushed between the roof and seat back as the bus overturns and the roof collapses. Extrication of victims is complicated and requires a rapid response and the correct equipment. Research, including wind tunnel tests, has shown that high-profile buses can blow off the road. Ten such cases have been reported.[51] Although this is especially true in windy winter conditions, simulation studies have also shown that on a dry road, a bus may deviate 1 m or more sideways in wind gusts.

As the Swedish Accident Investigation Board has described, these crashes illustrate the need for improved tactics, techniques, and rescue equipment. This is necessary to prevent rescuers from arriving unprepared at a crash site, for example to find that a timber truck has collided with a school bus and filled it with timber (Figure 18.13) or that a wobbling tractor trailer has collided with a tour bus on a cold winter night and filled it with paper bales weighting 800 kg (the Finnish incident described previously).

Fires can result from fuel spills in connection with a crash, but most fires originate in the motor compartment, wheel housing, or from failed electrical and hydraulic components. Tests have shown that up to 52 passengers can evacuate a double-decker bus in 1 minute. This rate of egress is usually sufficient to safely evacuate a vehicle on fire in most cases. A disabled person or an individual with a baby carriage can, however, delay the process significantly. Sometimes, the margin of safety can be tight, as illustrated by this anecdote. A fire originated in the rear motor

Figure 18.14. This tour bus drove off the highway and down an embankment, hit a boulder, rolled 180°, and landed on a roof that subsequently collapsed. Nine passengers died, but only two had lethal injuries. Six were jammed between the roof and interior structures (usually a seat back), and suffocated due to immobilization of the chest. It took 3.5 hours to extricate the surviving passengers. See color plate.

compartment of a bus traveling in a Switzerland tunnel. The driver recognized that as long as the bus traveled in a forward direction, the air movement over the vehicle would mitigate the effects of the fire and prevent the smoke from entering the passenger compartment. Consequently, he decided to drive to the end of the tunnel and did so successfully. During the drive, he lined up the passengers behind the doors. Upon arriving at the end of the tunnel, he stopped the vehicle, opened the doors, and all passengers escaped. Within a very short time, the entire bus was engulfed in flames (J. Andersson, personal communication, 2006).

Bus incidents that illustrate some of the factors in the Haddon Matrix are discussed next.

Errors: Human, Vehicle, and Regulation Factors

The Carrollton bus disaster in the United States incorporates multiple causative factors: a drunk driver, vehicle construction that enhanced the potential for fire, and a flaw in federal safety regulations.[47] The coach involved in this disaster was originally designated as a school bus with chassis construction regulated by older federal standards. Nine days after chassis assembly began, the federal government issued new regulations; however, buses already under construction were exempt and the vehicle was not upgraded to the better standards. These new standards mandated better fuel tank guard frames, emergency exits, and several other features.

This bus was eventually used by a church youth group. At 11 PM, the bus with 66 passengers on board was hit almost head-on by a pick-up truck at high speed, driven by an intoxicated driver, moving in the wrong direction on the road. The impact fractured the bus' suspension and drove pieces into the unprotected fuel tank. Fuel immediately leaked out and quickly caught fire. The fire spread into the bus and thick noxious smoke filled the passenger compartment. The front door jammed shut in the crash and fire blocked the path forward. All tried to evacuate through the single rear emergency door because victims could not open the windows or break them. A beverage cooler in the aisle contributed to problems with evacuation. The congestion of passengers at the rear emergency door also delayed egress from the vehicle. After approximately 4 minutes, the entire bus was on fire. Twenty-seven people died in the fire and 34 were injured, 10 of whom suffered severe burns. All suffered emotional trauma and survivor guilt syndrome. This bus had no window emergency exits or roof exits, as newer commercial and school buses have. If the bus had been classified for nonschool usage, the applicable standards would have required more emergency exits.

Errors: Human and Rescue Factors

In the winter of 2005, a previously healthy bus driver traveling at approximately 100 km/hour suffered a short absence seizure while behind the wheel. As a consequence, the bus veered off the road and down an embankment, struck a large boulder, flipped over, and landed on the roof (Figure 18.14). The roof collapsed and all the windows broke. The unrestrained passengers (59%) careened around the inside of the bus and a number of belted and unbelted victims became trapped between the roof and interior structures, mostly the seat backs. Extricating the passengers was extremely difficult and neither the rescue nor ambulance personnel had the training and the equipment necessary for an optimal effort. Traditional "heavy rescue" training was of little use in this situation, when even small degrees of carriage movement caused increased or decreased pressure on trapped victims. The ambulance crews working in the overturned bus had significant difficulties extricating people in the confined space. In addition, personnel had to evacuate the bus each time the rescue service tried to lift or move the bus. It took 3.5 hours to remove all survivors from the bus wreck, exposing victims to cold temperatures for a very long time. The last extricated living victim had a core temperature of 32°C when arriving at the hospital, and she later died.

Autopsies performed on the nine dead passengers revealed important findings. Only two of the nine victims had clearly lethal injuries. The remaining seven survived the initial crash. The forensic pathologist determined the subsequent cause of death was suffocation, caused by immobilization of the chest wall in six of the seven. In addition, the pathologist estimated survival times to be from 10 minutes to more than 1 hour. At least four victims could have been salvaged if extrication had proceeded more expeditiously (within 0.5 hours). It was not possible to determine whether the lethal compressing force resulted from the crash itself or the subsequent rescue efforts.

The Swedish Accident Investigation Board (2007) recommended the following actions.

- The National Road Administration should install guardrails preventing vehicles from driving off the road and down steep embankments.
- The National Road Administration should advocate for improvement in the European Union's safety standard for bus roof deformation in cases of a rollover. (Author's comment: The current standard with which manufacturers must comply is that the passenger space should not be compromised when a bus is tipped over sideways from a height of 80 cm. It must be quite rare for a stationary bus to roll over. Consequently, the test does not reflect real highway conditions. This crash demonstrated quite clearly how easily the roof collapses when a longitudinal force is applied.)
- The Swedish Rescue Service Agency should improve its tactics, techniques, and equipment for handling this type of bus crash.

Errors: Vehicle and Environmental Factors

In 2001, in windy winter conditions and with a light snowfall, an intercity bus emerged from a woodland area into an open field at a speed of approximately 90 km/hour. The driver states, "an invisible hand forced the bus to the right." The vehicle ran over and became entangled with a prebridge guardrail. The left front wheel followed the guardrail to the middle of the bridge before the bus tipped over and landed as "a bridge" over the creek (Figure 18.15). Twelve of 34 people on board were unconscious after the crash. This crash was linked to the wind sensitivity of high profile buses by using an algorithm developed from wind tunnel tests. The wind was blowing at a steady 13 m/second with 21 m/second wind gusts.

Figure 18.15. A high-profile intercity bus blew off the road after driving out from a forest into an open field. The final position of the bus across the creek resulted in lack of passenger exposure to the water, likely preventing morbidity and mortality. Victim evacuation was facilitated after rescuers discovered that the windows were so strong that personnel could walk on them. See color plate. Used with permission from Lars-Göran Halvdansson.

Figure 18.16. If people are trapped under a bus constructed of steel, it can be quickly lifted with extended hydraulic cylinders in the corners of roof hatches or with two air bags. See color plate.

Errors: Environmental Factors (Road and Rescue)

On a winter evening in 2003, a bus traveling at 50 km/hour slid off a small, slippery, road. It drove down a 2–3-m steep embankment and finally turned over to the right. Ten people were ejected. The rescue service lacked the capability to lift the bus quickly. In this situation, however, the terrain was uneven and provided survival space for several victims trapped underneath. Despite the fact that it took nearly 2 hours to lift the bus and extricate the passengers, half of those ejected survived.[52]

Preparation

PLANNING

A well-developed plan for a major traffic injury event is needed. Problems may arise, however, when individuals believe a plan is in place but have not examined its contents (Swedish experience). As these crashes usually occur during winter, equipment to protect victims from hypothermia must be included. Incorporating these assets in the plan avoids delays in deployment of appropriate resources.

EQUIPMENT

Equipment for heavy rescue is needed, but is not always available to smaller rescue organizations in rural areas. Procuring equipment that can quickly lift an overturned bus that has crushed victims underneath is a priority. A 2-year development project in Sweden on the management of crashes with buses overturned 90° has come to a number of conclusions.

- A bus built with stable steel bodywork may be lifted by hydraulic cylinders in the corners of the emergency roof hatches within 3 minutes (Figure 18.16).
- A bus built from aluminum cannot be lifted by the roof hatches (too weak), but may be lifted with short hydraulic cylinders against the lateral longitudinal beam, as long as the contact points are not too narrow.
- Two air bags can be used to lift both types of buses, but the lifting time will be more than three times as long as with the hydraulic cylinders.
- For rescue efforts inside the bus, low-profile equipment is preferred. A spine board may sometimes be difficult to maneuver.

TRAINING

During development of the bus rescue program, standardized extrication tests were created using a realistic case scenario involving 22 nonambulatory injured passengers (8 priority-1 cases and 14 priority-2 cases). In the first test, the extrication time averaged between 40 and 50 minutes. After a formal training program, the same rescue personnel successfully evacuated all victims within 9.5 minutes. New skills learned by the responders included the critical action of rapidly cutting an extra opening in the roof (requiring <2 min). This is just one example of the impact that standardized training has on performance and may give an indication of the potential for improvement with effective instruction.

Figure 18.17. Cutting an opening in the roof, which is feasible in 2 minutes with a circular saw, facilitates evacuation. This intervention permits ambulance personnel to work in the passenger compartment and to evacuate victims by using the most appropriate exit pathways. See color plate.

Scene Response

Command

In motor vehicle incidents, the area of the crash site is usually small. The officers from the ambulance, rescue, and police forces can easily communicate with everyone from a command post established on or near the highway. It is an advantage if the representatives from the ambulance and rescue teams act in close cooperation to facilitate extrication of the injured.

SAFETY

Ensuring the safety of rescue personnel from the threat of postevent fires, structural collapse, and on-coming traffic is important. The safety of survivors is a constant concern, especially if they are trapped under or inside the bus. In these situations, rapid extrication may be critical.

COMMUNICATION

As with command, problems with communication are generally minimal. The most significant concern is the availability of communication from crash sites in remote areas to the dispatch center.

ASSESSMENT

In developed countries, the potential for death or injury from a motor vehicle incident is usually limited to the estimated maximum number of passengers in the actual vehicles. Accurately estimating the number of injured passengers in highway crashes is generally easier than in other types of transportation-related events.

TRIAGE

In reality, triage prior to extrication has seldom been performed at an incident site. There may be several reasons for this: It is "forgotten," it is deemed unnecessary as sufficient ambulance personnel are on-scene, or responders believe the best way to extricate victims is to remove them in the order they are found. Many professionals advocate this latter strategy, arguing that it is the fastest and most effective method. In addition, they believe that for some situations, it might be the only method. To address this controversy, a Swedish project evaluated both strategies (triage vs. extrication in the order found) using the standardized injury model characterized by 8 priority-1 cases and 14 priority-2 cases. (All priority-3 cases are capable of walking out by themselves according to the MIMMS triage). Given that a victim's deterioration is related to the number of minutes the person remains trapped in the bus, the total number of person-minutes was used as the outcome variable. Investigators compared extrication time for the triage group (removing priority-1 patients first and priority-2 thereafter) to those extricated in order they were found. The researchers found that evacuation time for priority-1 patients when using the triage strategy was 20 person-minutes shorter than when using the alternative method. Extrication time for the priority-2 victims, however, was 150 person-minutes longer in the triage group than for those extricated using the alternative strategy. These results raise additional questions. It is possible that priority-2 cases may deteriorate to a priority-1 status as a result of the additional delay. One compromise would be to evacuate in order of priority, but if a priority-2 victim obstructs the evacuation process, that victim should be removed first.

TREATMENT AND TRANSPORTATION

In a typical single vehicle crash, head and upper-extremity injuries are the most common, followed by chest and abdominal injuries. Neck injuries are rare in single crashes but occur frequently (~50%) in multivehicle collisions. In a frontal impact crash, the typical movement of passengers regardless of restraint status is forward, head first, into the seat back in front of them resulting in extension of the neck. In a rear impact collision, especially in a bus with low seat backs, nearly all passengers would suffer neck hyperextension and subsequent painful injuries. Consequently, rescue personnel must be prepared to protect the cervical spine in these cases. People may also be wedged under seats, or found in difficult positions in a restricted space. In these situations, a simple cloth lift technique may be fastest and safest. Some of the trapped victims may require treatment on site; confined-space medicine techniques would be beneficial.

In a typical bus crash, the vehicle is usually found on its side after a 90° roll to the right. An effective rescue approach is to cut openings in the roof providing extra evacuation routes (Figure 18.17). The optimal responder configuration is four ambulance personnel in the front half of the bus and four in the rear half. This permits each group to evacuate victims by using separate routes, avoiding interference with each other. Evacuation through existing roof hatches is possible, but these openings are so narrow on many buses, that it is difficult to maneuver a spine board and patient out through these emergency exits.

RECOMMENDATIONS FOR FURTHER RESEARCH

Air Disasters

1) Mistakes, misunderstandings, and management errors continue to cause aircraft crashes. Behavioral scientists and others must address these problems and find ways to minimize further their occurrence. A potential solution might be implementation of an anonymous incident reporting system to help identify risk factors, such as the system now implemented for European civil aviation by a European Union directive. The aim of these anonymous reports is to find system shortcomings, not to punish individuals. A system that shares some of these features is also used in the United States. Further research on this promising concept is indicated.
2) The frequent postcrash fires remain a challenge. Increasing utilization of carbon fiber structures within airframes now under way in the aircraft industry will make these parts more fire resistant than the magnesium–aluminum alloy currently in use. When these carbon structures do catch fire, however, they produce very toxic fumes. Further research is needed to develop other nonflammable materials. As toxic smoke kills most people in aircraft fires, new strategies are needed to improve passenger survival. Potential solutions include supporting them with oxygen (an aircraft carries significant amounts of emergency oxygen), or through use of smoke hoods, as the Manchester crash investigators recommended.[12] Finding solutions to these problems remains a challenge for scientists and engineers.
3) The use of rear-facing seats would probably distribute crash impact forces more favorably, but scientific evidence from commercial aviation is scarce. In contrast, this seating configuration is used widely in space aviation to distribute forces.
4) After the British Broadcasting Company aired some concerning programs in 2006 on aircraft crew's alcohol consumption, the aviation industry examined the issue of substance abuse by their employees more closely. Some companies have introduced random testing programs. The effectiveness of these programs, as well as compulsory testing of all personnel, needs to be carefully evaluated.

Sea Disasters

1) The basic construction flaw with drive-on drive-off ferries needs to be resolved: both with respect to reducing the risk of water intake through the bow and stern openings, and with respect to reducing the movement of large water masses on the vehicle deck should water intrusion occur.
2) Better measures are needed to mitigate the threat of fires, including implementation of fire prevention and suppression strategies and interventions that reduce injury. Automatic sprinkler systems and other measures aimed at reducing and extinguishing fires are necessary and should be required on all vessels.[22] Because most deaths result from exposure to toxic smoke, it is critical to develop methods that will deliver breathable air to passengers and protect them from inhaling toxic fumes.
3) Lifeboats, life rafts, and life jackets (even those placed on modern vessels) have functioned poorly in rough seas, which is the typical condition when vessels are wrecked. Problems have also plagued helicopter winches. These experiences suggest more research and development is needed to ensure this equipment works appropriately.

Rail Disasters

1) Unlike the aviation and motor vehicle industries, safety issues within the rail sector do not receive the same level of scrutiny. The numbers of rail lines, train speed, and volume of passengers are increasing, and so are the numbers of rail disasters. Therefore, research devoted to the improvement of safety features on trains is necessary.
2) Avoiding injury incidents in the first place is the primary goal; however, experience to date demonstrates this is difficult, despite the increase in number and quality of signals and implementation of electronic control. Many improvements have been made in carriage design, including more robust construction, stronger couplings, and the addition of deformation zones; however, insufficient emphasis remains on the reduction of passengers' injuries related to the interior. This is a neglected research area, despite studies that show carriage interior has a major influence on these injuries. Therefore, further efforts are necessary to improve the interior design of trains to reduce injuries. One specific area for investigation is identifying the optimum method for storage of luggage and other unrestrained objects.
3) Preliminary studies show that a significant increase in injury risk exists when passengers are seated facing forward in a moving train. Additionally, these studies indicate the injury reduction potential for restraint devices. Owing to these findings, further research in this area has the potential to significantly improve passenger safety. Improvement in design and subsequent implementation of rear-facing seats and restraint devices could potentially reduce passenger injury in future crashes.
4) The last few decades have witnessed considerable changes within the railroad industry, especially concerning the construction of high-speed trains. Disasters involving these trains will place new demands on the tactics, techniques, and equipment used by rescue personnel. Studies from rail crashes show that passengers die of traumatic asphyxia and suffocation, as well as of crush syndrome in the absence of any other significant injuries. Therefore rescue activities must be rapid and efficient, with the goal of transporting the severe and critically injured to an appropriate medical facility as quickly as possible. Further research is needed to develop early and rapid passenger extrication techniques and training in confined-space medicine. Introduction of passenger safety instructions, improved emergency exits, larger and roof hatches are factors that may also improve the efficacy of evacuation and rescue operations.
5) Recent history has shown that the railway sector is vulnerable to hostile acts contributed to by the absence of passenger screening and the large number of people who utilize the system. Therefore, it is critical to identify measures that improve security and reduce the rail transport system's vulnerability. One possible solution is to design rail carriages that channel the blast wave from an explosion in a way that minimizes injuries to the passengers. Channeling the blast wave

through the roof might be one option. Such design changes could also facilitate passenger evacuation when a train has overturned. Additionally, trains can sustain severe deformation damage after an explosion and become wedged inside narrow tunnels. Implementing this new design for channeling the blast wave could minimize carriage deformation and thus prevent this problem from occurring inside tunnels. Further research is also needed to identify preventive measures that reduce the potential for hostile acts against railways and facilitate the discovery of additional unexploded devices. Last, finding solutions that minimize injuries and protect first responders from secondary explosions and exposure to chemical, biologic and radiologic agents remains a challenge. The development of training programs for responders in the management of terrorist attacks that involve explosives and chemical/biological/radiological agents is a priority.

Motor Vehicle Disasters

1) The stability problems, especially of high-profile buses with engine and cargo compartments in the rear, should be highlighted. This configuration results in a center of gravity displaced to the vehicle's rear with relatively less weight on the front wheels. These buses are extremely wind sensitive and their speed should be restricted in windy weather. The development of monitoring devices that can warn drivers of potentially dangerous wind gusts would improve bus safety.
2) The effectiveness of 2- and 3-point seat belts (and the anchor point of the diagonal belt) needs to be established and optimized, as well as the most beneficial type of locking mechanism. If such data were available, they could facilitate legislation mandating such devices. In addition to regulatory solutions, studies of human behavior to determine how to achieve compliance with seat belt use would be beneficial.
3) In case of bus bombings, a strategy to divert the shock wave away from passengers requires investigation. It might be presumed that an explosion in the upper compartment of a double-decker vehicle may be less damaging than one in the lower compartment (supported by the experience from the Madrid train bombing referred to previously).
4) Bus fires remain a persistent and serious threat. Fire indicators and automatic extinguishers in the engine compartment have the potential to substantially mitigate this danger, but so far, it has been difficult to enforce installation of these devices. Better bus construction to prevent fuel spills in case of a crash, such as installing crash safe fuel tanks similar to those in helicopters, would be a substantial improvement and justifies further investigation.
5) Rescue techniques and equipment require further improvements that will permit responders to manage incidents more rapidly and effectively when buses have landed upside down. Vehicles constructed with emergency exits and entry openings for emergency personnel would also minimize the time to rescue passengers. All these issues need further refinement through more research and development.

Common Challenges: All Modes of Transportation

Every method of transportation has its own specific problems; however, it seems all modes are at a growing risk from terrorist attacks. Suicide bombing has invalidated traditional security strategies. The approach to addressing this problem has been fundamentally different within the airline industry compared with other modes of transportation. Extensive and intrusive control of airline passengers is accepted in a way that probably would be questioned in other transport modes. It is also extremely expensive, not only with respect to direct costs, but also the cost of time air travelers loose waiting in the airport security queues. Therefore, this approach would be very difficult, if not impossible, to implement on public ground transport systems such as a subway in a major city used by millions of people every day. The London and Madrid bombings are examples of the disastrous impact terrorist attacks can have on commuter trains. The number of lost lives and injuries generated may be greater than from an attack against an aircraft (excluding the unusual attack on September 11, 2001 in the U.S.). New solutions to this problem must be identified such as: 1) strategies that reduce the opportunity to place bombs in critical locations, and 2) new methods to mitigate the impact of an explosion in case of detonation.

A second problem shared by all members of the transportation industry is the issue of alcohol and/or drug intoxication involving those who drive or pilot the various vehicles, vessels, and aircraft. It is well known that those in the transportation industry represent a group at risk for addictive behavior. Some companies have instituted random drug and alcohol testing programs, but verification is needed as to whether these interventions will be sufficient to improve safety or whether mandatory testing of all personnel is required.

A final common problem is that transportation disasters occur relatively infrequently, making it difficult to study them. This situation could be substantially improved if the world's experience with such disasters were available for investigation. This suggests a potential solution: incorporating the global experience with these events into a common, well-structured database. The existence of this repository could serve as a basis for significant future research.

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19

Emergency Medical Services Scene Management

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OVERVIEW

Responses to large-scale emergencies in recent years have reaffirmed what has long been said about disaster response: "all disasters are local." Those jurisdictions whose plans rely primarily on outside assistance beginning with the initial stages of response are destined to fail. Stepwise, scalable incident organization is essential to meet initial goals and objectives of the response to the emergency. Large-scale multicasualty emergencies and disasters involving large numbers of injuries or illness are complex and will initially or eventually involve many agencies at various levels of jurisdiction that may have little or no experience working together. Local planning, preparedness, interdisciplinary training, and exercises can improve familiarity with multiagency strategic and tactical plans and improve understanding of missions, cooperation, and interoperability.

The emergency medical services (EMS) mission of triage, rapid clinical assessment, critical therapeutic interventions, medical communications, and capability and capacity-directed transport of victims in the management of a large-scale multicasualty emergency is part of a complex set of overlapping missions. Immediate hazard mitigation or containment for the protection of responders and protection of victims from further injury is the first priority. This may be possible quickly and the EMS mission may proceed rapidly. There may, however, be fire suppression, rescue, or hazardous materials concerns complicating the missions of EMS and each response organization. Another critical early step is communication of the evolving situation to the local healthcare infrastructure to assist them with preparing to receive patients. That healthcare infrastructure will need to establish its own internal response organization to meet the needs of a potentially large number of new patients in addition to continuing to provide services to those patients already under their care and those regular patients who present for care unrelated to the disaster. This early notification may occur spontaneously through the news media or through structured lines of communication.

Preparedness and planning will include local assessment of EMS and healthcare resource depth. A jurisdiction's decision and threshold to request mutual aid will be determined by this local depth of resources. Other factors influencing decision-making include the size, scope, and anticipated duration of the multicasualty emergency and whether the local emergency response infrastructure remains intact or is damaged or overwhelmed in the course of the evolving incident. The need for EMS special operations may also determine the threshold for mutual aid requests. The following are among the EMS and healthcare requirement that determine the timing and nature of mutual aid requests: 1) law enforcement (EMS tactical response); 2) technical rescue (EMS operations); 3) waterborne or airborne rescue (EMS platforms); 4) victim emergency transportation; 5) incident, victim, or healthcare facility patient evacuations; 6) clinically oriented evacuee sheltering; 7) trauma, burn, or pediatric intensive care; 8) anticipated long-term specialized medical care (e.g., hemodialysis for traumatic rhabdomyolysis); 9) anticipated incident-specific pharmaceutical needs; 10) public health surveillance, epidemiology, or laboratory support; and 11) sustained hospital outpatient and inpatient volume.

The scope of emergency management is mitigation, preparedness, response, and recovery. Effective EMS scene management will contribute to the success of the response and mitigation phases. Because more than one jurisdiction will be involved, mutual aid resources must be requested, coordinated, and integrated at the local level with the assistance of a unified command structure. Resources may be requested through local jurisdictions, counties or regions, state, interstate, federal and, in some cases, international agencies.

CURRENT STATE OF THE ART

There are many international models for the management of multicasualty incidents. Some emphasize scene organization with the goal of rapid transport and limited focused prehospital medical interventions. Others emphasize more extensive field medical operations prior to transport. The variations between these models include those with no apparent structure whatsoever. The very nature of multicasualty and disaster medical operations makes it difficult to conduct longitudinal prospective studies to identify, characterize, and validate optimal operational parameters and practices that maximize victim survival

Table 19.1: Functions of the Plans Section

Plans Section
Resources
Situation
Documentation
Technical Specialists
Demobilization

Table 19.3: Functions of the Finance/Administration Section

Finance/Administration Section
Time
Procurement
Compensation and Claims
Cost

with practical application of available resources. The concepts discussed here are based on U.S. models of multicasualty incident management.

DISPATCH, COMMUNICATIONS, AND INITIAL INTELLIGENCE GATHERING

EMS scene management begins with the initial calls for help. The recognition of and reaction to a large-scale multicasualty emergency may be immediate through cellular or landline calls to a public safety answering point (PSAP) or may be delayed if the emergency concurrently damages communications or facilities. The specific location or locations of the emergency may be immediately apparent or difficult to determine if there is conflicting information from callers or widespread consequences. Emergency services access telephone numbers vary around the world and may function to allow voice communications with a public or private entity or may supply other information about the caller's location. In the U.S. many communities are served by the emergency access number 911 or enhanced 911 (E-911). Other communities use a 7- or 10-digit telephone number to access emergency services. E-911 allows both voice communication of the problem or emergency and displays the address of the telephone being used to make the call. If callers are unfamiliar with the area, unable to remember the location from which they are calling, or cannot identify where the emergency occurred, PSAP personnel will be able to assist because they will know the location of the telephone from which the call originates. E-911 also allows call backs from the PSAP to that telephone to recontact the caller for more information or clarification if necessary. The advantages of E-911 with caller address identification may be lost with calls from cellular telephones or voice-over-Internet calls or if there are no 911 services in the affected area. Global positioning systems technologies assist responders with caller and incident scene location. Telephones that operate over the Internet, however, may send U.S.-based 911 calls to distant operators, potentially introducing delays in determining the nature and location of an emergency and in identifying the appropriate response agencies.

When consequences of the evolving emergency are widespread, the local jurisdiction may dispatch fire suppression, law enforcement, and EMS resources to conduct a "windshield survey" of their primary response areas. These units will report back on their observations to help prioritize initial responses when needs clearly exceed initially available resources. With the loss of communications infrastructure, emergency communications will originate from individual jurisdictional law enforcement, fire suppression, or EMS response stations or units.

The first point of medical decision making for EMS scene management may take place at the level of the dispatch center when a caller reports a situation and requests EMS. In the U.S., emergency medical dispatchers are trained to assist rapidly the caller in characterizing the nature of the emergency by using directed systematic questioning. This strategy permits construction of an appropriate response to the emergency as well as provision of prearrival instructions to the caller in an attempt to mitigate immediate life-threatening problems. When emergency medical dispatchers are engaged in response unit coordination, they may no longer be able to triage medically calls for help or provide prearrival instructions to the caller to help reduce morbidity or mortality. However, they may be in contact with callers in immediate danger from the evolving hazards. Potentially life-saving advice may take the form of sheltering in place or evacuating the hazardous area as best assessed from information provided by the caller. Emergency medical dispatchers may be trained in the use of scripted protocols aimed at reducing immediate life threats at the scenes for special situations. Examples include a site where a perpetrator is firing a gun, a structure fire entrapment, a known evolving community infectious disease, a chemical or radiological release, or unknown evolving infectious disease. Syndromic or dispatch call type surveillance over time coordinated with local emergency management and public health resources may provide early information in an evolving, extended operations emergency. The situation may be dynamic, requiring case-by-case decisions based on dispatcher training and experience. Sufficient and accurate actionable information is frequently lacking and the most appropriate interventions for victim and public safety personnel are often not determined until

Table 19.2: Functions of the Logistics Section

Logistics Section
Communications
Medical (responder medical care)
Rehabilitation
Supply
Food
Facilities
Ground Support

Table 19.4: Functions of the Operations Section

Operations Section
Staging
Air Operations
Branches
Divisions
Groups
Task Forces
Strike Teams
Individual Resources

Table 19.5: Initial Multicasualty Incident Functions

Incident Command
Triage
Medical Communications

after the arrival of first responder agencies. This can be an extraordinarily high stress time for emergency medical dispatchers who are attempting to construct a picture of the emergency, structure response configurations, coordinate the response with considerable situational uncertainty, and manage calls from individuals in harms way.

INITIAL RESPONSE

As local media report on the emergency and local dispatch radio traffic is heard, there may be a self-dispatch of local or regional responders who may not be among the initial units sent. Agency and responder discipline and "freelancing" must be balanced with the judgment to dispatch the closest, most appropriate, and available response units. Such decisions are based on staffing, capabilities, proximity to the incident, immediate needs of the emergency, and information available to the public safety answering points and dispatch centers. Emergency unit utilization must also be balanced with the need to maintain availabilities to meet other local nonincident-related calls for assistance. One strategy is to bring requested mutual aid units into the incident and hold in reserve some local and reserve units familiar with the geography, procedures, and practices to respond to concurrent emergency calls. In part, self-dispatched units can be managed by staging incoming responders at a designated location. These assets will be under the control of a staging manager in communication with the incident command for operational assignments once an incident command structure is established.

Victim location may be known or readily apparent, or there may be the need for search operations. Search operations may take the form of systematic area searches by air, boat, or ground. Area searches are resource intensive and often are multiagency and multijurisdictional. A structural search may be initially limited by the need to triage buildings for stability by structural engineers. With proper building triage and emergency shoring as needed, a structural search may proceed using technical assets such as acoustic and imaging devices or may involve search dogs.

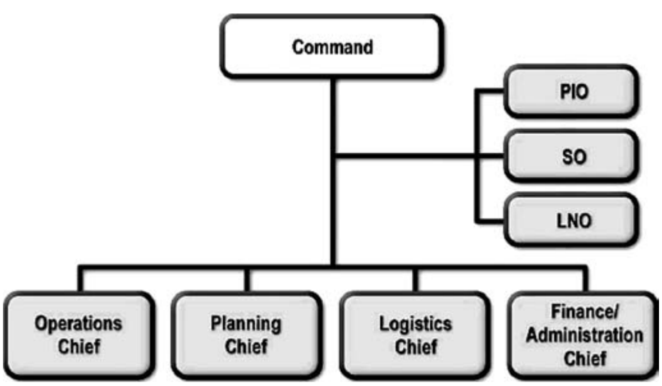

Figure 19.1. Command and general staff (PIO: Public Information Officer, SO: Safety Officer, LNO: Liaison Officer).

Table 19.6: Expanded Multicasualty Incident Positions

Incident Command
Triage Unit Leader
Medical Communications Coordinator
Ground Ambulance Coordinator
Treatment Unit Leader
Treatment Dispatch Manager

Although the objective of the search may be location of survivors, the discovery of nonsurvivors must be anticipated and their locations mapped.

The priorities for the initial responding units are: 1) scene survey (within the primary response area of individual response units); 2) critical hazard mitigation or containment (that might immediately increase mortality of survivors and include hazards such as fires, unsecured utilities, and structural instability); and 3) assessment of the need for additional resources and then requesting them. In truly widespread emergencies, it may be necessary to make the very difficult decision to first conduct area surveys and accurately report conditions that will contribute to better resource allocation and early specific mutual aid requests. Attempting hazard mitigation or addressing life safety must be initially deferred. Such activities may ultimately reduce morbidity and mortality among those victims with the greatest potential for survival. With the nearly immediate availability of airborne television reporting in urban and suburban areas, a visual area assessment may begin with video from television news reporting. Real-time surveillance is conducted by law enforcement or public safety agencies in some parts of the U.S. and within certain industries (e.g., hotels, casinos, and secured facilities) and cities elsewhere in the world that utilize extensive video or closed circuit television. This may also be a source of information if that infrastructure is not disrupted. This visual assessment over several local television channels or other sources combined with emergency response dispatcher and first responder information helps to define the scope of the emergency.

Survivors might perform initial search, light rescue, and first aid. This local citizen-based assistance may be spontaneous or may be structured. Businesses may have organized emergency response teams designed to meet the immediate needs of employees and trained in early mitigation of any hazards unique to that business. For example, businesses that manage secure information may have plans to care for their employees, mitigate hazards from building utilities, and maintain information security. Industries and universities may have hazardous materials

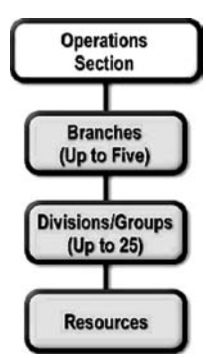

Figure 19.2. Operations section: geographic divisions, functional branches or groups.

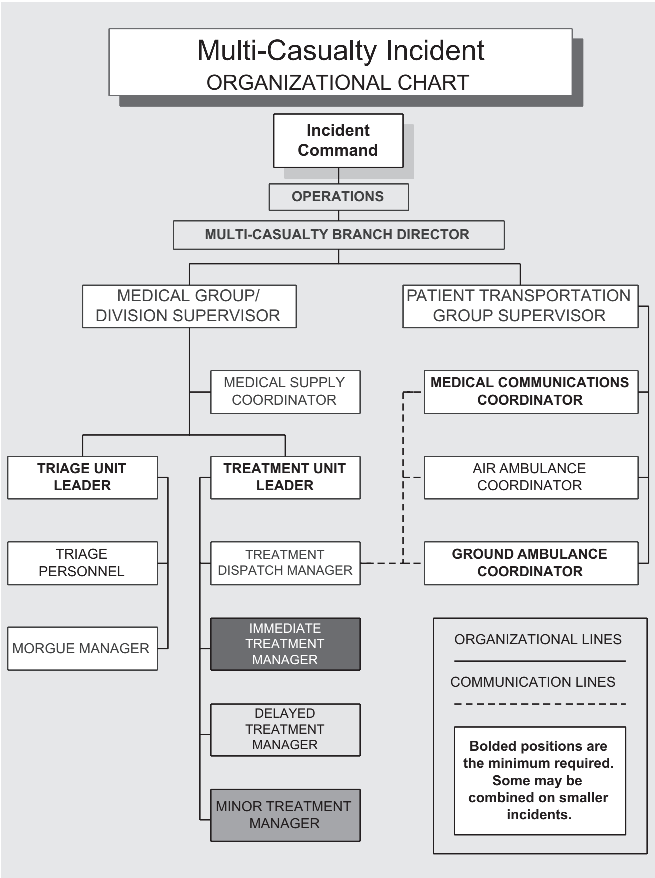

Figure 19.3. Multicasualty incident organization (adapted from FIRESCOPE). See color plate.

teams that are solely responsible to their facilities and serve to identify and contain any hazardous materials breaches. U.S. nuclear power plants have response, assessment, and mitigation teams for potential radiation dispersion. Communities may have organized volunteer response teams (e.g., U.S. Community Emergency Response Teams) trained in light rescue, residential utilities control, first aid, sheltering, and sustainment until professional help can arrive (see Chapter 9).[1] In larger emergencies these may be the earliest responders that victims encounter. Training and exercising of emergency responders should include anticipation of and coordination with spontaneous, business, or community citizen responders.

EXTENDED RESPONSE AND INCIDENT ORGANIZATION

In smaller-scope daily jurisdictional EMS incidents, the roles and responsibilities of first responders are well defined and frequently practiced. As the incident becomes larger or extends over a longer period of time, a few specific functions must quickly be established to manage the emergency. Incident organization can define success or failure of overall incident management. As resource availability and capacity allow, two initial and overlapping priorities will emerge: 1) immediate hazard mitigation and, 2) victim triage. To address these two priorities, two functional groups will be operating simultaneously: fire suppression/rescue and EMS. As the scope of the emergency is more completely determined and other priorities emerge, the response will become more complex. To address these complexities, an incident management system is necessary. Response organization can occur at many functional and jurisdictional levels, and terms used to describe functions and positions can vary. To create uniformity in incident management, the U.S. National Incident Management System was developed.[2] The adoption and implementation of the National Incident Management System at various jurisdictional levels is encouraged by tying its use in planning and preparedness to federal funding of eligible local jurisdictional programs.

Management of large and sustained incidents is structured around command and general staff in association with geographical divisions, functional branches, and groups. If the incident requires greater resources and organization, the functional branches are divided into groups. If that is not operationally necessary, however, the functional branches alone are adequate. Functional group resources can be further subdivided into task forces composed of multiple entities, strike teams composed of similar disciplines, or individual resources.

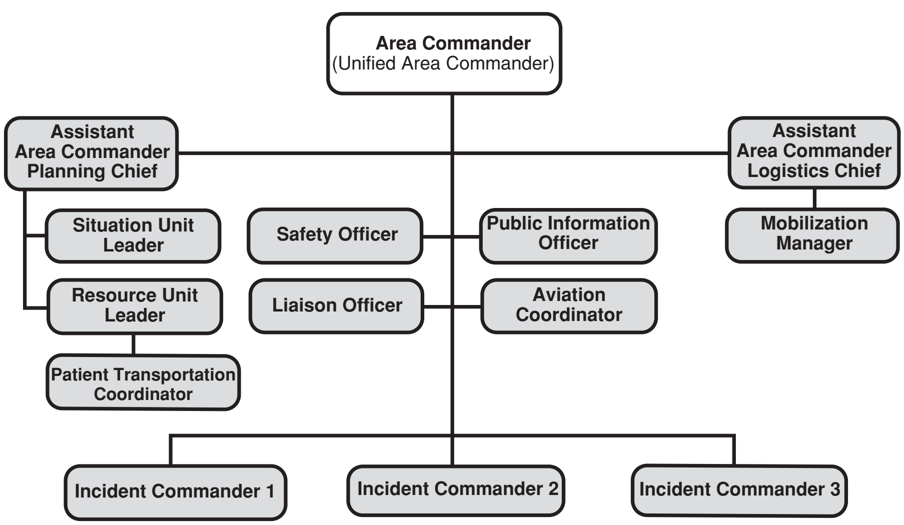

Figure 19.4. Example of area command organization.

COMMAND AND GENERAL STAFF

Command and general staff consist of an incident commander or a unified command when multiple disciplines are needed to manage the incident (e.g., fire, EMS, law enforcement, and public health). The incident safety officer, public information officer, and any responding agency liaison officers all report to the incident commander. Also reporting to the incident commander is the general staff: operations section chief, plans section chief, logistics section chief, and finance/administration section chief.

PLANNING SECTION

The Planning Section is responsible for incident intelligence gathering, documentation, anticipation and requesting of specialized resources, coordination of technical specialists necessary to support incident operations, and the briefing of responding agency leadership throughout operational periods. During sustained operations, the Planning Section has the responsibility for writing the Incident Action Plan with the concurrence of the command and general staff based on a standardized format.[3] The Planning Section is also responsible for organizing demobilization of resources as the incident resolves. For example, the Planning Section coordinates with local health department and hospital infrastructure to keep the Operations Section informed about hospital and specialty care resources (e.g., burn and trauma) and the ability to receive patients in an extended EMS incident. Incident EMS or medical supervisors coordinate with Safety and Hazardous Materials Officers to develop a safety plan that contributes to the Incident or Operations Action Plan and addresses occupational health hazards for remaining victims and responders. The Planning Section gathers information on agencies with the ability to transport victims greater distances to healthcare facilities remote from an emergency and writes the plan to guide the Operations Section on accessing those resources.

LOGISTICS SECTION

The Logistics Section is responsible for incident communications, acquiring and managing all equipment and materiel necessary to support incident operations, and managing and supporting a base of operations. If on-site medical care is provided to incident responders, that medical unit is also the responsibility of the Logistics Section.

FINANCE AND ADMINISTRATION SECTION

The Finance/Administration Section is responsible for tracking incident costs and personnel time and facilitating purchases for the logistics section. This section also tracks claims resulting from injuries to responders.

OPERATIONS SECTION

The Operations Section runs the various missions of the incident and is supported by the other three general staff sections. The Operations Section may be divided into geographical divisions based on incident priorities and physical boundaries that affect those priorities. The Operations Section is further divided into functional branches and/or groups. These functional branches or groups may include multicasualty, rescue, fire suppression, hazardous materials, or air operations branches/groups or any other function essential to the mission. Group supervisors report to branch directors, division chiefs, or the Operations Section chief depending on the level of organization necessary to manage the incident.

For extended EMS operations, the Operations Section will have a multicasualty branch. That multicasualty branch is divided into a medical group and a transportation group. If there are multiple sites in operation, geographical divisions can be assigned to further organize incident management. The medical group has a triage unit, treatment unit, and a morgue unit. The transportation group has a ground ambulance coordinator and medical communications coordinator. A treatment dispatch manager coordinates victim movement between the treatment unit leader and ground ambulance coordinator. If medical air transport services are in continuous use during victim movement, the transportation group supervisor coordinates with the air operations branch/group.

AREA COMMAND

In widespread emergencies with multiple incident sites, an area command can be established to manage the response. There may be one area command with a unified command, safety officer, public information officer, agency liaison officers, and section chiefs (planning, logistics, and finance/administration). Each operational site would then have an operations chief with geographical divisions or functional branches or groups.

Such extended incident organization develops over time, is structured to meet the needs of the incident, and is built from essential functions beginning with the initial responding units. To manage a multicasualty incident site, initial responders should establish an incident command system and appoint an incident commander and personnel to function as triage unit leader and medical communications coordinator. These essential three functions will meet the initial needs of organizing resources, assessing the incident, reporting conditions and hazards (scene safety), requesting additional resources, initiating victim triage, and establishing communications with the EMS and healthcare infrastructure.

VICTIM TRIAGE AND TRANSPORT

Victim triage strategies and challenges are discussed in Chapter 12. Further organization depends on the availability of additional resources to meet the needs of the incident. If sufficient ambulances are available to initiate immediate victim transport, a ground ambulance coordinator can be established and victims can be moved directly from triage to ambulances by triage priority with destination hospital or specialty receiving center determined by the medical communications coordinator. Management of arriving ambulances may be assigned to the ground ambulance coordinator on smaller incidents or may be assigned to a staging manager reporting to the medical group supervisor, medical branch director, or operations chief. If sufficient ambulances are not immediately available or the extent of the multicasualty incident exceeds local resources, a treatment unit will be necessary. Victims are moved to a treatment unit at a safe location by triage priority and subsequently transported in ambulances or other types of vehicles (e.g., buses or vans for minor casualties) as these resources become available. A treatment dispatch manager working with the treatment unit leader and ground ambulance coordinator controls victim movement based on triage category and ambulance availability. The medical communications coordinator determines destination hospitals in association with the healthcare infrastructure. The physical location of the medical communications coordinator will be determined by many incident-specific factors. One strategy is to geographically locate the medical communications coordinator so that the ambulances loaded by triage category receive their hospital or specialty center destination assignments as they are exiting the incident. This prevents slowing down the patient loading process by allowing the treatment dispatch manager and ground ambulance coordinator to load ambulances by triage category without waiting for destination decisions.

As incident organization increases, it is important to understand that these components are based on functions rather than on positions. If local responders are adequately trained and exercised on multicasualty incident management, the functions described will be accomplished without unnecessary focus on process and position titles.

Effective victim triage is essential to optimize use of limited on-scene resources and healthcare infrastructure in larger multicasualty incidents. Although many EMS systems have robust patient distribution systems, it is not uncommon that a disproportionate number of casualties are transported to the closest general or specialty hospital (such as a trauma or burn center). Examples include events involving the World Trade Center in New York City and the Alfred P. Murrah Federal Building in Oklahoma City.[5,6] Some degree of victim self-triage and self-transport can be expected, especially before effective incident management is established and adequate resources have arrived to the incident site. The magnitude of victim self-triage and transport can be substantial, even in industrialized societies with highly resourced EMS systems.[6,7] Victims who have or find their own transportation can be expected to go to the closest hospitals or to those most familiar to them independent of any plan to optimally utilize healthcare resources. Even if scene managers use a good patient distribution system, this can result in a maldistribution of casualties to local hospitals such that one or a few facilities are overwhelmed, while others receive few victims. Early communications about the nature and location of the incident is essential if healthcare facilities have only a very limited time to prepare for the arrival of victims. This is particularly true if decontamination of victims is necessary as part of their coordinated medical care. Hospital-based decontamination operations take time to establish. Hospitals may experience "reverse triage" such that self-transported victims with comparatively less severe injuries arrive before more seriously injured victims sent by the EMS system.[6] Bidirectional communication between the medical communications coordinator and hospitals will help determine whether victims of lower triage priority should be transported to more distant hospitals to avoid those that are closer and more affected by victim convergence. Communication with healthcare facilities may be direct using radios and telephones or indirect through a dispatch or regional coordination center. Other communications modalities include web-based real-time tracking systems for victim transport and hospital capabilities. Electronic victim and hospital tracking can take place via the Internet and can be backed up by microwave transmission. Effective hospital-based response to a multicasualty incident will depend on establishing an internal command structure just as it does in field incident management. The Hospital Incident Command System (see Chapter 20) is an example of a framework that defines positions and functions to assist hospitals with internal organization, requesting additional resources and optimal resource utilization for both in-house and on-call resources.[8]

Spontaneous responders can be a challenge to manage during a large incident. Spontaneous medical responders are unlikely to be trained, equipped, or experienced in providing medical care under hazardous conditions and unlikely to be familiar with EMS strategies and procedures. Informed and organized spontaneous medical responders can be an asset, however, when the size and scope of the multicasualty incident exceeds local capabilities. It is essential to have a plan to manage these well-meaning volunteers; otherwise they can distract resources from their primary functions and lead to inadequate scene management. One strategy is to attempt to collect spontaneous medical responders, brief them on the nature of the incident, and assign them to the treatment unit leader. The staging area for victims in the treatment unit awaiting transportation to hospitals will likely be in a comparatively safe location and the approach to these patients' care will be somewhat familiar to spontaneous medical responders who are healthcare providers.

MEDICAL MANAGEMENT

Specific treatment rendered during and subsequent to the triage process or in the treatment unit must be goal directed and will depend on the capabilities and capacity of the responding resources. Because the triage process is dynamic, an important function is interval victim reassessment and retriage if necessary after a victim arrives at the treatment unit. Newer triage tags are designed to display change in triage category with either improvement or deterioration. Treatment strategies likely to reduce morbidity and mortality among victims staged in the treatment unit include maintaining an open airway, decompressing a tension pneumothorax (needle thoracostomy), controlling external exsanguinating hemorrhage (wound packing or dressing, elevation, or arterial tourniquet) and spinal stabilization (if not already accomplished). Conversely, a clinical assessment to determine whether patients require or should remain in spine immobilization can be invaluable during multicasualty incidents. Such assessments can save scarce resources and reduce discomfort and complications for patients who do not require spinal stabilization. Using a validated protocol, properly trained personnel can systematically judge when spinal stabilization is necessary and when it is not.[9,10] Patients in whom spinal immobilization is deemed unnecessary require far fewer personnel and transportation resources.

The gamut of EMS therapeutic interventions may not be available, depending on the number and acuity of victims, available transportation resources, and capacity of the EMS system. Intravascular fluid resuscitation (intravenous or intraosseous) of profound hypovolemic shock with uncontrolled hemorrhage to permissive hypotension endpoints may influence victim outcome.[11,12] However, insufficient evidence currently exists to create multicasualty victim clinical management strategies. Decisions on airway interventions will be determined by the availability of equipment and personnel, sustainment of those resources (e.g., oxygen), predicted victim survivability, and the number of other victims who may survive. Selected goal-directed therapies for injuries or for exacerbations of underlying illnesses subsequent to those injuries will be considered on a case-by-case basis as resources allow. Pain control can be both a humanitarian and practical intervention. Nonpharmacological pain control may take the form of effective splinting and immobilization of fractures. Pharmacological pain control will depend on local scope of practice and available resources, but can provide comfort to victims immobilized for long periods of time or with painful injuries awaiting transportation. Other measures to address victim comfort include providing oral hydration when clinically appropriate and shade or shelter for the treatment unit. This will reduce exposure to temperature extremes, sunlight, wind, precipitation, and the sights and sounds of the incident itself.

Medical management of entrapped victims can be complex. When resources are available and the survivability of entrapped victims is sufficiently favorable to support extended technical rescue operations, certain medical interventions can contribute to both the stabilization of the victim and the tempo of the rescue. The treatment of easily reversible conditions and pain may allow some downward triage of selected victims (i.e., moving patients to a lower, less severe level) and allocation of scarce medical resources to victims more acutely ill. Inhalation injury, blunt and penetrating trauma, traumatic rhabdomyolysis (crush syndrome), hypothermia, dehydration, and exacerbation of chronic illnesses are among the conditions that may require field interventions. Depending on the nature of a structure's building materials and the nature of the event causing its failure, emergencies involving structural collapse may result in void spaces capable of supporting life. Rescuers can help reduce further risk of inhalational injury by providing void space ventilation and by administering a particulate respirator to the victim. Trapped casualties can receive void space ventilation either passively by opening the void space to the atmosphere or actively using ventilation fans. Anticipating predictable physiologic consequences of prolonged entrapment and coordinating goal-directed medical interventions with the rescue operation are important considerations. Preparing for traumatic rhabdomyolysis, blood loss, and intravascular fluid shifts during extrication can reduce the risk of precipitous hemodynamic destabilization when the victim is freed.[12] Pain management can substantially affect the tempo of a rescue effort by expediting extrication. Although extrication can involve moving the victim in ways that are unavoidably painful, pain exacerbation can be a warning that part of the rescue effort is placing the victim at risk of further injury. If victim discomfort causes the rescue effort to be repeatedly stopped and readjusted with no appreciable progress, pharmacological pain control should be used to facilitate the rescue process.

DECONTAMINATION AND SPECIAL HAZARDS

When chemical, radiological, and possibly biological hazards are present or when there is concern for secondary hazardous devices such as explosives, incident organization for the purpose of victim movement remains unchanged. Several other processes, however, must be inserted into multicasualty incident organization and structure. The first challenge is recognition and rapid assessment of the hazard. Responders must quickly determine whether there are surviving and accessible victims and what level of responder personal protective equipment will be necessary to make rapid entry and remove survivors to a safe area. The suspected nature of the hazard and initial operational decisions will be communicated to responding personnel. Performance of triage may wait until victims are moved to a safe area or after emergency decontamination. If triage is accomplished prior to emergency decontamination, triage personnel may need to work in personal protective equipment. Once the responders have recognized suspected hazard, donned personal protective equipment, accomplished initial victim rescue, and performed emergency decontamination, the process of organizing secondary triage (or primary triage if not yet performed), treatment, medical communications, resource coordination, and victim transport remains the same.

When there is a need for victim decontamination, a substantial layer of complexity and personnel requirements is added to EMS scene management. Within the U.S., if a need exists for emergency decontamination based on victim symptoms or known exposure, it will likely be the initial responding fire suppression units that will use handheld hose lines or elevated master streams with nozzles operated in a fog pattern as the initial approach. If contaminated victims are at risk from an immediate life or health threat, the U.S. Environmental Protection Agency has stated that responders are not required initially to contain the water runoff (e.g., it can be managed downhill from operating units on grass or gravel).[13,14] Runoff containment becomes a regulatory requirement after the life or health threat is mitigated. These regulations become effective when operations transition from emergency decontamination to technical decontamination during hazard mitigation, deceased victim recovery, or law enforcement investigation. An attempt should be made to cohort contaminated victims to the extent possible while establishing the emergency decontamination equipment. With proper training and exercising, decontamination systems can be synthesized very rapidly (within minutes) using equipment and devices carried on fire apparatus normally used for fire suppression. Victim contact for pre–decontamination coordination or life-threatening injury or illness intervention will likely occur with personnel wearing protective equipment and full-face, positive pressure self-contained breathing apparatus. If decontamination operations are sustained, the level of respiratory and splash protection necessary can be re-evaluated based on a more objective risk assessment (see Chapter 14). Critical pre–decontamination interventions may include removal of outer clothing (which results in substantial contamination reduction), containing important personal items (e.g., personal identification) and coordinating family or companion decontamination for ambulatory victims. For nonambulatory victims, pre–decontamination maintenance of an open airway, needle decompression of a tension pneumothorax, control of external exsanguinating hemorrhage, and spinal stabilization may be indicated. Pre–decontamination antidote administration may be impractical or medication may be unavailable. It is, however, technically feasible for providers wearing protective equipment to administer intramuscular injections of atropine and pralidoxime by using autoinjectors for critically ill victims of organophosphate/nerve agent toxicity. This intervention can stabilize the victim sufficiently to permit necessary decontamination prior to more definitive treatment. Exposure solely to vapors or gases (particularly less water-soluble gases) will not require immediate skin decontamination. Therefore, cyanide antidote administration to critically ill victims can proceed as soon as the victim is removed from the immediate inhalation hazard and the prehospital care provider can work safely without a respirator. Similarly, radioactive particulate contamination of victims from an explosive dispersion device is a lower priority than managing critical blunt or penetrating trauma resulting from the blast injury.[15,16] Removing the external layer of clothing, wrapping the victim to contain the radioactive contamination, performing critical prehospital interventions, transporting the patient to a trauma center, and initial resuscitation and damage control surgery are all priorities over radiological decontamination (see Chapter 30). Radiological decontamination can be performed at any point during medical or surgical management when the victim is stabilized. Victims with minor injuries or illness can be decontaminated prior to transport. Wound irrigation is part of the decontamination process. Because hospitals may not be sufficiently prepared to manage patients with radiological contamination, emergency planners should anticipate requests from hospitals for decontamination assistance (supplies and trained personnel), particularly if large numbers of self-transported victims arrive before hospital-based decontamination procedures are fully operational.

VICTIM TRACKING

Victim tracking is a challenging problem in EMS scene management of multicasualty incidents (see Chapter 25). With wireless telephone communications (including instant messaging and picture phones) widely available, victim involvement in an emergency can be known by family, friends, coworkers, and the media very early in the evolution of the incident. The status and locations of multicasualty incident victims who require custodial care (e.g., children, elderly, or disabled) will likely be sought even before the last victim has left the scene, with some caretakers arriving on the scene in the midst of ongoing emergency operations. There is a balance between efficient victim movement from the incident to definitive medical care and documentation of important victim information at the scene. Electronic devices to connect a triage tag identifier with the identity and destination of a victim have not been rigorously and objectively compared to paper-based tracking systems in efficacy, effectiveness, or practicality under operational field conditions. Electronic devices can fail due to power or weather situations and would need to be immediately and widely available and operable by EMS system personnel. Any procedure or device that is used only rarely and under exceptional circumstances is at risk for failure when it may be needed most. Hospital-based patient identification and tracking is a common practice and may be augmented with the assistance of nongovernment organizations (e.g., American Red Cross chapters) or local EMS communications infrastructure. This process, although effective, incorporates an inherent delay in victim information transmission.

MULTIJURISDICTIONAL COORDINATION

Large or widespread multicasualty emergency response by a jurisdiction will likely require outside assistance. "Automatic aid" refers to public safety answering points and dispatch centers sending the closest appropriate local units independent of geopolitical boundaries. "Mutual aid" refers to interjurisdictional assistance following a specific request for that assistance. Often, but not exclusively, this implies pre-event agreements defining available resources, response parameters, and administrative issues such as reimbursement procedures. Mutual aid can be between local jurisdictions, within regions of a state, from state government, between states (e.g., Emergency Management Assistance Compacts),[17] from the federal government, and between countries. Each responding mutual aid entity will have its own command structure that will integrate into a unified command, division, branch, or group organization of the jurisdiction having authority. Local or regional entities may request EMS mutual aid to assist with victim management at the scene. More distant EMS mutual aid may include ambulance strike teams[18,19] to assist with victim transport from hospitals to specialty facilities (e.g., trauma, burn, or pediatric) or from hospitals with a large number of victims to more distant hospitals to better manage victim distribution. EMS helicopters are less practical than ground transport units in multicasualty incidents. They require additional resources to operate safely and coordinate landing zones and they can generally only carry one or possible two victims. Air EMS resources can have value if they are used to transport properly triaged victims to specialty care centers (e.g., trauma, burn, or pediatric) distant from the incident due to geographical location or saturation of closer specialty centers. If extended rescue operations are necessary, specialty rescue teams or task forces with medical components may be deployed to the scene. Medical teams may be requested to support local healthcare infrastructure by expanding: 1) local or regional emergency departments, critical care, or medical–surgical units, or 2) public health capacity. They may also provide free-standing treatment stations or medical support to the community and shelters for special populations. Individual resources or strike teams such as specialty nurses (e.g., critical care, burn, and dialysis), pharmacists, or physicians may also be requested. Disaster management systems and healthcare facility disaster management are discussed elsewhere (see Chapters 9 and 20).

RECOMMENDATIONS FOR FURTHER RESEARCH

Planning for multicasualty incident response requires more than an analysis of the organizational and technical aspects. Multicasualty incident response plans must anticipate and incorporate the potential effects of victim self-triage and self-transport. Hospital and scene incident management must anticipate maldistribution of victims geographically and by acuity. In addition, response personnel must be knowledgeable, trained, exercised, and disciplined in the application of their multicasualty incident plan. The plan must be adaptive to allow flexibility and deviation to meet the specific needs of an incident. Frequent exercises and scaled application of the plan to more common smaller incidents will help achieve responder familiarity and comfort and improve plan compliance. Research on victim movement and incident organization will help identify those functions that are most critical to effective patient triage and transport and allow planning, training, and exercising to address those needs.

Healthcare resources in a community can be scarce, even during daily operations. To support multicasualty incident operations, particularly for victims triaged as minor, transport to free-standing emergency departments, urgent care centers and other alternate care sites might help unload acute care facilities allowing them to manage greater numbers of higher acuity victims. This is not common practice in the U.S. and will require research into the safest ways to distribute minor casualties into a broader healthcare system. In addition, regulators must address existing laws and the need for legislative relief to enable selected alternate care sites to receive victims from an incident.

Virtually every emergency incident or disaster after-action report mentions challenges with communications. Effective and sustainable communications within jurisdictional chains of command and with outside resources are essential for command and control and optimal resource utilization. The capacity of routinely used communications systems can be easily exceeded during major incidents. Cellular telephones and local emergency radio frequencies can be saturated with communications traffic, as can handheld satellite telephones. Distance from communications centers or communications transmission equipment or terrain can compromise radio or cellular traffic. Collateral damage to communications infrastructure or power supply can render wireless telephones unusable and radio communications may be limited to line-of-sight with handheld units. Portable radio battery life as well as opportunities for replacement, and recharging may be limited. Multijurisdictional radio interoperability may also be limited. Separation of law enforcement, fire suppression/rescue, and EMS radio communications may make coordination of resources difficult. Lack of redundancy in communications systems can compromise operations when one or more systems fail. Technological, political, and operational solutions are possible when combined with funding, equipment availability, familiarity, training, and exercising. As with triage strategies, communications solutions should be integrated into daily emergency services operations so that unfamiliar equipment and procedures will not be first used in times of high demand.

No triage decision scheme has been prospectively validated under large-scale multicasualty incident operational conditions. Retrospective studies on efficacy do not always translate to prospective operational effectiveness. Attempting to transport every "critical" victim to a specialty center by using advanced life support assets is not always the best use of resources or even possible to achieve. Arguably, effective triage strategies during a large multicasualty emergency are more important to victim outcome and resource utilization than in daily single-victim trauma triage. Under- and overtriage can substantially impact the volume and acuity of victims arriving by EMS at healthcare facilities, compromising the availability of these potentially limited resources for victims most likely to benefit and potentially compromising victim clinical outcomes.

Victim tracking from the scene, if done at all, can be as low-tech as paper documentation of victim name, triage category, hospital destination, and transporting unit identifier or as high-tech as encrypted electronic scanning and wireless transmission of victim data to multiple stakeholder agencies. Such information, secured as protected patient information, would promote improvements in victim management from the incident, healthcare interfacility transfers for specialty care, family notifications, and postincident analysis. The more complex equipment and procedures become and the less they are used under daily operational conditions, the more likely they are to fail. Practical, durable, affordable technological solutions or simple operational procedures should be developed.

Thoughtful, goal-directed, locally conceived and executed exercises and drills are essential to managing and coordinating the many challenges of a large multicasualty incident. Both insufficient funding and the process of obtaining funding through grants for exercises can result in training that is poorly conceived with goals that are too broad or general and with insufficient attention to local needs. The lack of sophisticated local systems, equipment, and procedures does not necessarily translate to poor multicasualty incident performance. Understanding local resources, optimizing those resources, and supporting training and exercises can result in a well-managed incident.

Continuous quality improvement studies are increasingly applied within EMS systems. Documentation of patient demographics and clinical condition may not be as thorough during multicasualty incidents as it is for incidents with few patients but postincident analysis can provide useful data for system and response evaluation. Time intervals for response, staging, victim transport by triage category, and ambulance departure-from-scene as well as cumulative victim transport numbers by triage acuity over time are parameters that can help characterize the timeframe of the response and of victim movement. Changes in these calculated intervals if operational changes were made on scene during the evolution of the incident can be very instructive. These time-related data may be more readily available in an EMS system than victim outcome data. When victim outcome data are available, this information can be useful to help assess triage sensitivity (false negative or undertriage rate) and specificity (false positive or overtriage rate). Typical data collected include: 1) hospital admission rates, 2) duration of stay, 3) admission diagnoses, 4) emergency department and hospital discharge diagnoses, 5) surgical intervention rates (e.g., trauma/general, orthopedic, and neurological surgery), 6) critical care unit admission rates, and 7) mortality rates. In well-designed multicasualty incident exercises with mock victims tagged with local triage scheme-specific parameters, both "victim" movement time analysis and triage scheme sensitivity and specificity can be assessed for the purposes of adjusting future training and system deployment. Such an exercise assessment is only an approximation of operational effectiveness but can identify extremes in performance that can assist with defining future training needs. EMS systems with well-developed data management and continuous quality improvement processes may be able to capture more objective, operational data and contribute to the knowledge base for multicasualty incident management by forming multicasualty incident registries.

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20

Healthcare Facility Disaster Management

John D. Hoyle Sr.

OVERVIEW

Disaster preparedness in healthcare facilities has historically been a low priority and is often viewed as a chore or unnecessary mandate. Too often it has not received the support of top management in a meaningful way. In some societies, healthcare is viewed as a right, with the expectation that the hospital be ready 24/7 to render care as needed. Lawyers may sue the unprepared hospital or healthcare professional after a disaster in some cultures. In past decades, many healthcare professional training programs, including those in the U.S., have not emphasized disaster preparedness in their curricula. Even residencies in emergency medicine sometimes neglect this important subject. Since the terrorist attacks of September 11, 2001 in the U.S., many healthcare training programs have begun educating students on this vital topic and its implications for their communities. Many hospitals have experienced a resurgence of interest in preparedness and have hired full-time emergency management personnel. In contrast, other institutions have only prepared minimally as required by outside entities (e.g., the local or national health authority or The Joint Commission in the U.S.). Hospital preparedness efforts have waxed and waned over the years, and the tempo of preparedness planning, training, and drilling has vacillated depending on national or local requirements or trends and real-world events. Because students in hospital and healthcare administration usually receive no training on this management topic, they are not fully cognizant of the possible demands that could be placed on them and their facility during a disaster or emergency situation. An additional factor inhibiting preparedness activities is the fact that individuals could work their entire careers in a hospital and never experience a disaster. At the time of this writing, preparedness efforts for hospitals, public health organizations, and long-term care facilities are gaining momentum. While the term "hospital" is used throughout much of this chapter, the principles discussed are meant to apply to all healthcare facilities.

History of Healthcare Disaster Planning and Preparedness

The initial efforts to formalize hospital disaster preparedness began in the United Kingdom in the days before the outbreak of WWII. As war with Germany became imminent, the British government completed planning activities started in the 1920s following the WWI bombings of London by Zeppelins. The government realized that modern airpower and munitions represented a severe threat that could produce massive numbers of casualties. Therefore, they implemented many medical preparedness measures and created the Emergency Medical Service (EMS) in the Ministry of Health to coordinate these endeavors.[1] The British EMS was unlike a 21st century prehospital system in the developed world, rather it represented a planning and control agency. This group had authority over all healthcare services and had the power to regulate hospitals, designate duties for each category of hospital, create new hospitals in prefabricated huts at distant locations from target areas, and dispatch ambulance trains and buses to remove the injured to hospitals in safe areas.

The United Kingdom was divided into 12 planning regions, with the London region further subdivided into 12 sectors because of the heavy population density. Planners anticipated an initial casualty load of 35,000 victims from bombings.

Working with the military to devise estimated casualty figures, EMS quickly placed orders for 150,000 beds with linens and blankets. At the same time, EMS also ordered 226,000 litters that, with their wire mesh, could be easily cleaned or even used as decontamination stretchers. The large number of litters was also desired to reduce the frequency of transferring patients from bed to bed as they moved through multiple treatment venues. Also ordered were massive quantities of pharmaceuticals and dressings to provide for 250,000 hospital beds, 3,000 First Aid Posts, and 2,000 smaller First Aid Points.[1] Those staffing the First Aid Posts included physicians and nurses performing casualty clearing. Gas decontamination units were also organized and the EMS issued guidance documents.[1]

- "Structural Precautions for Hospitals Subject to Bombing Effects"
- "System for Wartime Organization of Hospitals"
- "Formation of Casualty Bureaus"
- "Medical Treatment of Gas Casualties"
- "Training and Work of First Aid Parties"

Also during this period, numerous medical faculty members published books such as *Medical Organization and Surgical Practice in Air Raids*, *Casualty: Training, Organization and Administration of Civil Defense Casualty Services*, and *The Treatment of Burns*.[2–4]

Before hostilities began, hospitals were reinforced with wooden beams and some constructed bed space and operating rooms in their basements. Casualty Bureaus were created to organize the medical records on patients and the deceased, and report their statistics twice daily to the EMS. An alerting system for hospitals was established. Upon receipt of a warning, each hospital had specified actions to take in preparation for the arrival of casualties. The British government offered reimbursement to hospitals for upgrading their facilities and providing care to casualties.

The EMS had a Medical Director appointed for each region and sector whose responsibilities included[1]

- Liaise with the hospitals in the region or sector.
- Build cooperation in planning the precise use of each hospital.
- Distribute medical personnel between the inner and outer zone hospitals.
- Act on behalf of the hospital while also being an agent of the Ministry of Health.

Within the EMS headquarters, physicians were assigned as Principal Medical Officers of EMS for each of the following services[1]

- First Aid Posts
- Ambulances
- Medical Equipment and Supplies
- Evacuation Trains
- Pathology
- Radiology
- Blood Transfusion
- Dental

On September 3, 1939, the United Kingdom declared war on Germany. The Ministry of Health issued orders to evacuate completely certain hospitals to make capacity available for potential war casualties. In addition, they removed civilian patients from hospitals located in areas at risk for German attack. By that evening, all such patient movements were completed. From 34 London hospitals some 3,000 patients had been transferred to their previously planned destinations by using 18 of the 21 improvised hospital trains. Approximately 2,000 children were evacuated to outlying hospitals by buses converted to hold 10 stretchers each. The London Passenger Transport Board had fittings and hardware prepared in advance to equip 320 buses for a medical evacuation role within 12–24 hours. In other parts of the United Kingdom similar plans resulted in a total of 163,500 beds being made available for casualties. The London area contained 51,000 of these beds. In subsequent days, the number of beds made available continued to increase. Later, the EMS relaxed some of its standards and the percentage of hospital beds held in reserve for casualties was decreased. Additionally, the EMS reimbursed hospitals for empty beds.[1]

Of special concern were the cancer specialty hospitals with their stocks of radium. Authorities feared that if the hospitals were bombed, the radium might be widely dispersed and, with its long half-life, would present an environmental hazard. EMS decided to assist those hospitals with protecting their therapy sources by drilling deep bore holes in which the radium containers would be lowered during air raids. For those hospitals with small quantities of radium, a specially designed steel box was created for storage. Although many hospitals suffered bomb damage, both methods were successful in protecting the therapy sources.[1]

Special centers were also established for casualties with major psychiatric illness and orthopedic, plastic, chest, head, and burn injuries. The government took over country homes and schools and established 10,000 rehabilitation and convalescent beds in these facilities.[1] All the organizational efforts by the EMS and hospitals proved to be effective when the bombing began.

Table 20.1: Medical Guidance Developed for the United States During WW II

- Equipment and Operation of Emergency Medical Field Units
- Protection of Hospitals
- Central Control and Administration of Emergency Medical Services
- Guide for the Training of Volunteer Nurses' Aides
- Field Care and Transportation of the Injured
- Treatment of Burns and Prevention of Wound Infection
- The Clinical Recognition and Treatment of Shock
- First Aid in the Prevention and Treatment of Chemical Casualties

The United States Prepares

The United States government sent observers to Britain from military and other agencies, including the National Fire Protection Association, to observe the function of the U.K. civil defense, fire service, and EMS system. When these observers returned to the United States, they quickly began to develop systems modeled on the information obtained from the United Kingdom. On December 1, 1941, the Office of Civilian Defense (OCD) was created. On December 7, 1941, Japan attacked the U.S. naval fleet at Pearl Harbor, Hawaii. German submarines then launched torpedo attacks on freighters and tankers off the eastern seaboard of the U.S.

Following these attacks, officers of the U.S. Public Health Service (PHS) were assigned to OCD to begin developing organizational schemes, medical doctrine, and determining supply requirements, while seeking the help of U.S. hospitals. The American Hospital Association, the American Medical Association, and the American Nurses Association were also instrumental in promoting medical preparedness. Guidance was developed and included publications such as those listed in Table 20.1.[5]

Hospitals developed blackout plans and formed field medical teams composed of physicians and nurses. OCD provided each team with a two-suitcase set that contained surgical instruments, pharmaceuticals, and other medical supplies. The Military Mobilization Committee of the American Psychiatric Association prepared a publication for OCD entitled, "Reactions of People Under Stress: Anxiety and its Control."

Nurses took a leadership role in preparedness, and the publication *R.N. A Journal for Nurses* carried many articles on the subject. Furthermore, the government established the U.S. Cadet Nurse Corps in 1943 to train nurses on a massive scale to meet the needs of military and civilian hospitals. Congress passed the *Nurse Training Act* and it became Public Law 74 on July 1, 1943. Women at least 17 years of age who were high school graduates and in good health were eligible to apply. A massive recruiting campaign ensued with various Hollywood stars promoting the program. Major corporations and women's magazines ran advertisements featuring Cadet Nurses. A 10-minute film was produced with Hollywood actresses playing the role of Cadet Nurses. This film was subsequently shown in 16,000 movie theaters before an audience of 90 million. The recruitment campaign was very successful and the yearly quota for 65,000 recruits was easily met. The last year for new admissions began in October 1945 and the final Cadets were graduated in 1948. The program was administered by the U.S. PHS, which had enlisted the participation of nearly all nursing schools.

The PHS not only paid the tuition but also a room and board monthly stipend. Students pledged that, in return for education, they would serve wherever needed by the government. The Cadet Nurses also were furnished uniforms specially designed for the program, bearing the insignia of the U.S. PHS. The program was an immense success with 124,000 nurses graduated by its end.[6]

By 1944, the Allied Powers were prevailing in the struggle and OCD began to dissolve itself. At war's end in 1945, the United States quickly demobilized its military and the nation concentrated on the civilian economy.

The Cold War Period

In 1949, the Soviet Union exploded an atomic bomb signaling the start of the Cold War. In 1950, the U.S. Congress passed the *Civil Defense Act* and created the new Federal Civil Defense Administration (FCDA). The FCDA, like its predecessor the OCD, had a medical division and again enlisted the aid of hospital and medical organizations. Planning focused on the massive casualties possible from nuclear weapons. Comparing possible casualty figures from a nuclear attack against the available number of hospitals, medical resources were inadequate. In 1952, the FCDA developed the prototype Civil Defense Emergency Hospital that contained 200 beds, operating room equipment, an x-ray unit, generators, a water tank, pharmaceuticals, and medical and surgical supplies. It was a complete but austere hospital, designed to be assembled in an existing building such as a school. Furthermore, the government developed First Aid Station units and created a huge medical supply stockpile that was distributed across the nation in 21 warehouse complexes. In addition to the portable hospitals, the supply sets in these warehouses comprised:[7]

- First Aid Replenishment Unit – supplies to allow operation of a First Aid Station for up to 48 hours after a disaster. Weight: 1,026 kg
- Hospital Replenishment Unit – supplies necessary for operation of a 200-bed civil defense emergency hospital, or existing hospital, for 7 days. Weight: 5,464 kg
- Blood Collecting Replenishment Unit – supplies for collecting 1,000 U of whole blood. Weight: 1,410 kg.
- Intravenous Solutions Replenishment Unit – supplies designed to provide intravenous solutions and sets for 100 patients for 7 days. Weight 3,529 kg.
- Medical Supplies, Hospital Back-Up – supplies in original manufacturer shipping containers sufficient for 10,000 patients for 7 days. Weight 71,840 kg.
- Blood Expanders – 24 U of dextran injection. Weight 37 kg.

Subsequently, the FCDA created improved models of the Civil Defense Emergency Hospitals and supply quantities were increased. Later, the U.S. PHS assumed operation of the improvised hospital program and produced the largest and final model in 1962. Those hospitals were named Packaged Disaster Hospitals (PDHs). The United States had a total of 2,600 PDHs, which gave the nation a medical surge capacity of 512,000 PDH beds and 7,800 PDH operating rooms. Also created was a unit named the Hospital Reserve Disaster Inventory (HRDI). This unit consisted of pharmaceuticals, medical and surgical supplies, instruments, sterile gloves, x-ray contrast media, plaster bandages, and numerous other items. HRDIs were built in 100-bed increments and civilian hospitals could apply to receive an HRDI, at no cost, based on the number of beds they had. A hospital signed an agreement that it would integrate the HRDI items into its inventory, periodically using and replacing these supplies, thus keeping the materials from expiring. In addition, the FCDA distributed publications such as *Health Services and Special Weapons Defense*, to train healthcare personnel about nuclear, biological, and chemical weapons effects.

Fallout shelters were also created during this period to protect the occupants from radiation in the event of a nuclear attack. Fallout shelters were equipped with food, water, sanitation kits, medical kits, and radiation measurement kits to support the civilian population in these structures. The medical kits came in two sizes depending on the capacity of the shelter and contained antibiotics, sulfa drugs, and other pharmaceuticals as well as first aid supplies.

The Medical Education for National Defense (MEND) program was another notable Cold War initiative to train physicians in the U.S. in disaster medicine. MEND enlisted the support of all the nation's medical schools. Contracts to some universities were issued to create mass casualty curriculums. These, in turn, were distributed without charge to the medical schools to teach their students. The MEND Program operated from the mid-1950s until 1972 when it was cancelled.

All of the Cold War medical preparedness programs enjoyed the support of the various national and state medical and healthcare organizations. Notwithstanding this fact, funding for the PDH program and the medical warehouses ceased in 1972. These programs were cancelled despite many protests, and by the mid-1980s, most PDHs had been dismantled or given to the Agency for International Development. Parts of remaining PDHs were used to equip the first Disaster Medical Assistance Teams of the new National Disaster Medical System, which was created in 1984. The warehoused supplies were given to state surplus property programs and others were sold at auction.

The Modern Era

In the U.S., various healthcare organizations and professionals made efforts to continue some of the momentum in medical preparedness that the Cold War created; however, with the demise of the Soviet Union, less attention was paid to these matters. Nevertheless, disasters continued to occur and various scientific journals reported recurring problems with emergency management systems. The 1995 sarin nerve agent attack by cultists in Tokyo caused worldwide concern and increased emphasis on both war-related and industrial chemical training, equipment, and preparedness.

In 1999, the Congress ordered the U.S. PHS to assume control over the former Noble Army Community Hospital facility located at the recently closed Fort McClellan in Alabama and convert it into a mock hospital training facility. At this renamed Noble Training Center, civilian healthcare personnel, PHS officers, and other emergency responders took courses in disaster medicine, hospital preparedness, and the medical effects of weapons of mass destruction.

The U.S. Centers for Disease Control and Prevention (CDC) developed the National Pharmaceutical Stockpile, later renamed the Strategic National Stockpile. This stockpile consists of antibiotics, chemical agent antidotes, radiation treatment drugs, ventilators, vaccines, and other pharmaceuticals and supplies configured into Push Packages (see Chapter 16). Each package weighs 50 tons and is ready at all times for immediate air delivery to a stricken area. Conceptually, from the time the order is received to ship supplies, a Push Package can be delivered to the designated receiving point within 12 hours. Although New York City received a Push Package within hours following the terrorist attack of September 11, 2001, several days elapsed before these materials arrived in New Orleans after Hurricane Katrina. Pharmaceutical manufacturers also maintain additional vendor-managed inventory for the Strategic National Stockpile. Governments at the local, county, and state levels have undertaken planning to receive, store, secure, and distribute the Push Package contents. The early training courses for this program were taught at the Noble Training Center. The U.S. Department of Veterans Affairs (the largest integrated healthcare system in the nation) has also developed disaster augmentation supply units for each of its approximately 162 hospitals nationwide.

The terrorist attacks of September 11, 2001 in the U.S. heightened preparedness efforts worldwide. In this event, nearly 3,000 persons were killed and hundreds injured. Articles began appearing in the professional literature on mass casualty issues, universities held disaster medicine seminars, and the U.S. PHS commissioned numerous studies.

In the U.S., the American Hospital Association (AHA), American Medical Association, American Nurses Association and numerous healthcare professional organizations have become involved by promoting preparedness to their members, to healthcare facilities, and to communities at large as well as by supporting government preparedness programs. Examples are the support offered by the American Medical Association's Center for Public Health Preparedness and Disaster Response.[8] In a video, the organization describes the need for physician involvement and training in disaster medicine to include the knowledge needed for:

- How to develop rapid protocols for triaging patients
- How to access current antidotes and vaccines
- How to link with local community resources and local public health officials
- How to assess and implement the local disaster plan
- How to obtain reliable information about patients' medications without their medical records
- Ethics and rationing

Other examples of current preparedness efforts include numerous new publications. A few samples are listed.

- *Are You Prepared? Hospital Emergency Management Guidebook*, by the Joint Commission on Accreditation of Healthcare Organizations and Dr. Christopher Farmer. ISBN 0-86688-953-1, 2002.
- Emergency Preparedness, Response and Recovery Checklist: Beyond the Emergency Management Plan, by the American Health Lawyers Association. Washington, D.C., 2004.
- *Providing Mass Medical Care with Scare Resources: A Community Planning Guide,* Agency for Healthcare Research and Quality, AHRQ Publication NO. 07-0001 November 2006.

Likewise, the AHA and their affiliated organization, the American Society of Healthcare Engineers, continue to assist the preparedness effort with increased activities. Many healthcare professional societies promote preparedness to their memberships with publications and seminars. Healthcare professionals contribute literature to professional journals and are serving on preparedness committees in their communities. The U.S. Agency for Healthcare Research and Quality of the Department of Health and Human Services (HHS) continues to produce publications covering many aspects of healthcare preparedness. The Health Resources and Services Administration of HHS supervises a hospital preparedness program and awards grants for healthcare preparedness activities and equipment.

STATE OF THE ART

Healthcare Facility Preparedness

Increased interest in addressing the need for surge capacity both in the prehospital and hospital settings emerged in 1995 with Presidential Decision Directive 39: U.S. Policy on Terrorism.[9] This Directive resulted in local governments creating Metropolitan Medical Response Teams to increase their abilities to manage mass casualties. The effort was later expanded when HHS broadened the concept of the National Disaster Medical System. Originally designed to include general medical and veterinary teams, the program subsequently created burn, mental health, crush injury, international response, and other specialty teams.

The U.S. Congress passed and allocated funding for the *Defense Against Weapons of Mass Destruction Act*, promoting surge capacity building.[10] Other federal programs brought much needed weapons of mass destruction training to healthcare personnel. Researchers published numerous articles and manuals, and policy makers developed seminars devoted to medical surge capacity building. In January 2001, The Joint Commission made significant improvements to its emergency management accreditation standards that strengthened preparedness in hospitals. The Joint Commission also defined surge capacity to include potential patient beds, available space for triage, patient management, decontamination, vaccination, available personnel of all types, necessary pharmaceuticals, supplies and equipment, and legal capacity to deliver care under situations that exceeded licensed capacity.[11] The Joint Commission has continued to expand emergency preparedness standards requirements each year. A central principle to these standards is the requirement that accredited hospitals have an Emergency Management Committee (EMC).

The Emergency Management Committee

Each facility's EMC should be given the charge to:[12]

- Develop all-hazard emergency plans
- Perform a hazard vulnerability analysis (HVA)
- Coordinate with other community agencies such as fire, police, EMS, public health, public works, the emergency management agency, hazardous materials unit, and ambulance dispatch center to encourage interoperability
- Coordinate with the medical staff and each department of the facility
- Assist in training stakeholders in the plans it develops

The Committee needs broad participation and must be multidisciplinary. Participants should include representatives from hospital administration, the medical staff, nursing staff, emergency department, security department, environmental services, plant operations, materials management, pharmacy, laboratory, radiology, ancillary services, food service, volunteer services, and all other departments of the facility. Ideally, the leadership should appoint persons to the EMC with a known interest in disaster preparedness, or who are at least known for their enthusiastic approach to projects. The chairperson needs to be carefully selected and understand how to lead a meeting. A secretary/recorder should keep accurate minutes in a timely manner. A library of healthcare disaster materials needs to be established for all to use and each committee member should be notified as new publications become available. Members should be encouraged and funded to attend healthcare disaster seminars and to observe as many drills and exercises as possible. Plans developed should be concise, straightforward, and widely promulgated to all operating departments and nursing areas. The inclusion of disaster plan knowledge as a factor in annual employee evaluations is also an option. A good chairperson will continually challenge members to think of "what if" or "worst-case scenarios" and stress that plans must be flexible because unforeseen incidents may happen.

In today's world, EMCs need to consider the medical impact of biological, chemical, nuclear, and explosive weapons and adopt treatment protocols such as those found on the U.S. CDC website (www.bt.cdc.gov). The committee also needs to ensure that the hospital stockpiles sufficient personal protective equipment (PPE) for employees and medical staff members and trains these individuals in its proper use. Additional training should include methods of decontamination, protection of the physical plant and the airflow into the hospital, obtaining supplemental supplies, and ensuring the security of utilities and the physical plant. Communications, both internal and external, can prove vulnerable and systems frequently fail. Planning for alternate methods of communication including use of amateur radio operators and messenger services are indicated. The EMC has a large task and an even greater responsibility to the hospital and community it serves. Proper executive support and funding is essential.

Familiarization with Standards for Healthcare Emergency Management

It is essential that each member of the EMC is aware of standards and guidance that have been promulgated for healthcare emergency management. The Joint Commission standards are one example of benchmarks for accredited facilities in the U.S. or worldwide through the Joint Commission International program. The Joint Commission standards for hospital emergency management are contained in The Comprehensive Accreditation Manual for Hospitals. Comprehensive Accreditation Manuals have also been developed for

- Ambulatory care
- Behavioral healthcare
- Healthcare networks
- Critical access hospitals
- Long-term care facilities

For members of the hospital EMC, the accreditation standards are found in the Environment of Care (EC) Section. The standard EC.4.11 states: "An emergency in a health care hospital or in its community can suddenly and significantly affect demand for its services or its ability to provide those services." Therefore, a hospital must have a comprehensive plan that describes its approach to emergencies in the hospital or in its community. The Comprehensive Accreditation Manual for Hospitals includes the term disaster under its definition of an emergency. The definition is somewhat long but comprehensive. The manual defines an emergency as: "A natural or man-made event that significantly disrupts the environment of care (for example, damage to the organization's building(s) and grounds due to severe winds, storms, or earthquakes); that significantly disrupts care and treatment (for example, loss of utilities such as power, water, or telephones due to floods, civil disturbances, accidents, or emergencies in the organization or its community); or that results in sudden, significantly changed or increased demands for the organization's services (for example, bioterrorist attack, building collapse, or plane crash in the organization's community)."[12] In 2009, the Joint Commission in their prepublication version of the chapter on Hospital Emergency Management states in Standard EM.02.01.01 that the Emergency Operations Plan identify "alternative sites for care, treatment, and services that meet the needs of its patients during emergencies.[28] The numerous emergency management plan components, standards, and responsibilities of hospital leadership and medical staff are listed within EC.4.10 and EC.4.20.

In the U.S., staff members who are trained for decontamination that requires them to wear PPE must be familiar with and comply with the applicable standards of the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor. OSHA regulates the safety and health of workers by setting and enforcing standards, as well as providing training, outreach, and education. Of particular concern to the EMC are the following standards

- Title 29, Code of Federal Regulations (CFR) 1910.120 Hazardous Waste Operations and Emergency Response
- Title 29 CFR 1910.132 Personal Protective Equipment Standard
- Title 29, CFR 1910.134 Respiratory Protection

OSHA has also produced a detailed publication that recommends best practices.[14] This publication discusses PPE and training for hospitals first receivers. Additionally, it contains valuable references that can assist the EMC in achieving a better understanding of the issues surrounding personal protective equipment (PPE) and for building a reference library. Specific

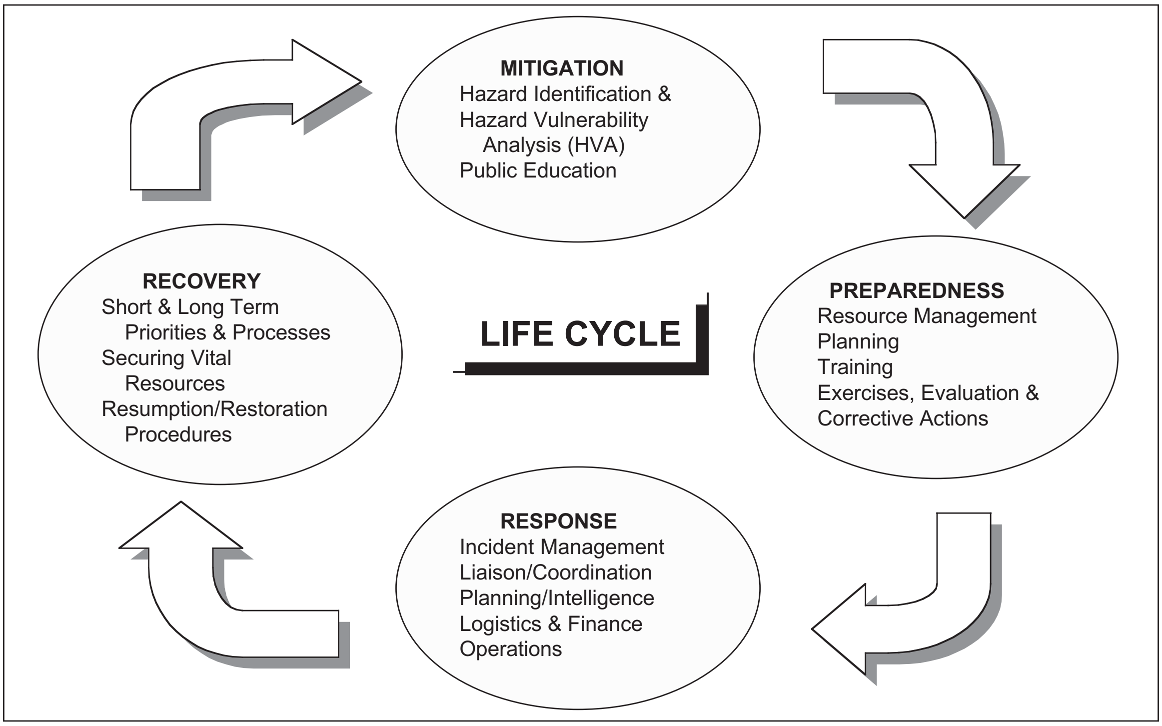


Figure 20.1. The four phases of Comprehensive Emergency Management.

recommendations regarding selection of PPE can be found in Chapter 13. There are other organizations and agencies with regulatory authority but the EMC should start with the Joint Commission and OSHA requirements.

Performing a Hazard Vulnerability Analysis

The Joint Commission requires accredited hospitals to have a formal document known as an HVA.[15] This process is used to identify those risks in the community that could cause an interruption or loss of a critical function or service, cause casualties, and possibly damage the hospital's physical plant. Subsequent analysis of risks identified in the HVA can then be addressed in the Emergency Management Plan.

Remembering the four phases of emergency management can aid in the preparation of an HVA.

- Mitigation – Those activities that can be taken, predisaster or emergency, to lessen the severity of an event. Also includes measures that will reduce the potential physical damage to the facility during an event
- Preparedness – Those activities, programs, and systems that are in place before the disaster or emergency and that are used to support the response to the event. Creating inherent capacity for response to an occurrence is included
- Response – Activities undertaken to address the immediate and short-term effects of a disaster or emergency. In the case of hospitals, it would involve casualty care
- Recovery – Activities and processes that must be undertaken to restore predisaster normality to the individual, facility, or community that had experienced a disaster or emergency

The U.S. Department of Veterans Affairs Emergency Management Strategic Healthcare Group has envisioned these four phases as depicted in Figure 20.1.[16]

The American Society of Healthcare Engineers of the AHA pioneered the development of hospital HVA in 2001. That same year, the Kaiser Permanente Foundation Health Plan issued their version of HVA. Both are now used extensively by U.S. hospitals. The Kaiser Permanente HVA worksheets are shown in Figures 20.2 and 20.3, and Tables 20.2–20.5.[15]

Once complete, the HVA requires a thorough review. After examination of the report, hospital emergency managers can determine the most likely threats to the community and hospital. Given this information, the institution can move to develop mitigation, preparedness, response, and recovery portions of the emergency management plan that address these hazards. The chair of the EMC must challenge members to think "what if" and "worst-case scenario," as well as to consider the impact of multiple events occurring simultaneously.

The hospital should work in collaboration with the community. The HVA should be compiled with the assistance of the local emergency management agency, fire department, EMS agency, police, hazardous materials unit, and with input from community organizations. These include the American Red Cross Disaster Services, Salvation Army Disaster Services, and Voluntary Organizations Active in Disaster, as well as neighboring hospitals and the area hospital council. Furthermore, if there is a major waterway or airport in the area, then HVA discussions should include airport authorities, Army Corps of Engineers, Coast Guard, and state waterway police.

After generating the HVA, the next step is to rate the probability of occurrence and level of preparedness for each event. The resulting information can then be used to prepare or strengthen the facility and the emergency management plan. Nevertheless, it is possible that the HVA will not identify all potential casualty-producing incidents. The potential risks from poorly controlled nuclear weapons and radioactive material are increasing. Although the danger of all out nuclear warfare is probably

KAISER PERMANENTE.

Medical Center Hazard and Vulnerability Analysis

Issues to consider for **preparedness** include, but are not limited to:

1 Status of current plans
2 Frequency of drills
3 Training status
4 Insurance
5 Availability of alternate sources for critical supplies/services

Issues to consider for **internal resources** include, but are not limited to:

1 Types of supplies on hand/will they meet need?
2 Volume of supplies on hand/will they meet need?
3 Staff availability
4 Coordination with MOB's
5 Availability of back-up systems
6 Internal resources ability to withstand disasters/survivability

Issues to consider for **external resources** include, but are not limited to:

1 Types of agreements with community agencies/drills?
2 Coordination with local and state agencies
3 Coordination with proximal health care facilities
4 Coordination with treatment specific facilities
5 Community resources

Complete all worksheets including Natural, Technological, Human and Hazmat.
The summary section will automatically provide your specific and overall relative threat.

Figure 20.2. Medical center HVA. Used with permission from Kaiser Foundation Health Plan.

minimal, the possibility that terrorists could use one or several nuclear devices against a modern city should be addressed.

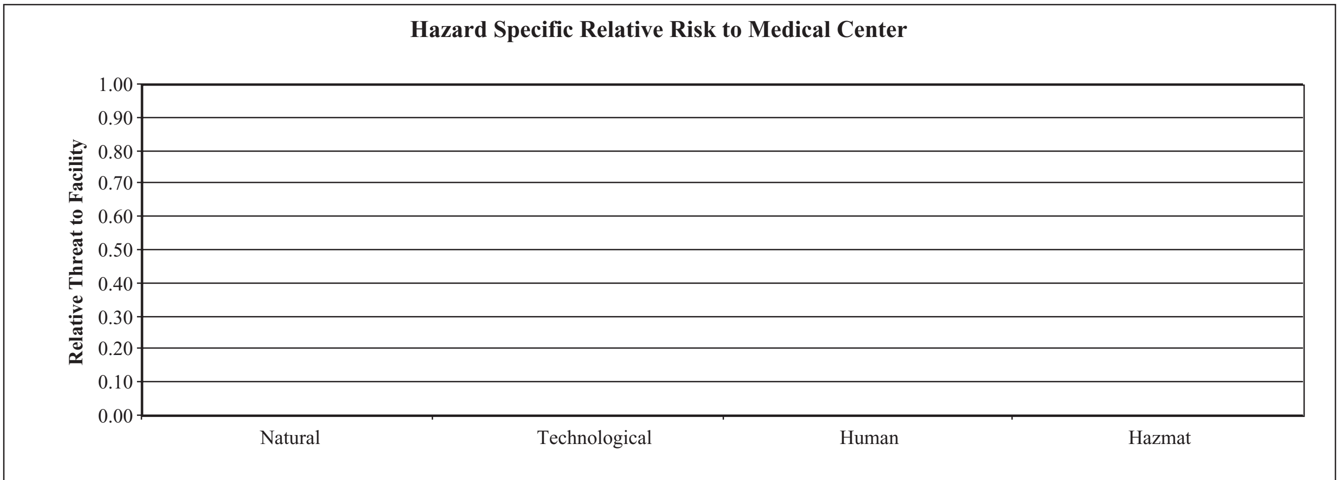
Common Factors in Disasters

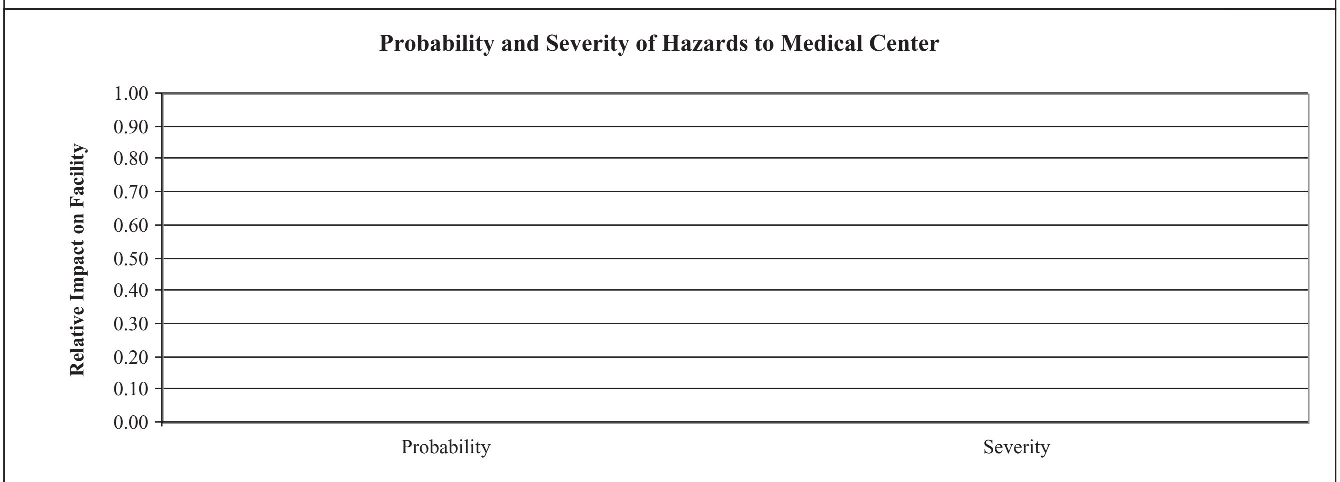
To facilitate their work, the EMC should consider several factors that are common to many disasters.

1) Uncertainty – In the early stages of a disaster, it is often unclear what is transpiring, to what extent additional resources are needed, how many casualties have resulted, and the extent of the medical requirements. In addition, the exact location and magnitude of the incident may be unknown.
2) Casualty Arrival – In mass casualty incidents, especially those occurring over a wide area, the standard operating procedure of ambulance crews triaging patients and removing them in an orderly manner may not occur. In such disasters, it is common for up to 80% of the casualties to self-refer and arrive at the hospital without the benefit of prehospital care and transportation. Casualties able to ambulate will often transport themselves to area hospitals rather than waiting for arrival of EMS professionals. Well-intentioned bystanders will often transport victims in their automobiles, including those with severe injuries. Patients contaminated with hazardous materials will arrive at the hospital without having first been decontaminated at the scene. This convergence phenomenon can inundate the hospital closest to the scene with casualties, whereas other nearby facilities may receive few to none of the victims. Last, less serious cases may arrive well ahead of the most seriously injured, many of whom may be trapped in rubble.
3) Communications – Communication systems connecting the hospital to the rest of the community are vulnerable. Telephone service may fail due to overloaded circuits or physical damage. Cellular telephone communication is unreliable as the available cells can quickly become saturated. This also occurs with satellite telephones, as reported during Hurricane Katrina in the U.S. Monitoring local fire, EMS, and police frequencies and having direct radio communication with first responders can greatly aid the hospital incident commander in decision making. The hospital emergency management plan should also include a provision for the use of messengers to carry information throughout the hospital in the event of telephone and computer failures. As hospital pay phones frequently function when the regular hospital exchange has failed, a supply of coins should be kept available along with signs that indicate these phones have been commandeered for hospital use only.
4) Patient Care Capacity – Maintaining patient care capacity including beds for those requiring hospital admission may be problematic due to a high in-patient census or the influx of numerous casualties. The early discharge of stable patients can help the situation but the process of doing so is time-consuming, especially when family members are unable to assist. Another option includes the use of other areas in the hospital such as meeting rooms, physical therapy suites, or auditoriums for patient care to temporarily increase surge space. Hospitals must plan for supplies and staffing of these areas during the preparedness phase.
5) Staffing – Ensuring the presence of sufficient numbers of physicians, nurses, and other support personnel to staff existing patient care areas and temporarily expanded space used for surge can be problematic, depending on the type and location of the disaster. In a severe blizzard, many individuals may have difficulty reaching the hospital. In anticipation of such circumstances, the emergency management plan should contain a list of volunteers who have four-wheel drive vehicles and are willing to transport employees and medical staff members to the hospital. In a hurricane, employees and physicians may be victims themselves, dealing with destroyed homes and offices and injured family members. In such

SUMMARY OF MEDICAL CENTER HAZARDS ANALYSIS

	Natural	Technological	Human	Hazmat	Total for Facility
Probability	0.00	0.00	0.00	0.00	0.00
Severity	0.00	0.00	0.00	0.00	0.00
Hazard Specific Relative Risk:	0.00	0.00	0.00	0.00	0.00





This document is a sample Hazard Vulnerability Analysis tool. It is not a substitute for a comprehensive emergency preparedness program.
Individuals or organizations using this tool are solely responsible for any hazard assessment and compliance with applicable laws and regulations.

Figure 20.3. Summary of center hazards analysis. Used with permission from Kaiser Foundation Health Plan.

instances, the hospital must support the staff and their family members with sleeping accommodations, shower facilities, and food service. In an infectious disease outbreak, some staff may be unwilling to report to work. Thus, the plan must account for the fact that not all staff will be willing or able to come to the hospital. The emergency management plan must provide a method for temporarily credentialing medical volunteers and a strategy for utilizing medical personnel from country-specific systems such as the Medical Reserve Corps or the National Disaster Medical System in the U.S.

6) Decontamination – Hospital personnel must be prepared to decontaminate victims needing such treatment prior to allowing them entrance to the facility. Decontamination is essential not only to support patient care but also to prevent cross contamination of the hospital itself. The healthcare institution must maintain sufficient quantities of PPE to permit rotation of decontamination staff, taking into

Table 20.2: Hazard and Vulnerability Assessment Tool for Environmental Events

EVENT	PROBABILITY	SEVERITY = (MAGNITUDE - MITIGATION)						RISK
		HUMAN IMPACT	PROPERTY IMPACT	BUSINESS IMPACT	PREPARED-NESS	INTERNAL RESPONSE	EXTERNAL RESPONSE	
	Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interruption of services*	*Preplanning*	*Time, effectivness, resources*	*Community/ Mutual Aid staff and supplies*	*Relative threat**
SCORE	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = High* *2 = Moderate* *3 = Low or none*	*0 = N/A* *1 = High* *2 = Moderate* *3 = Low or none*	*0 = N/A* *1 = High* *2 = Moderate* *3 = Low or none*	0 - 100%
Hurricane								0%
Tornado								0%
Severe Thunderstorm								0%
Snowfall								0%
Blizzard								0%
Ice Storm								0%
Earthquake								0%
Tidal Wave								0%
Temperature Extremes								0%
Drought								0%
Flood, External								0%
Wild Fire								0%
Landslide								0%
Dam Inundation								0%
Volcano								0%
Epidemic								0%
AVERAGE SCORE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%

**Threat increases with percentage.*

RISK =	PROBABILITY *	SEVERITY
0.00	0.00	0.00

Used with permission from Kaiser Foundation Health Plan.

consideration the fatigue factor and heat load stress when wearing PPE. The selection of PPE is a complex task but ideally should be approved for safe use with as many hazardous materials as possible (see Chapter 13). This is essential for worker safety.

7) Prophylaxis – It may be necessary to offer hospital employees and the medical staff antibiotics and vaccinations as prophylaxis during an epidemic or after the terrorist release of a biological agent. A protocol is needed to ensure adequate supplies and efficient distribution methods.
8) Laboratory Support – Most hospital laboratories lack the capability to definitely identify many biological weapons agents, emerging infectious diseases, or hazardous materials. The EMC must know the capabilities of the in-house laboratory in these regards and ensure that arrangements have been made with state, national or international reference laboratories to supplement diagnostic resources within the facility in the event of an outbreak or exposure.
9) Media Relations – Members of the media will telephone or quickly arrive at the hospital when disaster strikes. A plan must be in place to accommodate the media and also to manage them, restricting their access to patient care areas and preventing them from disrupting the hospital's response. Often, accurate information may not be immediately available to the healthcare facility's designated public information officer. Other information may be known but disclosure may not be possible as it would violate federal privacy laws. The U.S. Federal Emergency Management Agency's (FEMA) Emergency Management Institute offers disaster public information training for health department and hospital personnel.
10) Morgue – Hospitals generally have limited refrigerated space for the temporary storage of the deceased. Consideration must be given to a potentially large death toll and the subsequent need for increased storage space for remains (see Chapter 21).
11) Utilities – A disaster event could curtail some or all of the hospitals utilities. Water is especially critical for hospital operations and back-up supplies must be organized in advance. Storage of water on the grounds of the facility is one option. Generators supplying emergency power may prove unreliable for extended operations. Plans should exist for renting generators and wiring them to the hospital's electrical grid. If the hospital uses fuel oil to power the generators or boilers, the EMC should calculate the number of hours or days of supply the institution has on hand under both temperate and winter conditions.
12) Supplies – With the healthcare industry relying on just-in-time inventories, supply shortages may quickly manifest. Plans are needed for emergency resupply if contracted vendors cannot respond or normal supply channels are disrupted. Additionally, hospitals must include items appropriate for pediatric care in their supply inventories as they must prepare for the arrival of pediatric patients.

Table 20.3: Hazard and Vulnerability Assessment Tool for Technological Events

EVENT	PROBABILITY	SEVERITY = (MAGNITUDE - MITIGATION)						RISK
		HUMAN IMPACT	PROPERTY IMPACT	BUSINESS IMPACT	PREPARED-NESS	INTERNAL RESPONSE	EXTERNAL RESPONSE	
	Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interruption of services*	*Preplanning*	*Time, effectivness, resources*	*Community/ Mutual Aid staff and supplies*	*Relative threat**
SCORE	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	0 - 100%
Electrical Failure								0%
Generator Failure								0%
Transportation Failure								0%
Fuel Shortage								0%
Natural Gas Failure								0%
Water Failure								0%
Sewer Failure								0%
Steam Failure								0%
Fire Alarm Failure								0%
Communications Failure								0%
Medical Gas Failure								0%
Medical Vacuum Failure								0%
HVAC Failure								0%
Information Systems Failure								0%
Fire, Internal								0%
Flood, Internal								0%
Hazmat Exposure, Internal								0%
Supply Shortage								0%
Structural Damage								0%
AVERAGE SCORE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%

**Threat increases with percentage.*

RISK =	PROBABILITY *	SEVERITY
0.00	0.00	0.00

Used with permission from Kaiser Foundation Health Plan.

13) Blood Products – During a disaster, blood and blood product usage may rise above normal levels. Hospitals must anticipate this contingency and plan to address any shortfalls. Conversely, in some types of disasters, additional blood is not needed. However, well-meaning volunteers may present in large numbers wanting to donate. A system for volunteer management is important to avoid redirecting resources needed for control of the incident to handle this influx.
14) Medical Equipment – In a disaster situation, a hospital may face a shortage of beds, ventilators, respiratory therapy equipment and supplies, oxygen cylinders, intravenous infusion pumps, wheelchairs, and gurneys. Institutions must plan for supplemental delivery of these items.
15) Service Deliveries – Ensuring continuity of critical service deliveries such as medical gases, generator fuel, linens, medical and surgical supplies, foodstuffs, and waste removal is essential to continued operations. Plans must exist that maintain the flow of these critically needed items.
16) Security – Plans are required for securing the facility and grounds, directing traffic, protecting human remains, and managing personal effects. During a disaster, requirements may exceed the capacity of the security department. In support of increased security demands, the emergency management plan should assign nonsecurity personnel to provide some security duties, such as traffic direction or supervision of facility entrances. In addition, hospital security plans must permit rapid implementation of a total facility lock-down, allowing only certain supervised entrances to remain open. This is especially important when faced with contaminated casualties. Reliance on local law enforcement personnel to respond and assist is usually not an option as they will be occupied managing the disaster within the community.
17) Care of Relatives – During a disaster, family members may rush to a hospital, even with just the suspicion that a family member was taken there. Plans must exist for receiving and assisting family members of victims.
18) Damaged Hospitals – Hospitals are susceptible to physical damage. Tornados, hurricanes, and earthquakes have repeatedly compromised hospital function. Healthcare institutions must plan for emergent damage inspection and repair resulting from these hazards. In severe situations, hospitals must also have a strategy to evaluate hospital structural integrity and evacuate the facility if necessary.

Health Facility Management of Disaster

When a disaster occurs and the emergency management plan is activated, the healthcare facility must quickly mobilize its resources and key personnel, ideally before the first casualty arrives. The hospital may organize its response in a variety of ways, as long as the Joint Commission or similar requirements for coordination with community plans are met.

Table 20.4: Hazard and Vulnerability Assessment Tool Related to Human Activity

EVENT	PROBABILITY	SEVERITY = (MAGNITUDE - MITIGATION)						RISK
		HUMAN IMPACT	PROPERTY IMPACT	BUSINESS IMPACT	PREPARED-NESS	INTERNAL RESPONSE	EXTERNAL RESPONSE	
	Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interruption of services*	*Preplanning*	*Time, effectivness, resources*	*Community/ Mutual Aid staff and supplies*	*Relative threat**
SCORE	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	0 - 100%
Mass Casualty Incident (trauma)								**0%**
Mass Casualty Incident (medical/infectious)								**0%**
Terrorism, Biological								**0%**
VIP Situation								**0%**
Infant Abduction								**0%**
Hostage Situation								**0%**
Civil Disturbance								**0%**
Labor Action								**0%**
Forensic Admission								**0%**
Bomb Threat								**0%**
AVERAGE	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0%**

**Threat increases with percentage.*

RISK =	PROBABILITY *	SEVERITY
0.00	**0.00**	**0.00**

Used with permission from Kaiser Foundation Health Plan.

Table 20.5: Hazard and Vulnerability Assessment Tool Events Involving Hazardous Materials

EVENT	PROBABILITY	SEVERITY = (MAGNITUDE - MITIGATION)						RISK
		HUMAN IMPACT	PROPERTY IMPACT	BUSINESS IMPACT	PREPARED-NESS	INTERNAL RESPONSE	EXTERNAL RESPONSE	
	Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interruption of services*	*Preplanning*	*Time, effectivness, resources*	*Community/ Mutual Aid staff and supplies*	*Relative threat**
SCORE	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = Low 2 = Moderate 3 = High*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	*0 = N/A 1 = High 2 = Moderate 3 = Low or none*	0 - 100%
Mass Casualty Hazmat Incident *(From historic events at your MC with >= 5 victims)*								**0%**
Small Casualty Hazmat Incident *(From historic events at your MC with < 5 victims)*								**0%**
Chemical Exposure, External								**0%**
Small-Medium Sized Internal Spill								**0%**
Large Internal Spill								**0%**
Terrorism, Chemical								**0%**
Radiologic Exposure, Internal								**0%**
Radiologic Exposure, External								**0%**
Terrorism, Radiologic								**0%**
AVERAGE	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0%**

**Threat increases with percentage.*

RISK =	PROBABILITY *	SEVERITY
0.00	**0.00**	**0.00**

Used with permission from Kaiser Foundation Health Plan.

THE INCIDENT COMMAND SYSTEM

The Incident Command System (ICS) is a disaster management strategy that is growing in popularity among hospitals. The ICS was first developed by California firefighters for better management of wide-scale forest and wildfires. The group who developed the ICS was known as FIRESCOPE. ICS offers hospitals many advantages in managing their disaster responses[17]

- Standard organization and procedures
- Modular and scalable system for any sized disaster
- Interactive management components
- Management by objectives
- Manageable span of control
- Designated incident facilities
- Comprehensive resource management
- Integrated communications
- Procedures for establishing and transferring command
- Accountability
- Easy integration with the community response
- Avoiding duplication of effort

ICS is essentially a toolbox that provides utilities for the command, control, and coordination of resources during a disaster. ICS clarifies roles and responsibilities between all persons in the system, while also organizing resources, personnel, facilities, equipment, and communications through common procedures.

The basic ICS is composed of an Incident Commander assisted by an Operations Section, Planning Section, Logistics Section, and Finance/Administration Section (see Chapter 9).

Operations Section

- Directly manages all incident activities and implements the Incident Action Plan
- Works closely with other members of the command and general staff to coordinate response tactics

Planning Section

- Gathers, analyzes, and disseminates intelligence and information gleaned from available sources
- Manages the planning process and maintains incident documentation
- Compiles and develops the Incident Action Plan
- Tracks all incident resources
- Manages the activities of assigned technical specialists
- Develops the demobilization plan

Logistics Section

- Meets the support needs for the incident, including ordering resources through appropriate procurement authorities from nonincident locations
- Provides facilities, transportation, supplies, equipment, maintenance support, fueling, food service, and communications

Finance/Administration Section

- Establishes whether there is a specific need for financial, reimbursement, and/or administrative services to support incident activities. Takes responsibility for time-keeping records and compilations of hospital costs incurred during the disaster response

MULTIAGENCY COORDINATION SYSTEMS

In large incidents, a Multiagency Coordination System (MACS) may be established. A MACS is a combination of facilities, equipment, personnel, procedures, and communications integrated into one common system and principally relying on an Emergency Operations Center (EOC). Within the EOC, a Medical Operations Center or joint public health command center is usually established. The hospital disaster command structure will usually report to this entity. A MACS is especially helpful in areas of high population density or where the disaster is geographically widespread. Figure 20.4 illustrates the basic incident command structure.

THE HOSPITAL INCIDENT COMMAND SYSTEM

Initially developed as the Hospital Emergency Incident Command System, in its fourth revision, the name was changed to the Hospital Incident Command System (HICS). The historical development of HICS is as follows.[18]

1987 – Hospital Council of Northern California adapts FIRESCOPE ICS to hospitals.
1991 – Hospital Emergency Incident Command System, version 1 (HEICS I) first released.
1993 – HEICS II released.
1998 – HEICS III released.
2006 – U. S. government funded project to revise HEICS. The development of version IV creates the HICS in compliance with the National Incident Management System (NIMS).

The revision project involved an initial analysis by numerous organizations representing multiple disciplines, followed by a second multidisciplinary review group that performed review and comment by using a formal evaluation tool. Further assistance was rendered by the AHA, Joint Commission, American Society for Healthcare Engineering, NIMS Integration Center, FEMA Emergency Management Institute, and the Health Resources and Services Administration.

The resulting HICS resources include[19]

- Exercise scenarios
- Planning guides
- Job action sheets
- HICS forms
- Training materials

HICS adds healthcare-specific titles to the ICS. For example, on the organizational chart for the command and general staff, the Incident Commander (IC) has the prerogative to add components to the chart, identifying individuals who report to the IC. An example is a medical/technical healthcare specialist needed for a response to a particular disaster. Such individuals would include

- Infectious disease consultants
- Chemical and radiological consultants
- Hospital administration representatives

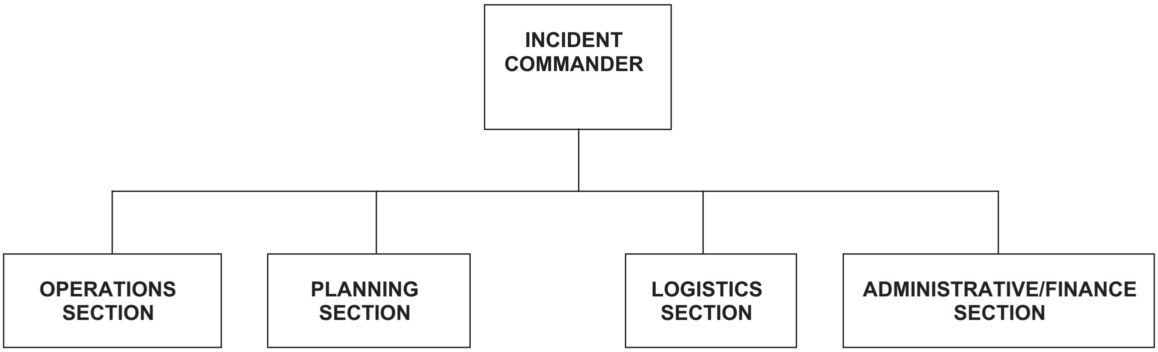


Figure 20.4. Basic incident command diagram.

- Hospital legal officers
- Hospital risk managers
- Medical staff officers

As previously mentioned, all ICS systems including HICS are modular and scalable according to the requirements to manage the disaster, the hospital size, and the availability of personnel and medical staff. The EMC should decide in advance what roles will be needed and initially staff these positions with on-duty personnel. Following activation of HICS, additional personnel determined by the hospital's response needs would then be recruited to back-fill these positions.

The command and general staff sections of Operations, Planning, Logistics, and Finance/Administration also follow a span of control. Each section can be further divided into branches, with various defined groups, led by a supervisor, under the branch and reporting to the Branch Director. Graphically, the Operations section could appear as shown in Figure 20.5.[17] An example of a Planning section chart appears in Figure 20.6.[17] The Logistics section is graphically depicted in Figure 20.7.[17]

The Finance and Administration section of HICS includes important units for documenting costs and hospital and employee compensation during the hospital response and recovery phases. Because many hospitals have cash flow problems, this is a very significant postdisaster function. In the U.S., the hospital may be eligible for reimbursement from the federal government if the President declares the event a disaster. Also, the Procurement unit within this section must keep the hospital supplied with

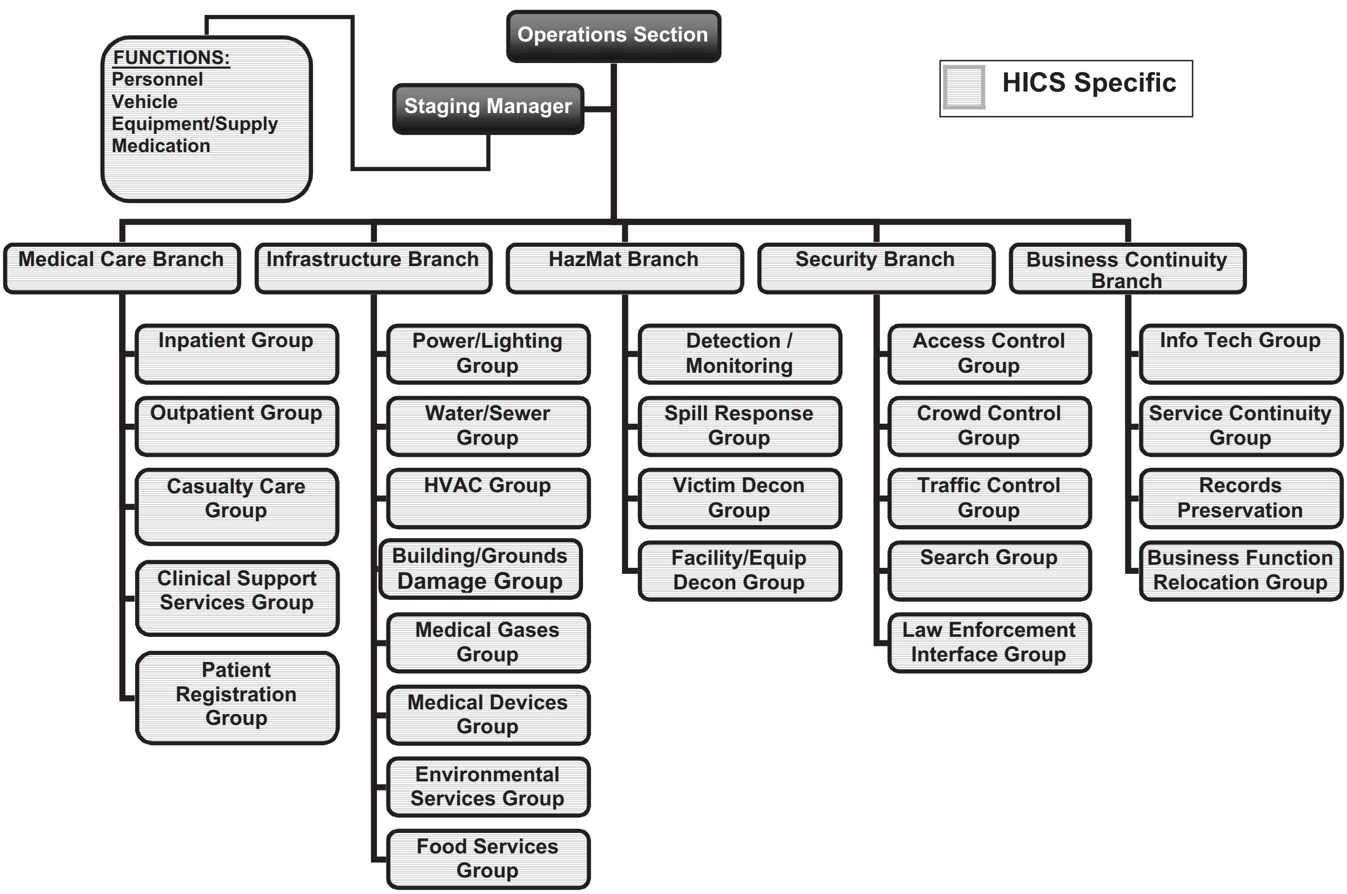


Figure 20.5. Operations section.

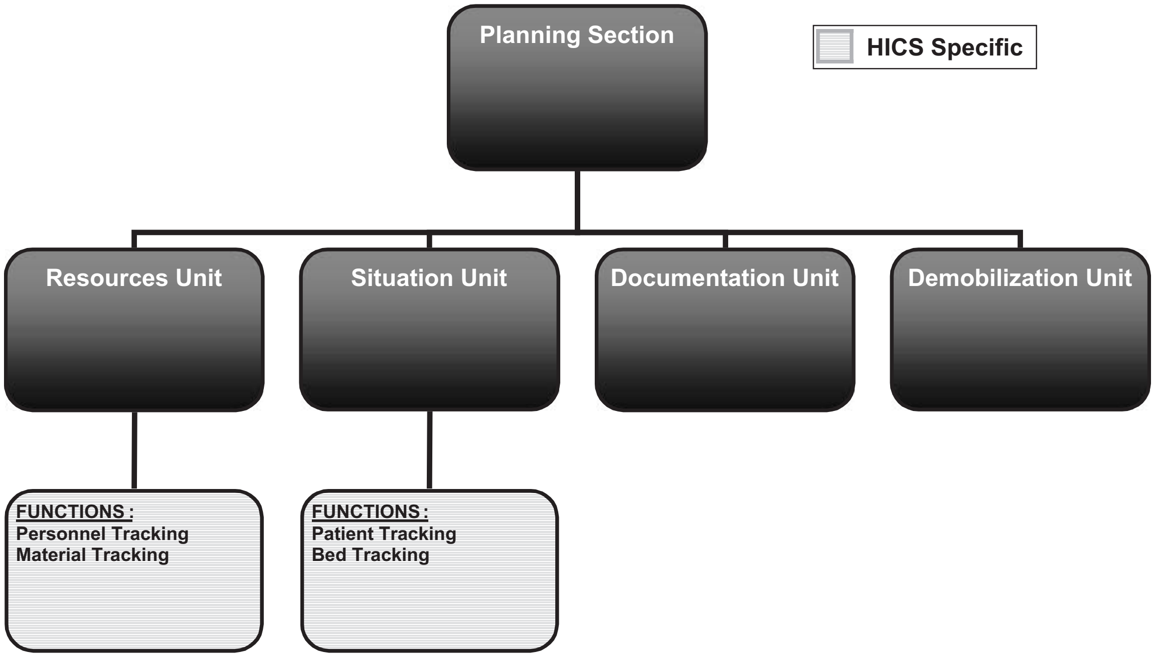


Figure 20.6. Planning section.

consumable items and must arrange contracts for emergency supplies. A typical Finance/Administration section chart would be similar to that shown in Figure 20.8.[17]

Every hospital has a defined table of organization for normal operations. HICS tables of organization provide a logical framework with which to coordinate the hospital's response. Additionally, these tables allow individuals with particular strengths, not listed on the table of organization for normal operations, to be used in the most effective manner. For example, the chief of surgery may request the assistance of another surgeon, perhaps with military combat medical experience, to head the Medical Care branch that will deal with mass casualties.

In smaller incidents, it may not be necessary to activate and staff the five basic HICS positions. The Incident Commander may perform all the functions alone in some cases. What is essential is that the Incident Commander has a clear picture of the incident, the estimated casualty load, and the response needed, and staffs the HICS system accordingly. HICS training is available without cost online (courses IS-100HC and IS-200HC are found at: http://www.training.fema.gov/EMIWeb/IS/is200HC.asp).

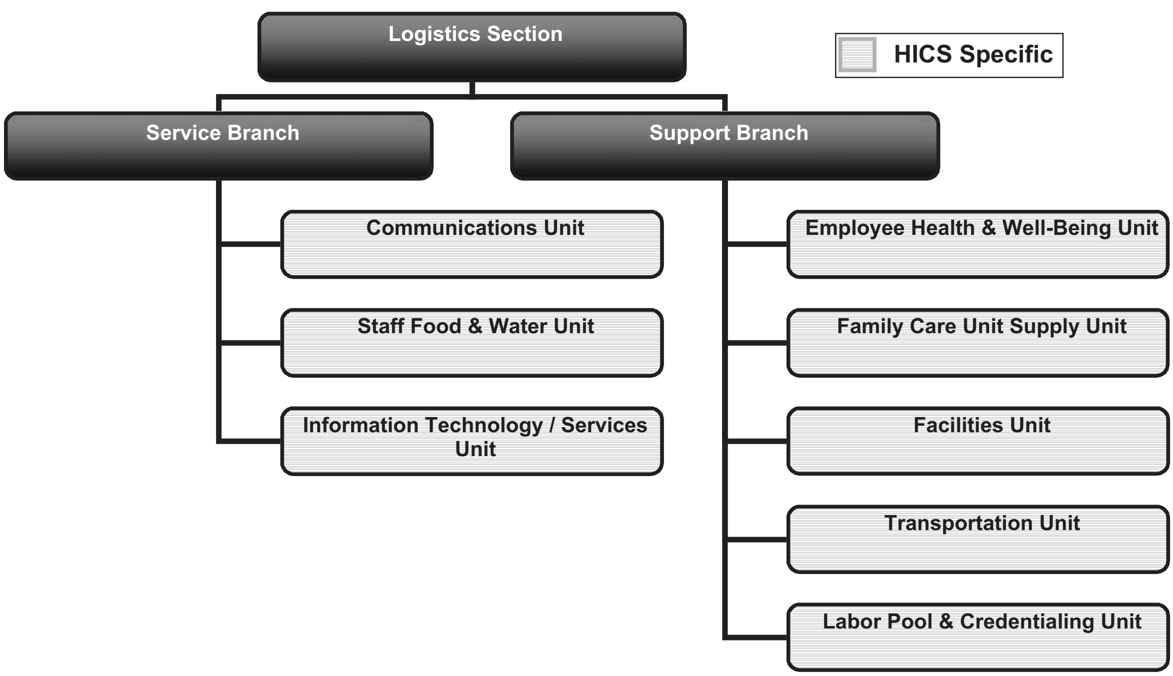


Figure 20.7. Logistics section.

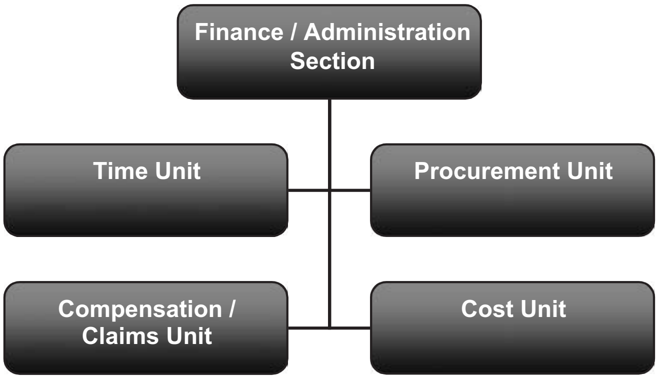


Figure 20.8. Finance and Administration section.

The National Incident Management System

The ICS is an integral part of a post-September 11, 2001 U.S. initiative in managing all-hazard incidents. In 2003, the President of the United States issued Homeland Security Presidential Directive 5 (HSPD-5), directing the Secretary of Homeland Security to develop and administer the NIMS. This system provides a consistent nationwide framework that enables federal, state, local, and tribal organizations to work together effectively to prepare for, respond to, and recover from all-hazard incidents regardless of cause, size, or complexity, including terrorist attacks. NIMS is built on existing concepts of incident management that have stood the test of time. NIMS represents a core set of doctrines, concepts, principles, and terminology that permit effective collaboration in incident management at all levels of governments and private organizations. HSPD-5 requires all federal departments and agencies to make adoption of NIMS by state and local organizations a condition for funding from federal preparedness grants. The components of NIMS include[19]

- Command and Management
  - Incident Management System
  - Multiagency Coordination Systems
  - Public Information Systems
- Preparedness
  - Planning
  - Training
  - Exercises
  - Personnel Qualifications and Certification
  - Equipment Acquisition and Certification
  - Mutual Aid
  - Publications Management
- Resource Management
- Communications and Information Management
- Supporting Technology
- Ongoing Management and Maintenance

NIMS was launched by then Secretary of Homeland Security, Tom Ridge, on March 1, 2004. In September 2006, FEMA announced the publication: *NIMS Implementation Activities for Hospitals and Healthcare Systems.*[19] The publication outlines the 17 elements healthcare facilities must accomplish to become NIMS compliant and eligible for federal preparedness grants.

Element 1 – Adopt NIMS at the organizational level.

Element 2 – Manage all emergency incidents, exercises and "preplanned" events utilizing the HICS.

Element 3 – MACS: Develop connectivity capability with the area hospital command center, as used in catastrophic, wide geographical areas, or in smaller incidents to the local EOC, local 911 centers, local public health, EMS, local emergency operating center, and others as appropriate.

Element 4 – Public Information System – The healthcare facility manages information with the various healthcare partners and response agencies through a Joint Information System and Joint Information Center.

Element 5 – The hospital/healthcare facility/healthcare system will track NIMS activities annually as part of the organized emergency management plan.

Element 6 – Development and coordination of a system to track local, state, and federal preparedness grants. Document that preparedness grants received meet any funding commitments.

Element 7 – Revise and update plans and procedures to incorporate NIMS components in all emergency phases and activities.

Element 8 – Participate in and promote interagency mutual aid agreements with public and private sectors.

Element 9 – Train those personnel who have emergency preparedness and response duties in NIMS by completing the free online course IS-700 NIMS: An Introduction. This online course can be found at http://www.training.fema.gov/EMIWeb/IS/is700.asp.

Element 10 – Train those personnel who have emergency preparedness and response duties in the National Response Plan by completing the free online course IS-800 NRP: An Introduction. This course can be found at: http://www.training.fema.gov/EMIWeb/IS/is800HC.asp.

Note: for both courses, it has been recommended that a phased approach would allow employees and physicians to complete the training without a time constraint burden on the hospital. Successful completion of both courses could be an element in the employee periodic performance evaluation.

Element 11 – The organizations primary emergency preparedness and response personnel complete free online courses: IS-100HC: Introduction to the Incident Command System for Healthcare/Hospitals, and ICS 200HC: Applying ICS to Healthcare Organizations. These free online courses can be found at http://www.training.fema.gov/EMIWeb/IS/is100HC.asp and http://www.training.fema.gov/EMIWeb/IS/is200HC.asp.

Element 12 – Preparedness Exercises. The organization's emergency management program training and exercise documentation reflects the use of NIMS/ICS.

Element 13 – Participate in an all-hazard exercise program based on NIMS that involves responders from multiple disciplines, agencies, and organizations.

Element 14 – Hospitals and healthcare systems will incorporate corrective actions into preparedness and response plans/procedures.

Element 15 – Maintain a current resource inventory of medical-surgical supplies, pharmaceuticals, PPE, staffing, etc.

Element 16 – To the extent possible and permitted by law, the organization should work to establish common equipment and communications data interoperability with other local hospitals, EMS, public health, and emergency management agencies.

Element 17 – Apply standardized and consistent terminology, including the establishment of plain English communication standards across the public safety sector.

The Hospital Physical Plant and its Preparedness

The EMC is most focused in the facility's emergency response to direct patient care and often forgets that a fully functioning physical plant is essential for optimal patient outcomes. Rarely do hospital personnel, even executives, think about the physical plant becoming nonoperational. Hospitals and other healthcare facilities have suffered significant damage resulting from hurricanes, tornadoes, fires, and earthquakes. Therefore, the EMC must become familiar with the physical plant and its systems, and work with the plant operations leader toward preparedness. Ideally, the head of plant operations should be a member of the EMC. The critical hospital systems that must remain functional include

- Electrical
- Heating, ventilating, and air conditioning (HVAC)
- Water and sewer
- Medical equipment including vacuum and medical gases
- Various life support and critical care systems
- Communications systems: pagers, public address, computers, and radios

ELECTRICAL

In the U.S. model, there has historically been a disparity between what building codes require that emergency generators support and the hospital's electrical power requirements for patient care. The codes are designed to address life safety issues and protect the occupants in the event of a power failure, fire, or other emergency. The level of electrical generator support is limited to that required to permit the occupants to exit the building safely. The code does not recognize the need to provide power for operating autoclaves, laboratory and radiology equipment, and other devices necessary for hospital function during a disaster. The members of the EMC should know what equipment and what locations receive power from emergency generators in the event of a power failure, how long the fuel supply will last when the generators are running, and how long they will run if the fuel must be shared with the boilers. Further action may be necessary to ensure these additional essential components receive emergency power. Another approach to minimize the threat of power disruption is to provide normal electrical service to the facility from two different utility substations.

Time of year can also increase the fuel consumption needs of boilers as well as pose other challenges. During a blackout in a New England winter, a small community hospital initially received emergency power from its generators. The hospital had an above-ground fuel storage tank and had forgotten to connect the immersion heater to the generator circuitry. After several hours the fuel cooled, became more viscous, and resulted in a generator shutdown.

In August 2003, a considerable portion of the northeast United States experienced a blackout, at first thought to be caused by a terrorist attack but later found to be caused by faulty equipment in Ohio. Hospitals throughout the region were forced to use emergency power–supplied by generators. As had been reported in previous disasters, several institutions experienced failure of this critical equipment and lost power. This illustrates the importance of the EMC needing to identify and maintain equipment and locations that receive emergency power from the generators.

An additional concern created by use of emergency generator power is the extent to which the laboratory and radiology can operate their equipment relying on this source. It is more than a question of furnishing generator power to these departments. Some devices have unique requirements relating to electrical current flow and personnel must know whether the cyclical fluctuation of the generator will cause delicate equipment to malfunction or fail completely. Such conditions must be anticipated pre-event and addressed through discussions between the EMC and plant operations representatives.

Because generators and transfer switches can malfunction even after proper maintenance, the hospital should have an ample supply of flashlights, battery-powered lights, headlamps, and batteries as a safeguard against generator failure. Illumination sources using light-emitting diodes conserve battery power and should be considered.

Natural gas is a common fuel and may power the hospital's air conditioning system, boilers, hot water, cooking ranges, ovens, and generators. Although natural gas is more reliable during storms than overhead electrical lines, it is extremely vulnerable to earthquakes and mudslides.

HEATING, VENTILATING, AND AIR CONDITIONING

In compliance with ventilation codes, a hospital can draw in more pounds of air per day than pounds of water. The typical hospital will have multiple handling units that pass the incoming air through mechanical or electronic filters, heat or cool the air, humidify or dehumidify the air, and send it to the various areas of the hospital. This air does not linger in the building and is removed by exhaust fans. Hospitals have high energy costs due to compliance with these building codes. Little recirculation is permitted as an infection control measure, and a large number of air exchanges per hour are required. If the hospital does not have adequate emergency generator capacity, there will be a shutdown of this system and also air conditioning. If the air conditioning chillers are fueled by natural gas, the loss of this supply will also shut down the units. During and after Hurricane Katrina in the U.S., many hospitals in the affected area experienced temperatures of over 37°C, creating a significant hardship for patients and staff. Certain types of equipment cannot function in that temperature range. Because the applicable codes do not require emergency generator power to HVAC equipment, the prudent facility spends the extra money and purchases larger-capacity generators after a thorough analysis of emergency electrical needs. This pre-event purchase analysis can pinpoint the multiple needs not addressed by regulatory codes that are required to operate the hospital and provide patient care. Whatever the type of disaster, planners must keep foremost in their minds that loss of power or other utilities can also overload the facility with casualties.

The hospital's HVAC system can become a safety hazard in the event of a chemical spill. Transportation and industrial accidents can release chemicals that are carried through the air. If a hospital is downwind of a chemical plume, it will quickly draw the chemical into the building by the air-handling units, and this may in turn sicken or even kill staff and patients. The EMC, as an all-hazard planning committee, must be cognizant of this possibility and plan accordingly.

The first consideration is the location of the air intakes for the hospital. Because many chemicals are heavier than air, ground level air intakes are particularly susceptible to drawing in contamination. Some hospitals have intakes mounted on the side of the building, which is better, especially if they are 4.6 m or more above the ground. The best location is on the roof; however, even roof top units do not guarantee that the hospital cannot become contaminated. Due to the risk of terrorism, the hospital must be mindful of the need for security of these air-handling intakes. The reader can learn more about protecting the building and its occupants by reviewing *Guidance for Protecting Building Environments from Airborne Chemical, Biological or Radiological Attacks.*[20]

To protect the facility from such an event, the EMC must develop a plan to lock all external entrances to the hospital and to guard them. The engineering department must rehearse the shutdown of all air-handling units to prevent the chemical or smoke from entering into the building. Also, security officers should be taught this procedure to assist the engineer on duty or in case the engineer becomes incapacitated. If evacuation of the facility is not appropriate, using this shelter-in-place strategy to protect patients is best.

WATER

Water is an absolute necessity to keep the hospital functioning. The EMC should determine whether the utility company feeds water to the hospital from two directions. This is a safeguard in the event of a main break. Another option is to have a continuous loop that surrounds the hospital property. Some hospitals have storage tanks that are constantly refreshed by a main water line filling them. An additional tank for fire protection is also a prudent investment. Alternative strategies for water supply include bottled water, arrangements with water-hauling companies, and pre-event discussions with the community emergency management agency for assistance. In the case of slow-onset events such as hurricanes, the hospital can fill water bladders if they have them. These can be purchased in a variety of sizes. Bladders are also useful for onsite storage of delivered water if a means of extracting the water is available.

The EMC must also develop a water-rationing plan including alternate means of disposing of human wastes. To avoid further loss of limited supplies, patient and employee commodes can be lined with plastic bags. Following use, several ounces of chlorine bleach can be added and then the contents can be double bagged. Determine as part of the plan how the facility will dispose of human waste. A standby contract for portable toilets can be helpful, especially for hospital personnel and visitors.

Some hospitals have wells on their campuses and the EMC must ensure the pumps are connected to the emergency generator. Wells, however, can be damaged or destroyed by earthquakes and some other types of disasters.

DAMAGE CONTROL

Healthcare facilities can be damaged in a disaster; however, they are expected to remain functional and continue providing patient care. For the protection of patients and personnel, the facility should have a damage control plan. The damage control plan should be developed jointly by the plant operations personnel and the EMC. The plan outlines a methodology whereby reports are received from the various departments regarding damage their area has experienced at a central point such as the hospital EOC. At the same time, management staff should dispatch employees to conduct a rapid needs assessment of every floor and department. These employees then report their findings to the EOC. A person/position designated in the Damage Control Plan then reviews the damage list and determines the emergency repair priorities in consultation with the Incident Commander and Chief of the Operations Section. The work of the damage control team can be greatly facilitated if the following equipment is contained in a storage area on site: floor plans, rolls of plastic and lathing strips for covering windows, spools of wire, sprinkler plugs, hand tools, gasoline-powered rescue saws with blades for steel and concrete, dewatering pumps, portable oxyacetylene torches, flashlights, headlamps, portable flood lights, sheets of exterior plywood, saws, pry bars, and materials for controlling chemical spills. Large-sized facilities should consider creating several such storage areas. The hospital must aim toward self-sufficiency for the first 72 hours and not expect much assistance from emergency response agencies because these groups are fully committed in a disaster and their capabilities are frequently exceeded.

SUPPLIES

From a preparedness standpoint, a weakness in the hospital industry is the Just-in-Time inventory system. Although such systems improve cash flow and are efficient during routine operations, they cannot be relied on in a disaster, especially one that covers a large geographical area such as Hurricane Katrina. Because a Just-in-Time system relies heavily on truck transportation, this can become problematic due to obstruction of transportation corridors after a disaster.

The AHA's Association for Healthcare Resource and Materials Management (AHRMM) in concert with the Health Industry Group Purchasing Association and the Health Industry Distribution Association created a preparedness document.[21] This publication consists of a core and pediatric inventory and then adds specific items needed for managing the effects of terrorist attacks with chemical, radiological, explosive, nuclear, or biological weapons. The document also contains recommendations for staff PPE. Laboratory and radiological supply needs are not included. The Minnesota Department of Health's website contains a more refined list.[22]

As previously cited in the section on History of Hospital Disaster Planning, the United States no longer has the massive reserves of medical and surgical supplies of past years. In addition, reliance on the military medical service is somewhat problematic. Their first commitment is to national defense, so they are restricted in the degree to which their participation in civilian disaster response is possible. In addition, the reduction of combat support hospitals and other field medical units as well as diminished military medical supply inventories also limits their ability to respond.

The EMC should carefully consider the cited lists, determine desired inventory levels, and decide whether the hospital can afford to increase supply levels of frequently used items. Additionally, the materials management department can craft pre-event purchase orders, arranging contracts with suppliers for emergency shipments and mutual aid agreements with neighboring hospitals or as part of a multihospital system. These arrangements should be made as part of community-wide planning to avoid multiple facilities in the region depending on the same supplier. Standby agreements should also be established with medical suppliers outside the immediate area for use if local suppliers are unable to deliver the requested inventory.

COMMUNICATIONS

Communications problems are a recurring issue in most disasters. The EMC should review the stability of existing communications systems in the hospital such as the telephone, paging, and computer systems. Emergency responders increasingly rely on web-based toolboxes for disaster management. If the hospital also uses these tools and the Internet fails, an auxiliary system must be available. Implementation of paper documentation is an option.

The use of cellular telephones may prove unreliable as available circuit capacity can quickly be exceeded. The same occurs with regular telephones. For any given system, the equipment is designed to handle only a certain percentage of the telephones in the area at any one time. If too many individuals attempt to place calls simultaneously, the system will not function even if there is no physical damage. During Hurricane Katrina, even satellite telephones proved unreliable for the same reason. As an alternative to the usual communication devices, the hospital should consider purchasing handheld portable radios. In addition, it is prudent to have a hospital radio system for communicating with local responders and the area emergency management agency. The greater Cincinnati area pioneered a radio system linking all hospitals, the dispatch center, weather bureau, and three mobile units in 1965. A supervisory committee provides system quality and procedure review, updates policies, and is contemplating a third system revision with 800-MHz units at the time of this writing. This system has proven effective over the decades.

The hospital EMC can also establish a relationship with an area amateur radio unit that performs disaster and emergency communications. These operators can be very helpful to the hospital for both internal and external communications. Such emergency radio teams usually belong to organizations such as the Amateur Radio Emergency Service, the Radio Amateur Civil Emergency Service, or the Salvation Army Team Emergency Radio Network.

For internal communications, the EMC should devise a plan to use messengers should other systems fail. These individuals can visit each important location within the hospital and collect and distribute the messages.

SURGE CAPACITY FOR HEALTHCARE FACILITIES

Background

Beginning in the early 1990s, increased attention has been paid to surge capacity issues. The U.S. suffered devastating hurricanes, earthquakes, and terrorist attacks and is concerned about mass casualties from a pandemic. Canada had a severe acute respiratory syndrome outbreak that could have overwhelmed national healthcare assets, and did in Toronto. Many other nations have experience significant events such as tsunamis, catastrophic earthquakes and terrorist attacks. There have been numerous articles and seminars on surge capacity. While the concepts have been well defined, substantively little has been done to operationalize them. One reason for this is that there is little funding to hospitals to encourage development of surge capacity.

The loss of surge capacity has a variety of causes. The U.S. government cancelled the Packaged Disaster Hospital and Hospital Reserve Disaster Inventory Programs. In addition, managed care and the move to the outpatient care model have contributed to hospital closures and conversion of this space to other uses. To reverse this tread, the development of surge capacity will require new emphasis on personnel, medical supplies and equipment, and patient care space, frequently referred to as the 3S concept: "stuff, staff, and structure" (see Chapter 3).[23]

Table 20.6: U.S. Population, Hospitals, and Bed Statistics

Year	*Population*	*Hospitals (All Types)*	*Staffed Beds*
1965	194,600,000*		
1990	248,709,873	6,649	1,213,000
2000	281,421,906	5,810	984,000
2005	295,895,897	5,756	946,997
2006	298,754,819	5,747	947,412

* Packaged Disaster Hospital Program: 512,000 beds and 7,800 equipped operating rooms were available.

Source: U.S. Census Bureau and American Hospital Association Research Department.

In 2005, the U.S. government developed a Target Capabilities List that identified priorities for Medical Surge and Medical Supplies Management and Distribution.[24] This was updated in 2007. The list defines medical surge as, "the capability to rapidly expand the capacity of the existing healthcare system (long-term care facilities, community health agencies, acute care facilities, alternate care facilities and public health departments) in order to provide triage and subsequent medical care. This includes providing definite care to individuals at the appropriate clinical levels of care, within sufficient time to achieve recovery and minimize medical complications. Medical surge is defined as rapid expansion of the capacity of the existing healthcare system in response to an event that results in increased need of personnel (clinical and nonclinical), support functions (laboratories and radiological), physical space (beds, alternate care facilities) and logistical support (clinical and nonclinical equipment and supplies)."[24] The document lists a variety of critical tasks in the areas of developing and maintaining plans, critical items, performance guides, and a variety of benchmarks. It is a comprehensive product that aims for high levels of preparedness, backed by exercises.

Hospital administrators, however, have expressed concern that little is being done at the federal level to help the nation's hospitals achieve these levels of competence in surge. They think that current initiatives fall short of the medical preparedness measures that were implemented between 1950 and 1975 as covered earlier. Yet the population of the United States continues to grow.

In the U.S., there are fewer medical assets per person today than there were many years ago. In many countries, hospitals often strain under their current patient loads and would not be capable of managing an increased demand for care associated with a catastrophic event such as a pandemic or an earthquake. As illustrated by this example from the U.S., as the population has grown, the number of hospitals and beds (and thereby patient care capacity) has declined (see Table 20.6).

Creation of a Surge Program

The creation of surge capacity requires philosophical as well as financial support. Everyday operational requirements of hospitals and physicians' practices make this difficult. The American

College of Healthcare Executives policy statement on the role of healthcare executives in emergency preparedness calls on its members to 1) be involved in emergency preparedness, 2) ensure that their organizations develop an emergency operating plan, 3) prepare the facility to become a casualty itself from the disaster, 4) become active in interagency planning efforts and encourage adoption of an ICS, and 5) support the NIMS system among others.[25] Healthcare executives may need to delegate these responsibilities. If so, they should ensure that their designees develop robust surge capacity programs, including designation of alternate care sites. The Joint Commission also urges hospitals to create surge capacity; it produced a publication regarding surge hospitals and safe care of patients.[26]

A surge capacity plan must consider all the hazards likely to create a sudden increase in healthcare demands. A pandemic would stress the hospital with patients from their own immediate service area and be coupled by loss of staff who become ill or stay home to care for ill family members. Staff in hospitals in earthquake prone areas should anticipate receiving large numbers of victims with crush injuries. A hospital in a community with a refinery or chemical plant could expect to receive patients with blast, burn, and pulmonary injuries.

Types of Surge Capacity

The hospital can expand capacity by using space within its own grounds and also in the community. This requires an inventory of available space that can potentially be used for patient care. Examples are conference rooms, meeting rooms, physical therapy departments, solariums, and hallways.

Capacity can be acquired outside the main hospital by using auxiliary buildings on the hospital campus. Some hospitals have purchased tents to be erected on the hospital grounds. Such tents can be equipped with heating and cooling equipment. Off campus surge capacity can be planned with community leaders and local public health officials. Such external capacity is best used for less acute patients or as a step-down facility during the casualty-producing period and can be established in a variety of buildings of opportunity such as convention centers, schools, and warehouses with owner approval. Pre-event planning must include an extensive review of the physical structure and environment. Sanitation and water availability are essential.[27]

Supplies

A variety of supplies are needed to support surge capacity and these include cots/litters, bedding, medical and surgical supplies, oxygen, pharmaceuticals, and sanitation supplies. Pre-event planning to acquire and store these items is necessary whether it be on the hospital grounds or held in reserve by a vendor. Some hospitals have acquired excess inventory by slowly buying the supplies over time and then rotating them into normal hospital operations. Other hospitals have stored supplies in trailers or cargo containers. It would be helpful if funds became available from third parties to permit acquisition of these supplies, such as the stockpiles and units of previous years. In the U.S., the CDC Strategic National Stockpile has limited quantities of medical and surgical consumables and should not be counted as the only source. In the prepublication version of the 2009 Emergency Management Standards for hospitals, the Joint Commission does not mandate that hospitals maintain a specified supply level. It does require that if the local community cannot provide the resources to support the hospital's surge capacity for 96 hours, the hospital must identify response procedures for this eventuality.[11] Other standards discuss alternate care sites and requirements for the emergency operations plan to identify sites, staffing, supplies, and methods for transporting patients.[11]

Staffing

Adequate staffing remains a challenge because there is currently a shortage of nurses and other healthcare professionals in the United States and some other countries. Beds are frequently closed due to lack of staff. In a catastrophic situation, especially one that requires the implementation of alternate care sites, pre-event plans are needed for management of volunteers, who in some cases are credentialed by states for disaster medical work. Emergency credentialing of volunteers can also be achieved by hospitals when additional staff are required within the first few hours.[29] Inclusion of retired personnel is an option but due to possible degradation of skills, these individuals should provide care to less acutely ill patients. Local emergency medical technicians, Red Cross volunteers, and home health aides can all be used in an auxiliary role to assist regular care providers; however, even reliance on primary staff personnel may not be feasible. The Hawaii Department of Health funded a study to assess the attitudes of all state licensed physicians and nurses regarding their willingness to work in a nonhospital field medical facility. The response was highest for "natural" disasters and lowest for radiological incidents.[30] A study in Maryland of health department personnel found up to 50% of public health nurses would not report for duty during a pandemic.[31] So even if "stuff and structure" are available, the staff may not be.

The U.S. Agency for Healthcare Research and Quality has produced many documents recommending ways to make the best possible use of existing staff and supplies during mass casualty events.[32,33] In addition to these publications, the Agency has also produced an online interactive tool that estimates resources needed for such emergency responses.[34]

Evacuation

For many decades, hospitals and other healthcare facilities have included evacuation procedures in their emergency plans, but the emphasis was on a response to fire events. The plans focused on movement of patients from the hospital wing on fire to an adjacent area and safely sequestering them behind fire-rated hallway doors and smoke barriers. This was the practice of "horizontal" evacuation. "Vertical" evacuation was usually in their written plan but not given a great deal of attention. Vertical evacuation moved patients from one floor to another. Even less effort was expended creating plans to clear the entire building and move patients to alternate treatment sites.

In a study of hospital evacuations in the United States from 1971 to 1999, Sternberg et al., found 275 reported evacuation incidents.[35] Many occurred in 1994, the year of the Northridge earthquake. The causes of these evacuations are shown in Table 20.7. In an article by Schultz et al., the authors studied hospital evacuations after the Northridge earthquake so that postevent decision making and evacuation techniques could be examined to improve the management of future evacuation events. The article also described a standardized data collection tool.[36]

Table 20.7: Causes of Hospital Evacuations in the U.S., 1971–1999

23% Fire within hospital	6% Fire in community
18% Hazmat within hospital	6% Flood
14% Hurricane	5% Utility failure
13% Human threat	4% Hazmat in community
9% Earthquake	

Following the 1994 Northridge earthquake in southern California and the 2005 Hurricanes Katrina and Rita in the U.S., issues related to hospital evacuation received greater attention. Standards from the Joint Commission require both evacuation and alternate care site plans. Many hospitals have improved their evacuation plans and have held evacuation drills. A notable community example is the Reno-Washoe County, Nevada hospital evacuation project. Undertaken with a grant from FEMA through the state emergency management agency, planning began on types of evacuations, methods of evacuation, review of transportation assets, staffing requirements, patient supplies and critical medications, and who could receive evacuated patients and continue care until the hospital returned to baseline operations.[37] The planning group also performed a real-time exercise to examine employee reactions and the amount of time required to achieve total evacuation from the hospital campus. The chosen facility froze their census at midnight for purposes of the exercise. Analysis of the exercise findings determined the amount of time and labor needed to accomplish a total hospital evacuation. The results of the planning and exercise led to the creation of the Multi-Casualty Incident Plan: Mutual Aid Evacuation Annex that was approved by the District Board of Health as policy for Washoe County.[37]

Evacuations can be partial or total depending on the situation. When an EMS helicopter crashed on the roof of a Michigan trauma center in 2008, leaking fuel flowed down an elevator shaft necessitating a partial evacuation of several floors. The associated loss of power required the use of stairwells to evacuate the patients and the injured pilot.

Evacuation plans have some common elements.

1) There is the need for a facility evacuation plan coordinated with the local community as well as a decision tree used to determine whether an evacuation order should be issued (Table 20.8).
2) Variance in philosophy on the order of patient evacuation (intensive care unit patients first or ambulatory patients first) is found in hospital evacuation plans. General consensus indicates that in emergency situations, one must accomplish the greatest good for the greatest number. An article published by Schultz et al., investigating hospital evacuations after the Northridge Earthquake in California suggests that ambulatory patients should be evacuated first when time is critical. When greater time for evacuation exists, intensive care unit patients should be transferred first.[38]
3) Internal patient transportation aids may be necessary. Devices most useful for individual patient movement are wheelchairs, wheeled-stretchers, backboards, and blankets. A staff member is assigned to each to make turnaround as rapid as possible. External patient transportation planning must account for the number of ambulances, wheelchair carriers, and commercial buses in the community, including how to contact them on short notice.
4) Procedures should exist for discharging as many patients as possible, including follow-up care instructions, medications if needed, and transportation to their domicile if a friend or family member is not available.
5) A patient tracking system is needed to monitor patients, visitors, destinations, and hospital staff members who accompany patients to alternate treatment sites (Figure 20.9).
6) Coordination with the local EMS system and EOC is necessary.
7) Medical records, medications, and medical support equipment should be sent with the patient to the receiving location. Special precautions are needed for controlled pharmaceuticals and syringes.
8) Traffic patterns, both vehicular and pedestrian, must be controlled. The hospital will receive an influx of ambulances, buses, EMS personnel, and others that must be managed for maximum evacuation efficiency. For example, if sufficient elevators are available, one can be designated for ingress of EMS ambulance personnel arriving to transport patients, and one for those exiting the facility. This prevents congestion at elevator lobbies. All unnecessary vehicles should be moved from the ambulance/bus staging area to allow optimal use of space.
9) Flashlights, headlamps, and battery-powered backup lights in corridors and stairwells are useful.
10) Staging areas are needed for patients waiting to depart the facility. This strategy prevents unnecessary exposure to outside elements. These should be under the control of an experienced fire or EMS officer, preferably equipped with a hospital frequency radio, who can supervise transportation assets in an efficient manner. Additionally, an internal triage team of physicians and nurses should be stationed in the patient staging area and in the vicinity of the loading point to render care as needed.
11) A method is needed to notify patients' family members of their alternate care destinations.
12) External security of the patient loading area is necessary to protect the patients and their privacy. Additionally, the hospital facility itself must be secured.
13) Receiving facilities must develop memoranda of agreement with neighboring hospitals as well as hospitals 80–160 km away to provide mutual assistance. Joint evacuation planning that clarifies the roles and responsibilities of the evacuating hospital and the receiving hospital is necessary (Table 20.9).
14) Situations could arise in which other healthcare facilities may be unable to assist as receiving hospitals and so alternate care sites must be identified. Pre-event planning should include the creation of alternate care sites such as auditoriums, hotels/motels, and schools that could be used to house patients when hospitals are unavailable. Although these sites have been used by others in need, they are not ideal for the practice of modern medicine. Nevertheless, they should be considered as they may be the only locations for sheltering patients too ill to return home.
15) The command structure must be clearly delineated. Policies created by the Continuum Health Partner Hospitals of New York City suggest using the HICS in reverse. For example,

Table 20.8: Hospital Evacuation Checklist

Evacuating Hospital		
Pre-event Actions	Completed	To Do
Does staff have family evacuation plans to include when to go, where to go, what to do with pets, food and clothes, important documents, and how to communicate?		
Has a memorandum of understanding been established with a partnering facility (a like organization in size and specialties) that addresses the sharing of staff, what is expected of the evacuating organization to bring with them, how staff will be utilized, reimbursement, liability, housing for evacuating staff, how workers' compensation will be handled, continuity of patient care, and location for evacuating organization's administrative staff?		
Have healthcare providers been credentialed and privileged for the partnering organization?		
Is there a written designation of who has authority to activate an evacuation, determine who will be evacuated, and what the "trigger point" will be?		
Are evacuation actions placed within the responsible individual's incident command Job Action Sheets?		
Has the expectation of who is to assist in the evacuation of the hospital (to include nonstaff physicians who have privileges) been placed in personnel policies?		
Has the expectation of who is to travel to the partnering facility with patients and work there under the established protocols (to include medical staff/residents/fellows) been placed in personnel policies?		
If a patient's physician cannot be contacted to authorize movement and coordinate transfer, who will do that?		
Has a designated "safe" location within the facility been identified for patients and staff who must remain with patients who cannot be evacuated?		
Have personnel from the Emergency and Engineering Departments been designated to either remain within the facility or locate to a temporary site until the event concludes for the purpose of reopening the building? Are agreements in place for staff's temporary housing?		
Have those persons designated to either remain in the facility or be in the "first back" group been advised to have several days of appropriate clothing and food?		
Has an evacuation staging area been coordinated with local law enforcement so that they can block roads?		
Has transportation for patients and staff who will accompany them been arranged?		
Has a reentry plan been developed to include checking and starting of equipment, cleaning, preparing for the reception of victims and return of patients, restocking supplies and medications, return of staff, contacting the licensing agency, advertising that the facility is "open for business," and other key items that staff will identify?		
Have protocols for the preservation of specimens, blood, and if applicable, research data and specimens been developed?		
Has the Engineering Department developed a protocol for closing the facility and turning off major equipment (e.g., air handlers, power, emergency power, water, medical gases)?		

Table 20.8 (*continued*)

Have windup flashlights been considered instead of battery powered?		
Have exercises been conducted (may be tabletop exercises with administrative staff) where the evacuating organization practices procedures and the partnering organization practices preparing for and receiving patients?		
Have both organizations visited each other's facility to gain a better understanding and appreciation of the issues each organization faces by this effort?		
Evacuating Hospital		
Evacuation Actions	Completed	To Do
Has the Hospital Command Center and ICS been activated?		
Has the partnering hospital been notified of the evacuation?		
Has local law enforcement been notified to block roads leading to the evacuation staging area?		
Have local and state officials been notified of impending evacuation?		
If applicable, have corporate entities been notified of impending evacuation?		
Have hospital board members been notified of impending evacuation?		
Have patients' families been notified of evacuation and where the patients will be transferred?		
Has local EMS been notified to divert any incoming patients?		
Has an identification device been placed on the patient (e.g., wrist band, triage tag)?		
Is the patient's chart in a waterproof container, along with medications, valuables, and personal items?		
Have both patients and staff been provided with "go nourishment kits" with water and nonperishable food? Keep insulin and sources of carbohydrates with diabetic patients.		
Have physicians of the transferred patient made arrangements with physicians within the partnering organization for continuity of patient care?		
Have the drivers been provided maps that include alternate routes to the partnering hospital?		
Does the driver or staff member have a communication device?		
Is there a patient tracking system that includes logging patients' names to the specific ambulances they are in and providing a copy to either the driver or staff member accompanying them and instructing the accompanying persons to insert the time that patients leave the facility, the time of arrival, and the receiving physicians' names?		
Has an administrative staff member visited the partnering facility to assist in arrivals prior to dispatching any patients?		
Once a patient has been removed from the room, place an identifying label on the door to show that the room has been cleared. This will assist in clearing the hospital and making sure that no one is left behind.		

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GNYHA Draft 08/20/07

Patient Critical Evacuation Information Tracking Form

NOTE: After completion of form please make THREE copies: ONE for sending facility, ONE for EMS, and ONE for receiving facility.

Sending Facility: ______________________________

Receiving Facility: ______________________________

Patient Name: (PRINT) ______________________________

Date of Birth: ____ /____/____ **Sex**: Male Female

Transferring Facility Medical Record Number: ______________________________

Method of Transport: Ambulatory Wheelchair Basic Life Support Advanced Life Support

Emergency Contact: ______________________________ **Telephone #**__________________

Notified of Transfer : YES NO

Attending Physician: ______________________________ **Notified of Transfer:** YES NO

Primary Diagnosis: ______________________________

Do Not Resuscitate: YES (attach copy) NO **Advanced Directives:** YES (attach copy) NO

Healthcare Proxy: YES (attach copy) NO

Date transferred: ____________________ **Time of arrival at receiving facility:** __________________

Equipment owned by sending facility accompanying patient during transport:

______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________
______________________________ ______________________________

COMMENTS: ______________________________
____
____
____

Prepared by GNYHA based upon documents developed by the New York State Department of Health, Continuum Health Partners, and Lourdes Hospital.

Figure 20.9. Patient critical evacuation information tracking form.

the Logistics Chief controls the movement of patients and supplies, whereas the Planning Chief assumes responsibility to track evacuated patients through the evacuation process and on to a final destination.[39]

The Recovery Phase of the Disaster

Each disaster has four phases: mitigation, preparedness, response, and recovery. Following the response phase, the hospital must recover and return to baseline operating status. If the physical plant has been damaged, the hospital can seek financial help from the U.S. Public Assistance program of FEMA or parallel programs in other countries. Here the Finance/Administration section of the hospital's ICS has a critical role. The Documentation Unit, Time Unit, Procurement Unit, and Compensation/Claims Unit must collect data and prepare them for presentation to FEMA. The Public Assistance program follows the rules and regulations elucidated by the *Stafford Act*. The Finance/Administration Chief needs a financial team to tabulate the costs the hospital has incurred related to the disaster. This team also provides documentation to the hospital's insurance companies as it relates to property, liability, and business-interruption insurances. Patients' health insurance companies can also be billed. Unreimbursed and donated care should be carefully documented as well as invoices for supplies and personnel wages. Such information can then be presented to the hospital's insurers and FEMA. Because of the healthcare institution's high cash demands to pay employees and vendors, the hospital may continue to incur bad debt and uncompensated care above the norm. To maintain cash flow, the hospital should discuss periodic interim payments with major health insurance companies (including the government programs Medicare and Medicaid in the U.S.) in advance of a disaster.

Table 20.9: Receiving Hospital Evacuation Checklist

Receiving Hospital		
Pre-event Actions	Completed	To Do
Has a memorandum of understanding been established with a partnering facility (a like organization in size and specialties) that addresses the sharing of staff, what they are expected to bring with them, how staff will be utilized, reimbursement, liability, housing for evacuating staff, how workers' compensation will be handled, continuity of patient care, and location for evacuating organization's administrative staff?		
Have healthcare providers from the partnering organization been privileged and credentialed?		
Has a location for the evacuating organization's administration to operate been identified?		
Has the partnering organization been provided a list of the types of medical specialists available to them?		
Has lodging for the evacuating hospital's staff been identified?		
Have arrangements been made with suppliers for additional food, linens, medications, supplies, equipment, and additional items and has a "trigger point" been identified for ordering and receiving them?		
Has it been determined where incoming patients will go (both ambulatory and nonambulatory)?		
Instead of discharging patients to make room, examine possible temporary arrangements (nontraditional care sites) for the patients to avoid revenue losses.		
Explain to the staff the protocols that have been established with the evacuating hospital and its staff.		
Have exercises been conducted where the evacuating organization practices evacuation and their partnering organization practices preparing for and receiving patients, beginning with a table top exercise with administrative staff?		
Have visits been made to the partner facility to gain a better understanding and appreciation of the issues each organization faces by this effort?		
Establish drop-off points so as not to interfere with day-to-day traffic.		
Receiving Hospital		
Evacuation Actions	Completed	To Do
Once notified of evacuation, establish a Hospital Command Center and activate the ICS.		
Activate initial receiving areas.		
Prepare beds or other locations to receive patients.		
Coordinate with suppliers for additional items.		
Prepare area for evacuating organization's administrative staff.		
Notify staff of incoming patients.		
Notify the licensing agency.		
Notify lodging facility.		
Notify local health department.		
Contact local law enforcement for keeping facility roads clear.		
Maintain integrity of identifying information and medical records.		

Table 20.9 (*continued*)

Summon additional staff per protocol.		
Alert behavioral health staff and chaplains.		
Set up area to receive donations of money and goods.		
Receiving Hospital		
Preevacuation Actions	Completed	To Do
Establish memorandum of understanding with partnering facility (like organization) that addresses the sharing of staff, what is expected of the evacuating organization to bring with them, how staff will be utilized, reimbursement, liability, housing for evacuating staff, how workers compensation will be handled, continuity of patient care, and location for evacuating organization's administrative staff.		
Credential and privilege healthcare providers with the partnering organization		
Establish a location for operations for the evacuating organization's administration.		
Provide to partnering organization a list of the types of medical specialists available to them.		
Assist in locating lodging for the evacuating hospital's staff.		
Arrange with suppliers for additional food, linens, medications, supplies, equipment, and additional items; and establish a "trigger point" for ordering and receiving them.		
Determine where incoming patients will go (both ambulatory and nonambulatory).		
Examine possible temporary arrangements (nontraditional care sites) for existing patients to avoid revenue losses that would result from discharging them.		
Explain to staff the protocols that have been established with the evacuating hospital and its staff.		
Coordinate exercises in which the evacuating organization practices evacuation and their partnering organization practices preparing for and receiving patients – even if it is a tabletop exercise with administrative staff.		
Visit each other's facility to gain a better understanding and appreciation of the issues each organization faces by this effort.		
Establish drop-off points that do not interfere with day-to-day traffic.		
After receiving notification of evacuation, establish a Hospital Command Center and activate the ICS.		
Activate drop-off points.		
Prepare beds or other locations to receive patients.		
Coordinate with suppliers for additional items.		
Set up area for evacuating organization's administrative staff.		
Notify staff of incoming patients.		

The hospital's capital requirements following a cataclysmic event must be fully understood. It is imperative that the hospital have solid documentation and meet the various deadlines for filing claims.

RECOMMENDATIONS FOR FURTHER RESEARCH

Protecting the Hospital from Chemical and Biological Threats

The hospital physical plant should be protected from chemical, biological, or radiological plumes that could be drawn into the building by its air-handling equipment. As stated earlier, a hospital draws in more kilograms of air daily than kilograms of water to meet the infection control codes. This represents a significant vulnerability to the hospital. Incidents with tank cars carrying toxic industrial chemicals are fairly common and some have led to deaths. A hospital cannot allow itself to become internally contaminated, as it then becomes not only a dangerous environment for occupants, but its critical role of providing healthcare to the community is also compromised.

The U.S. Army has consistently sought better devices to detect harmful agents and has a need for real-time, detection from a distance. To that end, the Army has experimented with laser beams that could reach out a few kilometers, sample the air, and sound an alarm if a harmful agent is detected. This standoff capability has also been developed into a package that can be carried by a helicopter and reach out several miles.

If this technology is successful, hospitals could incorporate this type of system into their overall response plans. On receiving the warning, the hospital could shut down its air-handling systems and perform a facility lockdown to protect occupants. Existing monitors are not necessarily real time and require follow-up of samples to analyze bioparticles. Research is needed into this technology to give not only real-time warning but also to allow technology to detect the presence of harmful agents before they can reach the hospital so timely protective actions can be taken.

Improved Reserve Supply Inventory

Just-in-Time inventory control systems are in use in hospitals across the United States and some other parts of the world. Therefore, a shortage of medical and surgical supplies and pharmaceuticals can be expected during a disaster. Research is needed on how to provide supply packages to equip providers to treat patients suffering from trauma, burns, respiratory injuries from chemicals, biological-induced illness, and radiation exposure. In addition, funding is needed to support the purchase, storage, rotation, and transportation of medical equipment to resupply hospitals on a timely basis. Such supply packages would contain the basic materials needed by physicians to treat the casualties from these events. This medical reserve inventory must be available at the local and regional levels to bridge the gap before supplies are available from outside sources such as the CDC Strategic National Stockpile program in the U.S.

Hospital Preparedness Funding

At the time of this writing, the U.S. Office of the Assistant Secretary for Preparedness and Response in HHS operates a bioterrorism grant program to assist hospitals with disaster preparedness. Awards to grantee hospitals are small. Preparedness costs money and health insurance companies do not consider this in their reimbursement formulas. Although communities routinely fund the operations of fire, police, and EMS through taxes, they do not share tax revenues for disaster preparedness with the first receivers of the victims – the hospitals. More funding for healthcare facilities is necessary for a comprehensive preparedness effort.

Research is needed to determine international, national, state, and local government priorities for funding hospital disaster preparedness as well as the perspective of the health insurance industry in this regard. From the research data derived, strategies can be crafted to obtain such specific funding. Hospitals must be willing to accept such funding as restricted grants and to monitor and document that the funds are being for their designated purpose.

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21

Mass Fatality Management

Paul S. Sledzik and Sharon W. Bryson

OVERVIEW

> For a civilization to deserve that name, all of life must be valued, including the absent life of the dead. *Mate Reyes*[1]

INTRODUCTION

Although many methods exist to measure the impact of a disaster, the number of dead speaks the loudest. Caring for the sick, injured, and displaced is understandably the most important work of disaster responders. For the public, media, government, and society, however, the number of disaster fatalities reflects the true magnitude of the tragedy. Acknowledging the effort of mass fatality managers is largely focused on the dead; the work is actually done for the living.

The disaster dead must be located, recovered, transported, stored, examined, documented, tested, identified, and returned to families for final disposition.[2–4] Each step requires specialists in forensic science and funeral services. The processing of the dead follows legal requirements dictated by the disaster and by the jurisdiction in which the event occurred. For example, scenes of terrorist bombings must be managed and documented at a level that would not be required for every type of disaster because terrorism is considered to be a criminal activity.

The physical processing of the dead encompasses logistical and scientific considerations, such as location and recovery of remains, forensic identification efforts, handling of the dead, and the final disposition of remains. Information about these processes must be provided to family members, the media, and politicians.[5] As the primary focus of mass fatality management, victim identification involves the collection of postmortem data from the victims and antemortem information from the next of kin, and comparison of the data to establish identification. The condition of the remains also influences the process of managing the dead. Such taphonomic factors as burning, decomposition, and fragmentation often make recovery difficult and identification more complex.

In many countries, mass fatality management has received limited attention from the emergency management and disaster response systems. Myths and uncertainty about the disaster dead are found in media reports, disaster response textbooks, and in comments made by public officials. The presence of large numbers of dead exposes fears and creates confusion among responders, leading to ineffective and misguided attempts to manage appropriately mass fatality events. This confusion is compounded by the fact that mass fatality management is not a traditional first responder or emergency management responsibility. It does not fall into typical disaster medical preparedness, training, and response models. Until recently, local jurisdictions and governments have largely overlooked funding, research, and planning for mass fatality management, despite scholarship and after-action reports detailing the short- and long-term implications for the psychological, social, and economic impact of thoughtless handling of the dead and their families. In the past decade, however, mass fatality management has become more formalized with best practices documents, research publications, and after-action reports now influencing the management of the disaster dead.

This chapter examines current methods for addressing disaster fatality issues and discusses some of the complicating factors encountered during a mass fatality response. Current best practices for managing disaster fatalities will be discussed. This will include exploring the unique nature of questions that mass fatality events raise, and a discussion of how to mitigate the impact of such events on families, communities, cultures, and governments.

STATE OF THE ART

Legal and Social Concerns in Mass Fatality Management

Effective mass fatality management addresses both the legal considerations for death and the humanitarian concerns guiding respect for the dead and their families.[3] Proper laws and procedures for mass fatality management must be in place before a disaster occurs.

Identifying human remains is a primary objective for the medicolegal, public health, or law enforcement agency responsible for investigating deaths.[6,7] In most cultures, an official identification must be done for legal reasons. Family members of the deceased require documentation of the death, usually in the form of a death certificate or similar legal instrument. Certifying death and the issuance of a death certificate allow the next of kin to legally resolve issues of insurance, wills, probate, child guardianship, and remarriage. For a typical nondisaster death, this process is usually straightforward. With large numbers of dead from a disaster, however, the process is quickly overwhelmed.

When a disaster management authority responds to a mass fatality event by using mass graves or cremations without an attempt to identify the dead, there are complex long-term political, economic, and religious effects.[3,8] If the domestic laws for certifying death are not followed, the next of kin may be unable to secure the proper legal documents to proceed with obtaining life insurance, inheritance, or government support. Jurisdictions may need to petition courts to issue documents concerning the deceased so that legal matters can be resolved.

In mass fatality events, tension may develop between individual and societal needs with regard to disposition of remains. Families wish to proceed with funerals and other grief rites that may be in conflict with medicolegal requirements for proper identification. If not kept informed about the process, family members and community leaders may begin to question the forensic efforts, particularly the duration of time needed for the identification process. Providing factual and realistic information on the process allows families to understand the procedures used to manage the dead and reduces frustration with the recovery and identification process.[9,10]

Broader than the legal considerations are the nearly universal humanitarian and moral obligations codified in state and national laws that govern the treatment of the dead, the need to identify decedents, and determining the status of unidentified remains.[3] Outside of national- or state-level laws, international guidelines reflect the importance of recovery, identification and burial of remains, and the proper treatment of the deceased's families.

In 1998, the United Nations Office of High Commissioner on Human Rights issued the Guiding Principles on Internal Displacement. The guidelines, although not legally binding, comprise provisions codified by international human rights and in humanitarian law that focus on persons displaced by disasters. The principles are well regarded and promoted among the United Nations members. Specifically, Principle 16 of the Guidelines states

1) All internally displaced persons have the right to know the fate and whereabouts of missing relatives
2) The authorities concerned shall endeavor to establish the fate and whereabouts of internally displaced persons reported missing, and cooperate with relevant international organizations engaged in this task. They shall inform the next of kin on the progress of the investigation and notify them of any result
3) The authorities concerned shall endeavor to collect and identify the mortal remains of those deceased, prevent their despoliation or mutilation, and facilitate the return of those remains to the next of kin or dispose of them respectfully

In the area of international humanitarian law, the Geneva Conventions and the Law of The Hague have provisions regarding the location, identification, and disposition of human remains resulting from armed conflicts. Although focused on armed conflict, they proscribe dignity in handling the dead (e.g., individual burial instead of mass graves) and the importance of positive identification of remains. These actions are considered fundamental rights by signatories to these conventions.

The international police organization, Interpol, has published a Disaster Victim Identification (DVI) Guide to support ongoing programs among its 186 member states. In addition to antemortem and postmortem data collection forms, the guide sets forth recommendations for planning and training in DVI. Interpol's Standing Committee on DVI issues guidelines to member states for establishing DVI teams composed of forensic specialists and for using the DVI Guide in all mass fatality events. The Interpol DVI Guide also details specific procedures for mass fatality management and the process of victim identification.

In the specific area of aviation accidents, the International Civil Aviation Organization (ICAO) promulgates standards and practices for international aviation operations and sets protocols for accident investigation involving multiple countries. Several ICAO documents address aviation accident victim identification.[11,12] Two important aspects of accident investigation involve understanding the actions of the crew and determining survivability of those onboard the aircraft. Identification and autopsy of passengers' and crew members' remains provides data for these determinations. The ICAO Manual of Aircraft Accident Investigation details the need for investigators to work with civil authorities in the legal identification of victims and in certification of their death.

The Pan American Health Organization (PAHO) provides a model document detailing guiding principles and procedures for states preparing for the management of human remains resulting from disasters.[3] The role of knowledgeable experts, the need for a responsible agency to coordinate efforts, the respectful handling of the dead, and the importance of keeping family members and the affected community informed are integral aspects of the model law. Despite such laws and accepted protocols, these tenets of proper treatment of the disaster dead are sometimes not followed. Mass graves were used following the 2004 Asian tsunami and comments by public officials following Hurricane Katrina in 2005 indicated a lack of scientific knowledge concerning the potential of disease epidemics from dead bodies.[13,14]

The bodies of those killed in mass disasters pose little risk of harboring diseases that are transmissible to the living. Typically, the myth is promulgated by the media, politicians, and misinformed disaster responders, and plays on unfounded fear of the dead.[13] Mass graves or cremations are the usual responses to the perceived problem. Such actions can exacerbate the distress experienced by family members of the deceased and the community because they are unable to grieve in the culturally accepted manner.[3,15] Two areas merit consideration: the overall public health risk and the more specific risk to those handling the dead.

For those not physically handling remains, there is little if any risk associated with the dead. Water- and insect-borne diseases such as dysentery, cholera, plague, and typhoid fever cannot be transmitted to the living from the dead. After death, body temperature drops, thus causing nearly all pathogens within the body to die quickly. In addition, most people killed in events such as earthquakes, floods, hurricanes, and disasters related to noncriminal human activity die as a result of traumatic injuries. Very few of such victims harbor infectious diseases that pose risks to the public.[3]

For those handling remains, there are risks from diseases such as hepatitis B and C, human immunodeficiency virus, tuberculosis, and other enteric pathogens;[16] however, forensic and mortuary workers take precautions against these risks during their regular work in medical examiner offices and funeral homes. Standard precautions and hygiene will typically suffice for those required to handle the dead following a disaster. Forensic and mortuary workers involved in body handling and the more invasive procedures such as autopsy should use the precautions taken by forensic pathologists in their daily practices.[17]

The contamination of groundwater due to the leaching of body fluids from mass graves is another common misconception. No reliable evidence of groundwater contaminated by infectious diseases from corpses has been documented by public health and landfill researchers.[15] The anaerobic soil environment and the time required for any biological fluids passing through the soil to reach the groundwater would kill viable pathogens.

The cause of a disaster may influence the use of specific regulations or procedures for managing the dead. Mass fatality events have been categorized into three types based on etiology: criminal, technological, and natural. Although similar activities occur following each of these types – search and recovery, victim identification, and disposition of remains – the event dictates how these actions are implemented, and whether additional procedures are used. For example, the response to a criminal event requires collection of evidence for potential legal proceedings. Determining the cause of a technological disaster requires collection of evidence so that recommendations to improve safety in the particular technology can be implemented. In "natural" disasters, the cause is often known, so collecting evidence is usually not required. Disease-related fatality events may require autopsy and evidence collection to determine the specific pathogen and its source and some events initially thought to be naturally occurring may later be determined to have other causes. Most of the evidence collected by morgue personnel for criminal and technological disasters centers around autopsy, physical evidence on the remains, identification of perpetrators (if they are killed in the event), and separation of investigative evidence that may be commingled with the remains.

In criminally related disasters, such as the September 11, 2001 terrorist events in the United States, the terrorist bombings in Bali in 2002, the July 7, 2005 London transit bombings, and the November 2008 Mumbai terrorist attacks collection and documentation of important forensic evidence was necessary, both at the disaster site and from the remains of victims. In these events, determining the identity of victims and the deceased perpetrators was a critical investigative avenue, as was detailing the victims' cause of death.

Following the 2002 terrorist bombing of a Bali nightclub, the Australian Interpol DVI team responded to support the Balinese officials. Once local police secured the scene, techniques were used to document and collect the remains. In this event, the condition of remains helped discern the center of the blast – an important forensic determination. Analysis of the scene indicated the bomb was poorly constructed and the blast was not as powerful as it could have been. Although the number of different nationalities represented among the victims complicated the collection of antemortem information, the DVI team was able to identify all 202 victims in 4 weeks. The importance of using accepted scientific methods for identification was underscored when the DVI team positively identified nine bodies that had been previously misidentified by family members using visual recognition.[18]

In a technological disaster, such as an aircraft catastrophe, building collapse, ferry capsizing, or industrial explosion, victims must be identified and the cause of death determined. Identifying the reason for the disaster also requires collection of evidence. Once the cause is determined, investigators often make recommendations to enhance worker or passenger health and safety. For example, correlating passenger injuries with seating assignments may aid in reconstructing the sequence of events at the time of a plane crash and are useful in evaluating aircraft safety equipment.[19–21]

Assessing the cause of mortality in disasters and the resultant changes in public health codes and building requirements underscores the importance of collecting information concerning disaster fatalities and the impact of this research on the safety of the community.[22–24] Surveillance of suspicious deaths, an often-overlooked responsibility of medical examiners and coroners, can distinguish bioterrorism events from noncriminal disease outbreaks.[17]

Mass fatality events caused by chemical, biological, and radiological sources pose complications for recovery, handling, processing, and disposition of remains.[25,26] To respond effectively, the chemical or biological agent must first be identified. Once known, forensic responders can plan for the level of decontamination and the level of personal protective equipment needed. The medicolegal authority should work with the appropriate health and environmental agencies to understand the local laws regarding handling and disposition of any contaminated remains. For certain types of chemical and biological agents, there are considerations regarding burial or cremation of remains. For victims killed by anthrax, smallpox, or viral hemorrhagic fever, cremation is recommended over burial. For victims of botulinum toxin, plague, and tularemia, experts recommend remains not be embalmed to reduce the risk to mortuary workers.[26]

Radiological contamination can be internal, external, or result from shrapnel from an explosive device. Removing clothing from the deceased can reduce the risk of secondary external contamination by 90% to those recovering and processing them; most of the remaining external radiological contaminants can be removed by washing the deceased. Monitoring radiological exposure to forensic and mortuary workers and coordinating with knowledgeable experts in radiology will also help to reduce risk.[25]

Deaths from pandemic events, such as those from pandemic influenza, pose challenges because of the wide geographical area affected and long duration of time for the event. Because pandemic influenza deaths will most likely occur in homes and in hospitals in numbers exceeding the normal capacity of the local death management infrastructure, storage of remains and final disposition will be important considerations.

Mass Fatality Response Agencies

Mass fatality events are infrequent, but when they do occur, the affected community often seeks assistance. Several public and private organizations can provide help, ranging from offering advice to providing personnel and equipment.

Interpol DVI teams – deployable to mass fatality events in the 186 Interpol member countries – comprise experts in forensic identification such as dentists, pathologists, fingerprint analysts, and experienced support personnel. In the U.S., the Disaster Mortuary Operational Response Team (DMORT), a division of the U.S. Department of Health and Human Services, provides support in victim identification for the medical examiner or coroner.[28] DMORTs are composed of forensic experts, mortuary personnel, and support staff. The DMORT program also maintains three mobile morgues staged across the U.S. The Federal Bureau of Investigation's Disaster Squad makes fingerprint examiners available, and their Evidence Response Team provides expertise and resources for site search and recovery, particularly in mass fatality criminal events and transportation incidents. International, federal, and private DNA laboratories are available for analysis and comparison of DNA samples.

Nongovernmental agencies such as the International Committee for the Red Cross and the PAHO have experts available to assist in planning mass fatality response operations. State and local funeral director or mortuary service associations can also provide assistance. Private companies specializing in disaster response operations have also developed teams to support mass fatality management and victim identification.

Methods of Identifying Disaster Fatalities

In most disasters, positive identification of disaster victims is based on the comparison of unique biological attributes observed in the remains with concurrent evidence of these features detailed in dental and medical records, radiographs, and other reliable documents.[6] This method of comparing antemortem records with postmortem findings is routine in daily nondisaster forensic casework. Four methods are most commonly used and each method is scientifically validated using verified and accurate antemortem and postmortem documentation.

1) Comparison of dental records (e.g., radiographs and charts) with dental evidence from remains
2) Comparison of fingerprint/footprint records located in reliable repositories with friction ridge patterns from the palms, fingers, and feet of victims
3) Comparison of medical documentation of highly unique physical characteristics with similar evidence found on the remains. Such evidence includes (but is not limited to) radiographs showing healed fractures and other unique skeletal structures, implanted medical devices with serial numbers, tattoos, scars, and birthmarks
4) Comparison of DNA profiles obtained from the remains to DNA samples of the victim (direct comparison) or DNA from specific blood relatives (indirect or family comparison)

The number of victims, the composition of the victim population, and the condition of the remains influence the comparison of evidence and ultimately the timeliness of identifications. If antemortem records are available, identifications using dental, medical, and fingerprint methods can be done quickly, usually within several days. These "conventional" methods of identification lead to the most immediate results because they involve on-site comparison of antemortem and postmortem data. The laboratory requirements of DNA analysis require more time than conventional methods, and DNA identifications take longer to complete.

The term "presumptive identification" is often used to refer to the process of using characteristics or items that suggest a victim's identity, but which are not unique enough to be definitive. A presumptive identification based on nonunique biological or portable evidence is often used as a step toward confirming an individual's identity by using some or all of the scientific methods listed previously. Jewelry, clothing, and visual recognition or facial features by next-of-kin are examples of methods used for presumptive identification. Personal effects such as clothing, wallets, and jewelry are portable items and are often displaced by the forces in play during a disaster. Visual recognition of facial features by next of kin has been shown to be inaccurate because of postmortem changes in the remains and the attendant psychological stress placed on family members involved in the process.[29,30]

Considerations in Mass Fatality Management

Before fatality management activities progress, the medicolegal authority and the primary forensic responders must answer several important questions.

- What is the number of fatalities?
- What is the potential cause of the event?
- What challenges exist in searching for and recovering the dead?
- Is the victim population open or closed (i.e., unknown or known victims)?
- What is the condition of the remains (e.g., complete, fragmented, burned, dismembered)?
- What are the availability, types, and accuracy of the antemortem information?
- Will forensic efforts focus on identifying all victims or all remains?
- What is the role (and the limitations) of DNA in the identification efforts?
- What are the concerns and expectations of society and the next of kin for the identification process?

The answers to these questions determine how forensic personnel will conduct their work, the amount of time the identification process will require, and the limitations to identifications.[2,31,32]

Certainly, the number of fatalities plays a role in the time required to complete the identification process, particularly when the figure rises into the thousands. It is, however, the associated factors of taphonomy and antemortem data availability that often have a more profound effect on the process of identification. As an example, consider two disasters each resulting in 100 fatalities. The first disaster leaves complete bodies with little taphonomic change (i.e., no burning, fragmentation, or decomposition) and antemortem records for the victims are easily obtainable. The second disaster causes fragmentation of remains, with nearly 5,000 fragments representing 100 victims. Little is known about the victims and locating their associated antemortem information is complicated. If the same amount of forensic capability is provided to both cases, resolving the second event will take longer, use more resources, and require more complex fatality management decisions.

Based on the information known about a victim population at the time of the disaster, the group is categorized as either open or closed. In a closed population, data about the number and identity of the victims are easily obtainable. Using a victim's name or other pertinent information, authorities can contact the next of kin to obtain antemortem information. The most common example is an aircraft incident wherein a flight manifest (supported by ticket purchasing and security procedures) is the initial source for collection of antemortem information. For example, under U.S. law, passenger names and contact information are provided to federal authorities within a matter of hours following a crash, and the collection of antemortem information can begin shortly thereafter.

Conversely, an open population defines a victim group in which neither the number of victims nor their names are known. Determining the identity of the deceased is often complicated by the public response to the disaster. Emergency managers and law enforcement agencies are often overwhelmed by massive numbers of inquiries regarding the missing – a common challenge with an open population disaster. Despite frequently held misconceptions, family members take actions to reunite themselves with their missing loved ones, including making phone calls to agencies responsible for tracking missing persons and going to the disaster site.[33] Creating an accurate list of victims and their status (i.e., alive, injured, or dead) requires a well-designed process, managed by the agency responsible for tracking missing persons, to sort those reported missing from those actually missing. Ideally, a designated missing persons or casualty call center receives all such inquiries and develops a comprehensive list of those persons reported as missing. From this list, investigators establish a second list of those actually missing through verifying the status of a missing person, eliminating duplicate reports, clarifying misspellings, and other errors. Once a victim is known to be missing, the process of obtaining and examining antemortem data can begin.

The challenges regarding management of missing persons in open population disasters are reflected in the initial reports of the number of fatalities, which usually differ substantially from the final figures. Following the September 11, 2001 U.S. World Trade Center disaster, initial media reports indicated that as many as 10,000 people were dead or missing. Subsequent days saw the number range between 3,958 and 6,453.[34] As of November 2005, the total number reported missing due to the disaster was 2,749, of whom 1,594 had been identified.[35] Recovery and identification operations were ongoing as of the end of 2008. Following the Asian tsunami of 2004, the World Health Organization reported 10,000 dead and within 10 days the number expanded to 153,000.[36] The final death toll was nearly 250,000, with an understanding that the true number will never be known.[29,37] After the terrorist bombings in London on July 7, 2005, a centralized casualty call center was established (per previous planning efforts) to manage missing persons calls.[5] The center received 42,000 calls within the first hour of operation. This number of missing person calls, for an event that killed 38 and injured over 700, underscores the intense public response following a disaster, and the need for authorities to implement a coordinated missing persons call center system.

The condition of the remains also impacts the methods used for their identification and processing.[38] When related antemortem records are available, complete bodies can be identified quickly because they encompass all the unique physical characteristics needed for identification. In cases involving whole or nearly complete bodies, once the body is identified, the decedent is also identified, that is, the number of bodies equates to the number of victims. Using conventional methods, identifications are completed relatively quickly and at comparatively low cost.

Complexities arise when the bodies of multiple victims are reduced to several hundred or thousand body parts of varying sizes and anatomical structures. Among the fragmented remains are those containing the unique physical characteristic that will lead to a positive identification, such as a hand with ridge skin or a jaw fragment exhibiting dental work. These parts are usually identified quickly (if antemortem data are available), and confirmation of both the victim's death and their identification is completed. Most of the fragmented remains, however, will not contain these features. These fragmented parts are examined using DNA analysis, usually resulting in identification of additional remains. These isolated body segments can be reassociated with previously identified fragments from the same individual. This ongoing process of identification presents a source of potential discomfort for the victim's next of kin. Once they are initially notified of the identification, family members should be asked if they wish to be notified each time a body part is identified, or if they prefer to be notified at the end of the identification process.

In both cases, all reasonable efforts to identify fragmentary remains are made, but there are usually remains that cannot be identified, often referred to as common tissue or group remains. These fragments must be managed carefully; families must be informed of their existence and be involved with their final disposition.

DNA and Mass Fatality Management

DNA analysis is a powerful tool in disaster victim identification and offers a high degree of statistical confidence in its results. DNA provides the ability to identify pieces of remains having no distinctive biological characteristics and the possibility of being able to identify very small fragments of bone. DNA analysis is a laboratory-based procedure, and as such, takes longer and is more expensive than other methods of identification. The overall DNA effort should be coordinated by the agency responsible for medicolegal DNA identification during nondisaster periods. Before DNA identification begins, several questions must be asked, the answers to which will influence the application of DNA analysis.[32] These include

- How important is DNA to the identification effort?
- Will every person or every fragment be identified?
- What is the minimum fragment size that will be identified?
- How difficult will it be to identify everyone?
- How long will the recovery efforts last?

DNA identification requires analysis of postmortem (victim) samples, and the collection and analysis of antemortem samples, called reference samples. Reference samples include personal items of the victim that would contain DNA (direct reference samples), DNA samples from biological relatives (family reference samples), and DNA extracted from remains that have been identified using conventional methods. Direct reference samples include toothbrushes, hairbrushes, personal hygiene items, and medical or pathology samples. Family reference samples are easily obtained by use of buccal swabs or blood samples, and the biological relationship of the family donor to the victim must be recorded. Processing of postmortem and reference samples requires the extraction of DNA. Once extracted, the DNA can then be compared for identification.

Not all samples tested provide DNA for analysis. Limitations in DNA analysis are typically in the extraction phase, where actions such as fire, chemicals, and decomposition can destroy or degrade DNA.[39] Very small pieces of bone can yield usable

DNA for comparison, but often these samples are destroyed in the extraction process. This creates a situation in which a body fragment could be identified, but in accomplishing this process, there are no physical remains to return to the family except the tube containing the extracted DNA.

Mass fatality managers must take care to adjust the expectations of family members, politicians, and the media about the use of DNA in the identification process because it is a powerful tool that is often misunderstood by nonscientists. Emergency managers provided the following figures to the public on a regular basis to control such expectations following the World Trade Center disaster: victim samples received; victim samples analyzed; reference samples analyzed; victims identified; victims identified by DNA only; and remains reassociated with victims.[32] Given this information, family members, the public, the media, and politicians could see the progress being made and place it in the larger context of the recovery and identification efforts.

Mass Fatality Operations

Mass fatality operations encompass several diverse activities: location, recovery, documentation, and identification of the dead; determining the final disposition of remains; and informing family members of progress and seeking their input on certain aspects of the process. Three operational locations of activity typically develop: the disaster site, the disaster morgue, and the family assistance center where families of the deceased gather to receive and provide information. An effective response allows for continual information exchange among all three sites.

Mass fatality response teams are multidisciplinary because the nature of their participation involves both scientific analysis and cultural and religious aspects of handling the dead. Victim identification teams usually include forensic pathologists, forensic anthropologists, forensic dentists, fingerprint specialists, DNA analysts, medicolegal investigators, and forensic managers. Funeral directors, clergy, crisis mental health experts, and similarly trained personnel support both the disaster responders and provide comfort and information to victims' families. The services and information provided to family members, often termed family assistance, are a critical element in a mass fatality response. Because the work of managing the dead is done for the living, the support and information provided to the next of kin must be appropriate and thoughtful.

Search and Recovery

In the overall disaster response timeline, search for and recovery of human remains follows the completion of life-saving efforts and other first responder requirements. Once the living and injured are treated and removed from the site, the search and rescue operations shift to search and recovery of the dead. The methods used to process a crime scene are logically applicable to the disaster scene. Appropriate search procedures document the scene, ensure that all areas are searched, and make certain that human remains are recognized and recovered properly.[40]

Forensic personnel work with first responders to document remains, personal effects, wreckage, evidence, and other pertinent materials before these are recovered. Photographs, video images, diagrams, and mapping technology (e.g., total station or global positioning systems) are used to document the recovery process and record the location of remains. Once documented, remains are then placed in body bags or other similar appropriate storage containers, tagged, and identified using a simple numbering system. They are then transported to a temporary storage location or transfer vehicle. Ultimately, the remains will be brought to the storage location at the disaster morgue.

Many factors influence the search and recovery process: size of the impacted area, number of fatalities, condition of the remains, season, terrain, and weather. For example, searching for complete bodies exhibiting little decomposition found in homes following a hurricane may require a period of time, but the actual documentation and recovery is relatively simple. Conversely, the fragmented and burned remains resulting from a relatively small high-speed aircraft crash caused by a terrorist event must be carefully documented at the scene and then analyzed thoroughly once in the morgue.

Disaster Morgue Selection

Selecting the location for processing remains is a critical first step in management of the dead. The disaster morgue is the site of intense, stressful work, lasting weeks or months and consideration for the needs of morgue personnel should be the primary focus in deciding where to locate this facility. Ideally, local authorities will identify a site before an event occurs. Selecting a disaster morgue site pre-event helps emergency managers understand the importance of fatality management before the arrival of forensic responders.

Health, safety, security, and adequate size are key considerations in deciding the location for the disaster morgue. Logistical considerations include adequate heating/ventilation/air conditioning, lighting, water supply, electrical capacity, telephone and high-speed Internet access, restrooms, drainage (for capturing biohazard wastes), nonporous floors, and forklift accessibility. Proximity to the disaster scene, adequate floor space, access for and placement of refrigerated trucks for remains storage, and office space for workers and support personnel are additional factors. The movement of remains through the morgue facility and other areas where intensive examination occurs should also be carefully arranged. A security plan should be implemented because the morgue often becomes a focus of attention for family members and the media.

Disaster morgues have been successfully established in aircraft hangers, unused warehouses, securable private buildings, and medical examiner or coroner offices when space and procedures allowed. In the latter circumstance, care is taken to separate the daily casework from disaster casework. Portable tents have also been used in situations where an existing physical facility is unavailable. Active public facilities such as schools or community centers should be avoided because of the psychological impact on the community. Hospitals should also be avoided because of potential confusion between family members of injured disaster patients, nondisaster patients, and fatalities. Although disaster victim identification teams have worked in austere conditions, the preference is for a facility that allows them to conduct their work in an appropriate environment.

Remains should be stored in refrigerated trucks or a facility cooled to a temperature that slows decomposition because this process can destroy certain soft-tissue characteristics useful for identification. Refrigerator trucks or similar storage facilities should be designated as "unprocessed" and "processed" to keep remains segregated and organized. Racking systems can be installed in refrigerated trucks or warehouse facilities to maximize storage of both complete bodies and fragmentary remains, which can be bagged and collected in bins. Careful management of remains in storage is essential so that specific body fragments

Figure 21.1. The DMORT disaster morgue at an aviation accident.

can be retrieved for reexamination or release. Remains may require storage for a long period following postmortem examination, particularly if DNA analysis is being used for identification.

Temporary burial is sometimes used as a method for storing remains awaiting examination. Although this method may slow decomposition, depending on the environmental conditions where the graves are located, it does require careful management and additional personnel. Temporary burials should be done individually and information about the location of remains thoroughly documented. Remains should be embalmed only after identification, as the chemicals used can destroy DNA and make reexamination difficult.

In the United States, the DMORT system has assembled Disaster Portable Morgue Units (DPMU) containing supplies and equipment for operating an incident morgue for large-scale fatality events. Some larger jurisdictions and states have also established portable morgues. DPMUs are transportable to the incident site via truck or aircraft and are supported by a team of trained responders who assemble, restock, and repack the DPMU. Equipment and supplies are stored in specialized cases and a load plan facilitates shipment. Once on site, the DPMU is usually operational in less than 24 hours. Figure 21.1 shows the DPMU established in an aircraft hangar following an aviation incident near Wilkes-Barre, PA in May 2000. Figure 21.2 shows the DPMU organized in an abandoned gymnasium on an active military base following the crash of EgyptAir 990 in October 1999. Note the walled sections denoting the workstations for the various parts of the morgue operation. Figure 21.3 depicts a

Figure 21.2. The DMORT disaster morgue showing forensic workstations.

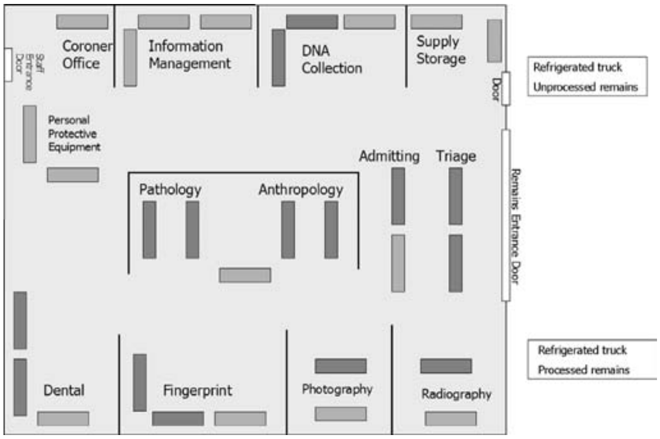

Figure 21.3. A schematic of a morgue layout showing work areas and remains storage locations.

schematic of morgue operations, with workstations, refrigerated trucks, and processing areas.

Incident Morgue Operations

Several standard operating guidelines for disaster victim identification and morgue operations are available from the websites of organizations such as DMORT, the National Association of Medical Examiners, the U.S. National Institutes of Justice, Interpol, and the PAHO. These guidelines reflect the importance of a standardized process for documentation, analysis, quality assurance, and respect for the dead. The particulars of the disaster may require modification of parts of the morgue process, but the procedures remain largely the same.

Before processing of remains begins, the medicolegal authority must answer the questions posed previously: Will the focus be on identifying and accounting for all the victims or on the identification of all fragmented human remains? The condition of the remains, the family expectations, the community concerns, the quality and quantity of antemortem information, and the available forensic resources impacting the processing of the deceased must all be considered.

Figure 21.4 demonstrates the typical movement of remains through the incident morgue. Controlling the flow of the deceased into the morgue allows for efficient processing and avoids overwhelming the morgue team with remains for analysis. For example, in an event with 100 whole-body fatalities, forensic examiners may choose to analyze only five bodies at one time. Once brought into the morgue, remains are radiographed in their container (e.g., body bag, pouch, or transfer case). Radiographs allow for evaluation of the container's contents prior to opening. For complete bodies, radiographs can reveal explosive devices or other hazards, personal effects, forensic evidence, the extent of trauma, and potential commingling with other remains in the same container. For fragmented remains, radiographs reveal potentially identifiable body portions, evidence, personal effects, nonbiological material, and the extent of commingling. Radiographs are essential for the next step, known as triage.

Triage is the process of sorting the dead, first to remove any material not related to determining identity, and then to assess their potential for successful identification.[41,42] In the first step, four categories of materials are typically separated: personal effects; wreckage or other types of evidence; remains with a potential for identification; and remains with no or little potential for identification. Nonhuman biological materials, such as animal bones, are also removed.

During the second step, each body or body part is assessed using a probative index that classifies remains according to their identification potential or investigative value. Triage personnel assess each body or body part for the number of positive and presumptive identifying features that may lead to dental, fingerprint, medical, or DNA identification. Remains usually suitable for identification include dental specimens, large body portions, hands, feet, prosthetic devices, and bone showing healed trauma. Accordingly, remains with the greatest potential for identification

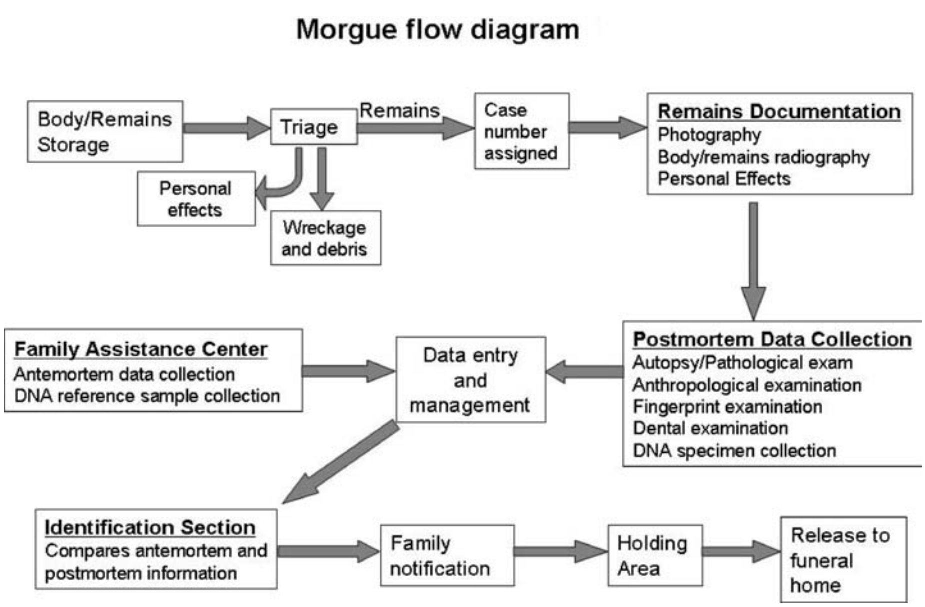

Figure 21.4. Morgue operational plan.

are analyzed first. Small pieces of skin, fatty tissue, muscle, and similar specimens lacking characteristics usable in the identification process are often set aside and do not initially enter the morgue processing stream. These specimens can, however, be reexamined if the initial identification process could not account for all victims.

The probative index is incident specific because factors such as availability and accuracy of antemortem information impact identification potential. Triage is typically used in cases of fragmentary remains, but it can be applied to complete bodies. Triage of whole bodies allows for sorting by the potential for identification, such as the presence of dental work or evidence of surgery.

Following triage, remains are moved to the admitting area where a case file containing postmortem analytical paperwork and other administrative data is created. Remains are also assigned a number corresponding to the case file. A simple numbering system reduces confusion and decreases administrative errors. Remains should be assigned consecutive whole number or a similar unique simple consecutive number. Letters, dashes, and similar characters should be avoided (e.g., 34/A-2, 96–0005A34). The first body or body part entering the morgue flow receives number 1, the second receives number 2, the third number 3, and so on. During the course of the morgue analysis, if additional remains are found commingled with a specimen, then the new body part can be brought to the admitting station and assigned the next consecutive number. Morgue personnel can preserve associated numbering systems assigned at the disaster scene if they apply a similar logic and simplicity. Data from the scene that are associated with the remains can be placed in the pertinent case file. After identification and reassociation of fragmented remains, the coroner or medical examiner assigns a unique victim number or case number to the remains comprising that individual.

Various technologies can assist in handling large numbers of remains by reducing numbering errors and increasing quality assurance. Computer-readable barcodes and radiofrequency identification chips have been used to manage remains in disaster morgue operations following the World Trade Center disaster, the Asian tsunami, and Hurricane Katrina.[43]

Once numbered, the individual remains are photographed, radiographed (for forensic analysis), and then escorted through the postmortem examination stations. Forensic scientists with mass fatality experience staff these stations, which are usually referred to by the discipline conducting the work – dental, pathology, anthropology, fingerprint, and DNA. Requirements of the investigation dictate whether remains will be examined at each station or just at stations that are relevant to a particular body part. For example, fragments of dental evidence would not be examined at the fingerprint station, but the fingerprint analyst may need to indicate on the postmortem forms that they chose not to analyze the fragment. At each station, information is collected according to a protocol created for the specific disaster response.

Forensic odontologists staff the dental station where they examine the maxilla, mandible, and any fragments thereof to document dental structures, fillings, and other unique features.[44] Fingerprint experts take prints from fingers, hands, and feet (if necessary) for comparison to existing print records. Forensic anthropologists document anatomical structures to determine sex, age, stature, and other pertinent biological attributes useful in identification, such as bone trauma or unique skeletal characteristics. Forensic pathologists examine remains for evidence of unique features, assess information relative to cause of death, and conduct autopsies if necessary. DNA technicians take samples from soft tissue and bone, which will later be analyzed in the DNA laboratory. Interaction across discipline boundaries is essential for successfully completing the process of postmortem documentation. Once finalized, postmortem data are entered into a data management system for later retrieval during the identification process.

These same forensic specialists are also involved in comparison of the postmortem data with the antemortem records – the process of positive identification. Regularly scheduled meetings between the medicolegal authority and the forensic experts allow for review of current findings and discussion of identifications. Details of each identification are documented, and the information is presented to the medical examiner or coroner for agreement and authorization. This process usually takes place at the disaster morgue for those identifications done by conventional methods. If DNA analysis is used, the identifications may take months to complete and a separate DNA identification team is established to document and validate identifications. Once a victim is identified, the next of kin is notified via the medicolegal authority's usual process for death notification. Remains may then be released to the next of kin for final disposition, or remains are maintained at the morgue awaiting reassociation based on the next of kin's decision.

Collection and Use of Antemortem Data

Collecting postmortem data is relatively simple compared with the collection of antemortem information. The resources and efforts applied to the recovery of remains often result in bodies or body parts available for analysis soon after life-safety operations have ceased. The standard procedures used in the disaster morgue lead to the accumulation of postmortem data relatively quickly. Locating, analyzing, and interpreting antemortem data is a more complex process because it involves work outside the morgue, reaching out to medical and dental offices, government agencies, and law enforcement bureaus. The presence and usefulness of antemortem data are easily affected by the disaster itself and the particulars of the victims impacted.

Locating the sources of the various types of antemortem records usually starts with contacting family members, friends, and the employer of the deceased. These sources can provide contact information for the dentist and physician of the victim, and may know if there are fingerprints on file for the deceased. If necessary, family members with the appropriate genetic relationship to the victim can provide DNA reference samples.

Antemortem data availability is affected by various factors within the victim population. For example, individuals of lower socioeconomic status may never have received dental care and thus will have no antemortem dental records. Antemortem records are also sometimes destroyed in the disaster, such as in the crash of a U.S. military chartered aircraft in Gander, Newfoundland in 1985 and following Hurricane Katrina.[45,46]

Antemortem data consist of three types: 1) medical, dental, and fingerprint records; 2) family interview information; and 3) DNA reference samples. Records, such as dental charts, radiographs, medical records, fingerprint cards, and photographs detail the presence of the unique biological characteristics of the victim. Because these types of records contain the most accurate and verifiable sources of information, they must be obtained through means that detail their source, that is, dental, medical, or government office. The Federal Bureau of Investigation, Interpol, and state law enforcement agencies may hold fingerprint records of a victim if there is a history of military service, federal or state employment, or a criminal record.

Interviews with family members and friends of the victim can provide information to help locate antemortem records, collect information required for completion of the death certificate, and determine the legal next-of-kin. A family assistance center or similar facility is often established where specialists in funeral service and forensic identification can interview the family members by using standard interview forms. Interviewers can also contact family members not present at the center by telephone or email to conduct interviews. Interviewers must be familiar with the antemortem data collection form and understand identification methods. Antemortem interviews are difficult for families, and interviewers should possess the ability to work with those suffering from grief. Answers provided by family members and friends regarding the deceased's biological and medical data should be considered somewhat inaccurate, and therefore, they should be verified before use in the identification process.[47] They may, however, be the only sources of antemortem information, particularly when no medical or dental records exist and when DNA will not be used.

If DNA will be used for identification, collecting direct and family reference samples requires coordination and careful documentation. For chain of custody reasons, the DNA laboratory conducting the analysis should also be involved with the collection of the reference and postmortem samples. Specific sample collection kits improve the reliability of family donor information; the biological relationship of the donor to the victim must be accurately documented.

The efforts of the missing persons call center and the antemortem data collection teams will result in the accumulation of large amounts of information. Data management software is necessary for effective data organization.[48] The nature of this large data collection effort results in errors from a variety of sources, and methods to locate and correct errors must be implemented. DNA data management is often handled separately, due to the unique features of the testing, but the data will be cross-referenced with related antemortem and postmortem information.

The amount of antemortem information, scene documentation data, and DNA-based records generated is often dramatically underestimated. For the World Trade Center DNA identification efforts, approximately 260,000,000 pairwise comparisons were made between the nearly 20,000 remains, 6,800 family reference samples, and 4,200 direct reference samples.[49] Although the actual comparison time using computer software took only several hours, creating the data for comparison, ensuring its accuracy, and interpreting the results required many months of work.

Ethical Questions in Mass Fatality Response

The decisions and processes involved in managing and identifying the disaster dead create unique ethical and moral questions arising from the interplay of three very different worlds: the remains of the victims, the expectations of family members and society, and the tools and technical limitations of victim identification science. These questions often concern how remains are identified, the extent of resource allocation to conduct identifications, and expectations about what is returned to the family for final disposition. Specifically, such questions include

- Should the limited resources available to conduct identification be used to identify all fragmentary remains or all decedents?
- Why does the identification process take so long?
- How large does a specimen need to be for testing?
- Why is not every specimen analyzed and tested?
- What if a specimen is consumed entirely in testing and yields DNA that leads to identification?
- What should be done with unidentifiable remains?
- Should remains recovered years after a disaster be processed for identification?
- At what point does the identification process end?

Answers to these questions are influenced by the characteristics of the disaster, the desires of the family members (individually and as a disaster-specific group), cultural and religious beliefs about death and final disposition of remains, societal expectations about what science can provide, and the availability of appropriate forensic identification tools and techniques.[3,32] These questions are not unique to disaster work, as forensic scientists involved in human rights investigations have raised similar concerns.[50] Additionally, the increased use of DNA testing for disaster victim identification has raised ethical questions about the use of samples for such events.[51]

As society's agents for managing the disaster dead, fatality managers and forensic scientists use all applicable techniques and technology in the identification process. The science has limitations, however, and these limitations must be explained to family members and society, as their expectations are often at odds with the scientific capabilities. When families believe that identifications will happen quickly, scientists must readjust the families' expectations to make them more realistic. This difficult but necessary readjustment helps families understand the reasons behind the answers to the aforementioned questions.[9,52]

Resolving these ethical quandaries is not often done through public dialogue, given the sensitivities of discussing the horrific details of the event. Informed public discussion is essential, however, to answer these questions appropriately.[53,54] Family members of the disaster dead want and deserve frank yet compassionate discourse on these questions. The discussion is difficult, but helps families navigate the complex grief process wrought by a disaster while assuring a community that the dead receive appropriate consideration and care.

Taking Care of Mass Fatality Workers

Despite the fact that they deal with death regularly, the psychological impact of disaster work on forensic responders should not be underestimated. Disaster forensic work is physically and psychologically stressful.[55–57] Even with the familiarity of working with human remains, certain events increase stress for most forensic responders.[58] These include the handling of personal effects, examining the remains of children, the condition of remains (particularly aspects of visual grotesqueness, odor, and tactile features), and exposure to a large number of victims. Identifying or personalizing with the victims increases emotional attachment to the remains, may reduce objectivity, and may increase vulnerability to psychological distress. Such stressors can result in normal emotional reactions, such as sadness, disgust, anger, pity, fear, and numbness. Physical reactions can include headache, sleep difficulties, intestinal problems, appetite changes, and fatigue.[59]

The most effective coping strategies involve talking with trusted coworkers, appropriate use of humor, reflecting on the larger purpose of the work, avoiding media coverage of the event (particularly information about the victims), and taking regular time off from the disaster work. Camaraderie and talking with colleagues both during and after the event has been shown to be an important source of positive feelings about a disaster response. Peer-support models, as found in fire/rescue and police agencies, are preferable for forensic responders, because outside mental health professionals typically do not understand the particular stressors of forensic work.[57] Despite the stress, forensic responders report that disaster work is a valuable experience, provides a sense of accomplishment, and increases their appreciation of life.[55]

Assistance to Victims and their Families

Because the work of mass fatality responders is performed mainly to comfort the living, it is important that appropriate support is provided to them. Issues to address include the type of help needed when a mass fatality occurs and identifying the needs of the victims and their families after the immediate emergency passes. Survivors of mass fatality events and family members of those killed often experience an "existential crisis" marked by a profound sense of emptiness and despair.[60] Family members, survivors, and others impacted in the community are likely to exist in a state of psychological shock, uncertain about the whereabouts of loved ones and about the future.[61]

Responding to the needs of those affected is complex from a logistical perspective, yet simple in determining a successful outcome. The complexities arise from the myriad of state, local, and federal agencies, private groups, and local community nonprofit organizations each attempting to provide assistance. The measure of success for those assisting family members is simple: it is determined by how effectively the needs of victims and their families are met and by the compassion demonstrated during the response.

Managing a mass fatality event requires coordination among all participants from each area of the disaster response. Prompt and precise communication about the needs of those impacted is crucial. In the chaos of the moment, however, responders can lose sight of the victim's real needs. There is a tendency to respond based on a broad generalization of what the disaster response should entail. Clearly, there are guiding general principles that influence responders when assisting victims; however, it is equally as important to stay focused on the individual impacted by the disaster. It is often best to reflect on who the victims are and what their needs may be in order to maintain the proper focus and deliver appropriate services.

Listening to victims and their families describe their needs and expectations can also help guide future responses. The U.S. Task Force on Aviation Disaster Family Assistance, formed by the passage of the Aviation Disaster Family Assistance Act of 1996, articulated a series of recommendations.[62] For the first time, family members, representatives from the commercial aviation community, government agencies, and nonprofit organizations attempted to create a more effective approach to meeting the needs of victims and their families following an aviation disaster. The guiding principles of this task force have influenced disaster response in ways reaching beyond aviation disasters.

Family members impacted by a mass fatality event describe an overwhelming sense of loss of control over their world. The loss they experience is often in the context of a larger public tragedy.[63] When individuals suffer a loss under such circumstances, they experience grief.[64] Grief is expressed in numerous ways, including physical, psychological, behavioral, and social and spiritual responses and reactions.[65] The nature of this larger public tragedy makes the grief process more difficult for victims and their families. An effective mass fatality response must carefully consider these aspects and integrate proper remedies.

The grief experienced in response to a mass fatality event is further complicated by the traumatic nature of the incident. Trauma refers to situations out of the normal range of experience and includes things such as suddenness and lack of anticipation; violence, mutilation and destruction; preventability or randomness of the event; and the mourners' personal encounters with death. The individual experiences either a significant threat to personal survival or a shocking confrontation with the death or mutilation of others.[66] Traumatic events challenge the many assumptions people have about the world and cause them to feel they no longer control the basic facets of daily existence. An effective and responsible effort to assist victims and their family members must consider the loss experienced and the grief response in the greater context of a traumatic event.

Corr and Doka observed two main elements in ongoing responses to public tragedy: coping with loss, grief, and trauma and finding ways to adapt to a changed world.[67] Janoff-Bulman states, "In the end, it is rebuilding of this trust – the reconstruction of a viable non-threatening assumptive world – that constitutes the core coping task of victims."[68]

The path from victimization to regaining a sense of control and trust requires the individual to cope with the traumatic event and the grief resulting from the loss of a loved one. Those responding to a mass fatality must be sensitive to this emotional state and have an understanding of what is needed. A systematic approach to address the physical, psychological, social, and spiritual needs of victims and their families is vital. These approaches, which take many forms depending on the disaster, help victims and their family members begin to reestablish a sense of control. When handled properly, such interventions will also help them rebuild the shattered trust caused by the mass fatality event.

Corr notes several ideas responders can use to aid people coping with public tragedies.[64]

- Assess the specific nature of the tragedy. Who is in need of help and what types of help are they seeking?
- Understand the distinct characteristics of the tragedy; each is different.
- Take stock of the available resources. What contributions and limitations exist in those providing assistance?
- Prioritize the various aspects of the response. Determine who needs help most urgently, and how and when tasks should be undertaken.
- Be flexible; needs will change during the event.
- Offer assistance to the responders, both in the immediate and the long term.

The lives of victims and their family members impacted by a mass fatality will be forever changed. The goal of any response should be to mitigate further trauma and help the victims reestablish a sense of control. Most individuals, with a little assistance, can use their coping skills to adapt to even the most horrific of circumstances.

RECOMMENDATIONS FOR FURTHER RESEARCH

Within the past 2 decades, the methods to manage the disaster dead have evolved from unscientific interventions implemented by emergency management to those involving experienced forensic professionals using well-designed and proven methods. In the U.S., for example, states have used Department of Homeland Security funds to purchase disaster morgues. Several medical examiner offices now employ full-time mass fatality planning and response staff. In the United Kingdom, the Home Office established a section to manage the overall cross-Government Mass Fatalities Workstream. Interpol maintains a Standing Committee on DVI that oversees their international efforts in mass fatality response. The PAHO published several important documents and papers in the mid-2000s that detail approaches to fatality management.[3,4] Forensic scientists have contributed to the literature of mass fatality management by developing new procedures for DNA identification and processing of victims.[2,26,32]

Several areas show promise for future areas of research. The large and complex sets of data developed during a mass fatality response require effective management.[48,49] Data management and quality control are critical to the victim identification process and any medicolegal considerations, but such activities are often created ad-hoc, with little knowledge gained from past events. Mass fatality mangers must develop well-designed, effective, and user-friendly procedures for data collection and management applicable across forensic disciplines and useful in any area of the globe affected by a mass fatality event.

More research is needed on understanding the accuracy, relevance, and utility of categories of antemortem information. The medical and dental fields generate the antemortem records used for identification, and forensic responders would benefit from working with medical records specialists to understand the nature and utility of this essential information. For example, understanding the frequency of chest radiographs (often used for positive identification) in certain cultural and socioeconomic groups (and knowing how and where these records are stored) would help mass fatality responders to know if and how to look for such records.

Continuing this trend, managers must standardize their procedures for all phases of mass fatality response. Given the international aspects of large-scale mass fatality events, standardizing methodologies for collecting postmortem and antemortem information will benefit all forensic responders. Similar work being conducted in several large-scale missing persons projects by the International Committee for the Red Cross and the U.S. Department of Justice should be of particular interest.[69,70] The similarities in data management, forensic procedures, and acquisition of antemortem information are striking, yet there has been little interaction between the two fields.

Each death in a disaster affects not only the family of that victim, but also the victim's community and culture. Effective mass fatality management not only focuses on the dead – the most immediate need – but also on providing information for the living. Mass fatality responders must provide a standard of care for the disaster dead and their families reflecting both the needs of the living and the complexities of managing the dead.

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22

Crisis and Emergency Risk Communication

Barbara J. Reynolds and Gilead Shenhar

OVERVIEW

Crisis and Emergency Risk Communication (CERC) is a recognized field of study that differs from health risk and risk communication. It is used in disasters and combines elements of the other types of risk communication, but has emerged as a new field recognized by academia. At the time of this writing, CERC is taught in 22 universities in the United States and is being diffused internationally. In addition, the Pan American Health Organization, World Health Organization, and North Atlantic Treaty Organization have adopted CERC principles for their communication work. Hence, CERC is the risk communication term that will be used in this chapter.

A CASE FOR EMERGENCY, CRISIS AND HEALTH RISK COMMUNICATION

Health risk communications are an important and necessary component of disaster management. Although a population or community faced with a PICE (potential injury/illness creating event) will not overcome its challenges solely through the application of appropriate communication principles, an organization can compound its problems during an emergency if it has neglected sound CERC planning. Failure to "be first," "be right," and "be credible" and deliver empathetic messages may interfere with what would otherwise be well-planned and executed response operations. Integrating CERC into the planning and early stages of disaster response will improve operations and speed recovery.[1–3]

Scenario 1. A chemical plant 3 km away appears to send a plume of black smoke directly over a neighborhood. A suburban parent of two preschool children calls the local emergency services number and expects to get answers. He is told there is no evacuation information for his address. He is given no alternatives.

Scenario 2. A single mom proudly moves into her first home. Three months later, she receives an official government packet in the mail – it contains iodine tablets for herself, and her children to take in case of a terrorist attack on the nuclear plant nearby. All the joy in her new home evaporates as she anguishes over the potential future radiation threat to her children. She calculates the cost of leaving the area.

Scenario 3. People in the community are suddenly dying in high numbers from an upper respiratory disease and tests have not confirmed the infectious agent. Some in the media are speculating that it could be a new disease and possibly a bioterrorist attack. Local health officials refuse comment until their tests are completed. Community members are demanding antibiotics from their physicians and local emergency departments are overwhelmed.

Three different public health scenarios with one common denominator – people in serious need of health risk information and officials who provided an inadequate communication response. In scenario 1, the family was not notified to evacuate because there was no risk to them. The government officials did not recognize that they may not only need to tell people when to evacuate, but also reassure families when it is safe to remain in their homes, especially when they observe families in nearby communities being evacuated. In scenario 2, government officials believed they had communicated the necessary information to the community member and that no other follow-up or reassurance was needed. In scenario 3, the government was focused on ensuring that whatever message they communicated was complete and accurate. They refused to be pressured by media speculation in the interim, which left the public without guidance.

EMERGENCY COMMUNICATION PURPOSES

The initial objectives for public information releases from response authorities early in a crisis are to 1) prevent further illness, injury, or death; 2) restore or maintain calm; and 3) engender confidence in the operational response.[4] During a crisis, good communication to the public is a necessity, not a luxury. For an optimal outcome, the public needs information from its leaders and leaders need support and cooperation from the public. Many predictable and harmful individual and community behaviors can be mitigated with effective CERC. CERC tools are critical disaster resources and CERC uses sound psychological and communication research in its approach to the selection of message, messenger, and method of delivery.

WHAT THE PUBLIC EXPECTS

The public wants to know what officials know. Although this may not always be possible, officials must understand the motivations behind the public's desire for information, especially early in a crisis. The public wants to accomplish the following five things with the information they obtain from responding organizations

- Gain the facts needed to protect themselves, their families, and their pets from the dangers they are facing
- Make well-informed decisions using all available information
- Have an active, participatory role in the response and recovery
- Act as a "watch-guard" over resources, including public and donated funds
- Recover or preserve well-being and normalcy, including economic security

Although the purpose of crisis response is to efficiently and effectively reduce and prevent illness, injury, and death and return individuals and communities to normal, the possibilities of harmful human behaviors combined with bad communication practices can lead to overwhelmingly negative outcomes. The following are some of the damaging situations response professionals could face

- Public demand for misallocation of limited emergency response resources
- Public mistrust or circumventing public health recommendations
- Opportunists who play on peoples' fear or uncertainties to provide fraudulent alternative treatments
- Increased disease and death
- Overreaction and wasted fiscal and medical resources during the emergency response.

If executed well and early, CERC can help reduce the tendencies of detrimental human behavior and prevent negative public health response outcomes.

CURRENT STATE OF THE ART

Defining Crisis and Emergency Risk Communication

Understanding how academics and practitioners define various categories of communication may be useful to inform disaster managers who face a broad and rapidly changing disaster response environment. Communication expertise that fulfills the needs of response professionals borrows from many areas of communication study. Professionals are increasingly calling this integrated model "crisis and emergency risk communication" because they recognize that no single communication field can fulfill the multiple and overlapping roles required of this era's complex sociopolitical environments, new technological media, and dynamic health disaster risks.[2] For a response organization to communicate successfully in a crisis, they must be fast, accurate, credible, consistent, and empathetic. To navigate the information needs of the public, media, and stakeholders during an intense public safety emergency requires more than attaching "appendix X" to an operational plan. In a crisis, the right message at the right time is a "resource multiplier" – it helps response officials get their jobs done. Many of the predictable, harmful individual and community behaviors can be mitigated with effective CERC. Each crisis will carry its own psychological challenges and disaster response officials must anticipate what mental stresses the population will experience and apply appropriate risk communication strategies to manage these stresses.

Crisis communication: Crisis communication can be defined in two ways and, therefore, can cause some confusion for a practitioner looking for expert training and counsel. The term is most often used to describe an organization facing a reputational crisis and the need to communicate about that crisis to stakeholders and the public.[5] Typically, a crisis is an event that occurs unexpectedly, may not be in the organization's control, and may cause harm to the organization's good reputation or viability. An example of an organization facing a crisis is the occurrence of a mass shooting of employees by a disgruntled worker. In most instances, the organization is facing some legal or moral culpability for the crisis (unlike a disaster in which a tornado wipes out the production plant), and stakeholders and the public are judging the organization's response to the crisis.

A second, simpler, definition of crisis communication separates the judgment or reputation factors in the communication and deals primarily with factual communication by an organization to its stakeholders and the public when a disaster or emergency occurs. In this context, crisis communication could simply be the effort by community leaders to inform the public that, by law, they must evacuate in advance of a hurricane. In this definition, the organization is not being overtly judged as a possible participant in the creation of the disaster, and the information is empirically sound, so the individual can judge its veracity without the help of an expert.

The underlying thread in crisis communication is that the affected organization is experiencing an unexpected situation and must respond. Crisis also implies lack of control by the involved organization in the timing of the event.

Communicator: Participant
Time Pressure: Urgent and unexpected
Message Purpose: Explain and persuade

Issues management communication: Issues management communication is similar to crisis communication; however, the organization has the luxury of knowing the impending crisis. It also has the opportunity, to some extent, to choose the timing of its revelation to stakeholders and the public and reveal the organization's plan to resolve the issue. Again, the organization is central to the event.

Communicator: Participant
Time Pressure: Anticipated; timing somewhat in control of the communicator
Message Purpose: Persuade and explain

Health risk communication: Health risk communication is a field that has flourished in the area of environmental health. Through health risk communication, the communicator seeks to provide the receiver with information about the expected type (good or bad) and magnitude (weak or strong) of an outcome from a behavior or exposure. Typically, the communicator provides information about an adverse outcome and the probability of that outcome occurring. In some instances, risk communication has been used to help an individual make a choice about whether or not to undergo a medical treatment, continue to live next to a nuclear power plant, pass on genetic risks, or elect to vaccinate a healthy baby against whooping cough. In some cases, risk communication is used to help individuals adjust to the knowledge that a previous event, such as an exposure to harmful carcinogens, may put them at greater risk for a future negative health outcome, such as cancer. Risk communication would prepare people for that possibility and, if warranted, give them appropriate steps to monitor for the health risk, such as regular cancer screening.

Communicator: Expert that did not participate in the event and is neutral regarding the outcome
Time Pressure: Anticipated communication with little or no time pressure
Message Purpose: Empower informed decision making

Crisis and emergency risk communication: CERC balances the urgency of disaster communication with the need to rapidly communicate risks and benefits to stakeholders and the public. It differs from crisis communication in that the communicator is not, at least initially, perceived as a participant in the crisis or disaster, except as an agent to resolve the crisis or emergency. CERC is the effort by experts to provide information to allow individuals, stakeholders, or entire communities to make the best possible decisions about their well-being within nearly impossible time constraints and to help people to ultimately accept the imperfect nature of choices during the crisis. This is similar to the communication that occurs in emergency departments, not in doctors' offices. CERC also differs from risk communication in that a decision must be made within a narrow time constraint, the decision may be irreversible, the outcome of the decision may be uncertain, and the decision may depend upon imperfect or incomplete information. CERC represents an expert opinion provided with the goal that it benefits its receivers and advances a behavior or an action that allows for rapid and efficient recovery from the event. CERC integrates elements of all of the afore-defined fields of communication and emphasizes each more or less depending on the type of disaster and the stage of the disaster response.

Communicator: Expert who is a postevent participant invested in the outcome
Time Pressure: Urgent and unexpected
Message Purpose: Explain, persuade, and empower decision making

ORGANIZATIONAL CREDIBILITY AND TRUST

Research indicates that the public perceives the success of the disaster operational response by the amount and speed of relevant information they receive from the emergency response officials.[6] Messages are more or less relevant as they do or do not answer important questions about actions to empower the receiver and reduce uncertainty.[7,8] Research also indicates that messages are most effective in a crisis if they are empathetic (taking the emotional perspective of the audience), appear honest and open, are relevant, and come from a trusted source.[1,9]

In several surveys, the public was asked who they would trust most as a spokesperson or reliable source of information if a bioterrorism event occurred in their community. Respondents trusted the local health department or a local physician or hospital representative the most. Respondents also trusted "quite a lot" or "a great deal" their own doctors, the fire chief, the director of the health department, the police chief, the governor, and a local religious leader (Pollard, 2003).

Communicating in disaster situations has become increasingly more difficult for responding organizations for a number of reasons. A complicating phenomenon is the reality that one's messages will compete with many others for credibility with the public before, during, and after the disaster occurs. Therefore, the organization's credibility, the credibility of the spokespersons who deliver messages, and the messages' soundness from the intended audience's perspective are critically important. The explosion of alternative information channels and sources allow people to "shop around" for messengers and messages. In addition, public suspicions of scientific experts and government are increasing. The suspicions are increasing for a variety of reasons, including access to more sources of conflicting information, a reduction in the use of scientific reasoning in decision making, and political infighting.[5,9,10] Also, the media has a tendency to interview two "experts" with diametrically opposed views (a point/counterpoint technique) and this can serve to confuse the public because there is no unified message. Finally, confidence in government, traditional social institutions, and industry, at least in the United States, has severely eroded in the last 30 years.[9]

REPUTATIONAL RISK MANAGEMENT

Organization reputational risk management is paramount because of this increasing lack of confidence, shifting of cultural norms and new, faster communication technologies. Changes forcing this rethinking include the global explosion of information access, the emergence of a victim culture, a decline in the understanding and reputation of science, and the increase of advocacy groups.[11,12]

An organization can measure its reputation through the level of stakeholder trust or mistrust. Stakeholders are people or organizations with a special connection to the organization. The Ethics Resource Council teaches that "trust is the natural consequence of promises fulfilled." Mistrust is an outgrowth of the perception that promises have been broken and values violated. Trust and credibility are essential elements of persuasive communication.[13] Empathy and caring, competence, commitment, and accountability contribute to trust.[1] Three important elements: speed of response, avoiding errors during the crisis response, and asking for forgiveness when mistakes occur greatly contribute to maintaining and building trust during a crisis response. It is best if events that affect the organization's trust never occur, but when they do, it is not the misstep itself that harms reputation, but the response to the misstep that harms the reputation, especially if an organization mishandles the early phases of correcting the erroneous action. An organization can be forgiven when something goes wrong. However, their apology may be ineffective if they are perceived as insensitive that problems have occurred. Early and empathetic action may mitigate damage. Unfortunately, most organizations are not structured to provide rapid responses. Furthermore, leaders are rarely trained for and committed to quick, caring action. If an organization and its leaders are unwilling to build and maintain trust with its stakeholders and the general public, then executing any other elements of the communication plan is a wasted effort. Trust is foundational to CERC. There are five key elements to building trust: expressed empathy, competence, honesty, accountability, and commitment.

EMPATHY

Research shows that an expression of empathy should be given in the first 30 seconds of starting to communicate.[14] To do otherwise is to waste one's time, because the public will be waiting to hear whether or not the spokesperson "get's it." The audience is wondering whether the response official understands that they are frightened, anxious, confused, or angry. If the official does not articulate what the audience or listeners are feeling in the moment, their minds will be consumed with the question: "do they get it" and they will not hear a thing the officials are saying. A sincere expression of empathy early in the communication will allow people to settle down the "noise" in their minds and actually hear what the official has to say.

When someone's life is turned upside down, it is important for that person to hear from the people who are there to help that they "get it." However, it is inappropriate to say "I know how you feel." That lacks specificity. Officials must take a moment and discern what emotion community members are feeling such as fear, frustration, anxiety, dread, or confusion and actually name the emotion. If uncertain, say, "I can only imagine I would be feeling pretty frustrated right now" and wait to see if heads start to nod.

From Aristotle to today's communication and psychological research, studies continue to emphasize that expressed empathy is a key component of building trust that cannot be omitted. Expressing empathy in a crisis situation is not a matter of luxury, it is a necessity and every credible response official who intends to be a spokesperson must be prepared to express and repeat empathy sincerely toward those affected by the event.

SHOW COMPETENCE AND EXPERTISE

Source competence is important.[13] If officials have a title and are part of the response to a crisis, the public will assume they are competent until something occurs to indicate otherwise. Education, position title, or organizational roles and missions are quick ways to indicate expertise. Previous experience and demonstrated abilities in the current situation enhance the perception of competence. Another useful tool for building trust is to have established a relationship with the audiences in advance of the emergency.[5] If that is not possible, using a third party, who has the confidence of the audience and expresses confidence in the response organization and its officials is useful.

REMAIN HONEST AND OPEN

According to recent research, communities believe that the U.S. government withholds information (U.S. Centers for Disease Control and Prevention, unpublished, 2003). Before communication with a community in crisis even begins, most of the population assumes officials are withholding information. Officials should strive to treat people as they would like to be treated related to the release of information. It is inappropriate to withhold information based on a well-meaning but misguided desire to protect people or to avoid a bigger problem. The motives may be noble, but the outcome could be the opposite. The U.S. Centers for Disease Control and Prevention (CDC) and five universities conducted a series of 55 focus groups in 2003. Among the findings, three themes emerged from the participants: any information is empowering, uncertainty is more difficult to accept than knowledge of something threatening; and participants seek out multiple sources for information.

Holding back information as a way to "manage" the crisis in not only inappropriate, it is also impractical. With modern information technology, the public can readily find information. Assume that if more than one person knows the fact, everyone knows the fact. Then ask, "Do you want to present the facts in context or do you want to try to clean up a mess of someone else's making?"

Bad news does not get better over time. There is consensus among professionals that the faster one delivers bad news, the better, because withholding information implies guilt and arrogance.

Do organizations choose to withhold frightening information because they do not want people to "panic?" Do they withhold the information because they think it will minimize the number of phone calls from the public and media requests from reporters? In actuality, not knowing is worse than knowing. People can cope with bad news and the anticipation of bad things to come. Conversely, at times there are good reasons to withhold certain information. When this is the case, respectfully tell the public you are withholding information and why. If the answer is "because we do not want you to panic," then there is no reason to withhold the information.

Honesty and openness in crisis communication means facing the realities of the situation and responding accordingly. It means not being paternalistic in communication but, instead, participatory – giving people choices and enough information to make appropriate decisions. In situations of great uncertainty, the public should be told why the information is not available for release at the time.[12] To build trust, the public should be allowed to observe the process while being reminded that this process is what drives the quality of the emergency response.

ACCOUNTABILITY AND COMMITMENT

For most people accountability literally means "keeping the books open." If government or nonprofit money is being spent in the response to a disaster, sooner or later the public and media will demand to know to whom that money or those resources are being distributed. A savvy official would anticipate the questions and have the mechanisms in place to be as transparent as possible, perhaps keeping an accounting on an Internet site related to the disaster and updating it weekly or monthly as appropriate.

An organization's credibility is important at any time, but especially so during a crisis. Although it is simple to analyze retrospectively another organization's crisis and clearly see that its leaders should have released information to the public earlier and more fully, it is much more difficult when it is "your" crisis.

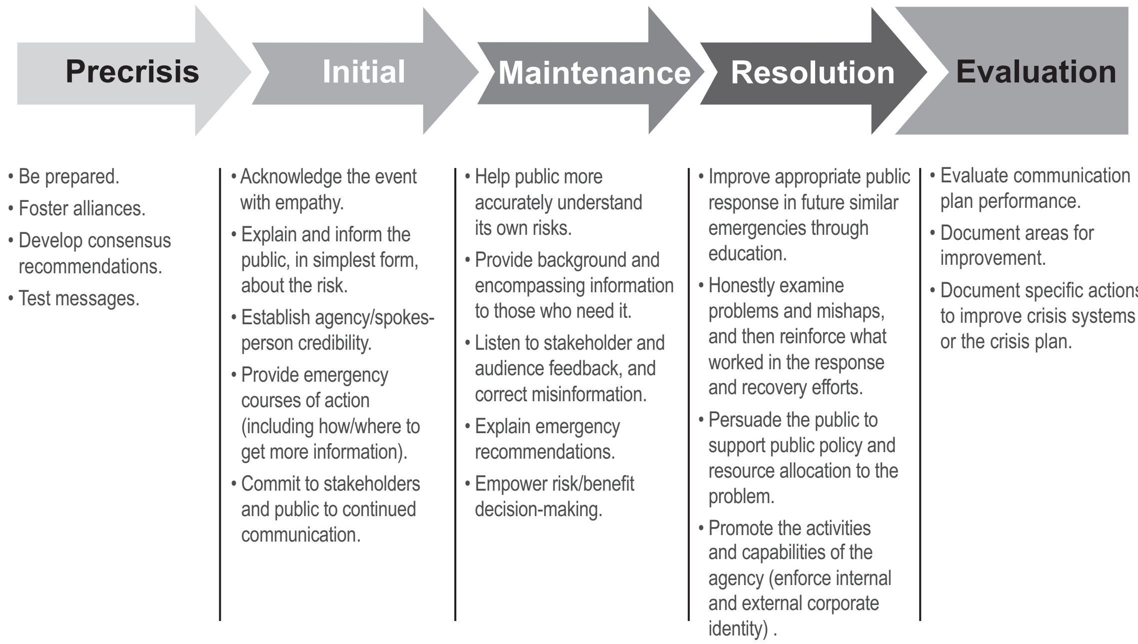

Figure 22.1. Crisis communication life cycle.

To achieve the appropriate degree of openness and empathy requires written policies that are practiced during exercises, have full commitment from the highest organizational leadership, and are modeled during noncrisis situations.

CRISIS COMMUNICATION LIFE CYCLE

Understanding the pattern of a crisis can help communicators anticipate problems and respond effectively. For communicators, it is vital to know that every emergency, disaster, or crisis evolves in phases and that the communication must evolve in tandem. By dividing the crisis into the following phases, the communicator can anticipate the information needs of the general public, stakeholders, and the media. Each phase has its unique informational requirements (Figure 22.1).

The movement through each of the phases will vary according to the triggering event. Not all crises are created equally. The degree or intensity and longevity of a crisis will impact required resources and staff.

Precrisis Phase

Communication objectives during the precrisis phase are as follows

- Be prepared
- Foster alliances
- Develop consensus recommendations
- Test messages

This is when all the planning and most of the work should be completed. Types of disasters that the organization should address can be anticipated via a standard hazard vulnerability analysis. Reasonable questions can be anticipated, and preliminary answers can be sought. Initial communication templates can be drafted with blanks to be completed later. Spokespersons, resources, and resource mechanisms should be identified. Training and refinements to plans and messages can be made. Alliances and partnerships can be fostered to ensure that experts are speaking with one voice.

Initial Phase

Communication objectives during the initial phase are as follows

- Acknowledge the event with empathy
- Explain and inform the public, in simple terms, about the risk
- Establish and affirm organizational/spokesperson credibility
- Provide emergency courses of action (including how/where to get more information)
- Commit to stakeholders and the public to continued communication on a regular basis

Simplicity, credibility, verifiability, consistency, and speed are critical when communicating in the initial phases of an emergency.

The initial phase of a crisis is characterized by incomplete data and intense media interest. Information is usually imperfect, and the facts are dispersed. It is important to recognize that information from the media, other organizations, and even within an organization may not be accurate. The communicator's role is to learn the facts about what happened, to determine the organization's response to the problem, and to verify the true magnitude of the event as quickly as possible.

In the initial phase of a crisis, there is no second chance to "get it right." An organization's reputation depends on what it does and does not say, when it says it, and the tone in which it is said.

One of the best ways to limit public anxiety in a crisis is to provide useful information about the nature of the problem and what the public can do to protect themselves. During the initial phase of an event, an organization must reaffirm or establish itself as a credible source of information. Even when there is little information to offer, it can still communicate what is currently known, how the organization is investigating the event and when more information will be available. At the very least, messages should demonstrate that the organization is addressing the issues head-on – that its approach is reasonable, caring, and timely.

The pressure to release information prematurely can be intense. Remember that all information must be approved by the appropriate managers before its release to the media and that the organization must speak with one voice.

In the initial phase of a crisis or emergency, people want information immediately. They want timely and accurate facts about what happened, where it occurred, and what is being done. They will question the magnitude of the crisis, the immediacy of the threat to them, the duration of the threat, and who is going to fix the problem. Communicators should be prepared to answer these questions as quickly, accurately, and fully as possible.

Crisis Maintenance

Communication objectives during the crisis maintenance phase are as follows

- Help people more accurately understand their own risks.
- Provide background and encompassing information to those who need it. (How could this happen? Has this happened before? How can I prevent this from happening again? Will I be all right in the long term – will I recover?)
- Gain understanding and support for response and recovery plans.
- Listen to stakeholder and audience feedback and correct misinformation.
- Explain emergency recommendations.
- Empower risk/benefit decision making.

As the crisis evolves, anticipate sustained media interest and scrutiny. Unexpected developments, rumors, or misinformation may place further media demands on organization communicators. Experts, professionals, and others not associated with the organization will comment publicly on the issue and sometimes contradict or misinterpret a spokesperson's messages. Expect to be criticized about the handling of the situation.

Remaining current regarding information flow and maintaining tight coordination are essential. Processes for tracking communication activities become increasingly important as workload increases.

The crisis maintenance phase includes an ongoing assessment of the event and allocation of resources.

Resolution

Communication objectives for the resolution phase are as follows

- Improve appropriate public response in future similar emergencies through education.
- Honestly examine problems and mishaps, and then reinforce what worked in the recovery and response efforts.
- Persuade the public to support public policy and resource allocation.
- Promote the activities and capabilities of the organization externally and internally reinforce corporate identity.

As the crisis resolves, there is a return to stasis, with increased understanding about the crisis as complete recovery systems are implemented.[5] This phase is characterized by a reduction in public/media interest. Once the crisis is resolved, an organization may need to respond to intense media scrutiny about how the event was handled. It may have an opportunity to reinforce public health messages while the issue is still current. A public education campaign or changes to a website may be necessary. Research has shown that a community is usually most responsive to risk avoidance and mitigation education directly after a disaster has occurred.

Evaluation

When the crisis is over, evaluate communication plan performance and determine specific actions to improve crisis systems or the crisis plan.

Communication in a Crisis Is Different

Communicating in a crisis is different from that during normal conditions. In a serious crisis, affected people may process and act on information differently. During crisis situations, individuals are often unable to collect and process information in a timely manner and, thus, rely on established routines for situations that are, by definition, novel.[5] Because people absorb information they receive during an emergency in a manner different from that in nonemergency situations, the potential for miscommunication increases.[7] The way people absorb information, process it, and act on it can change when they are under the threat of illness or death.[15] Importantly, people will simplify complex information, attempt to force new information into previous constructs, and cling to current beliefs.[16] Therefore, if the emergency message requires asking people to do something that seems counterintuitive, they may hesitate to act. Because people tend not to seek out contrary evidence and are adept at maintaining their beliefs, conflicting or contrary information may be misconstrued to conform to established beliefs.[11] They may reject new information.

It is useful to understand the impact of imagery on decision making and persuasion because people may be influenced by irrelevant factors.[13] Scientists are finding that people's brains are hardwired to engage in sensory-emotive logic. Messages created with the belief that people are linear thinkers who make logical decisions may fall short of their expectation.[17] Hill contends that the old way of thinking is that individuals go through steps in decision making from cognitive, to affective, and then behavioral. Scientific results based on tracing the brain's circuitry, however, show that long before learning based on the logical basis of the message people have been influenced on a largely unconscious emotive level. When individuals feel threatened and become anxious they begin to process information on an emotive level and less on a logical one.[1,17] Therefore, it is important that response officials consider what images are being presented to people and try to *show* people what they should be doing, not just tell them. Response officials should "model" the behavior they want from the public. The nonverbal behavior of the spokesperson is extremely important when people are feeling threatened.

Physical and mental preparation will relieve anxiety despite the expectation of potential injury or death. An "action message" can provide people with the feeling that they can take steps to improve a situation and not become passive victims of the threat. Therefore, to reduce the likelihood of victimization and fear, the public must feel empowered to take action. Show them the positive actions to take – avoid focusing on negative images.

Other aspects of decision making are also affected during a crisis. The following behaviors are commonly exhibited.

Simplify

Under intense stress and possible information overload, people will miss the nuances of messages or avoid the effort to juggle multiple facts by simplifying what they have heard.[17] To cope, people may not attempt an analytical and reasoned approach to decision making. Instead, they may rely on habit, long-held traditions, following the lead of others, and such stereotyping as classifying participants as "good guys" and "bad guys."

Maintain Current Beliefs

It may be difficult to change peoples' beliefs during a crisis or emergency, especially if the response official's communication requires asking them to do something that seems counterintuitive (e.g., getting out of a "safe" car and lying in a ditch instead of outrunning a tornado).[13] People are adept at maintaining faith in their current beliefs and tend not to seek out contrary evidence. They also exploit conflicting or contradictory information about a subject by interpreting it as consistent with existing beliefs. (e.g., "I believe that chocolate is good. Some studies say chocolate is bad for your health. Some studies say chocolate is good for your health. I choose to believe that no one knows for sure, and I'll continue to eat chocolate.")

> People may believe incorrect or conflicting information. People remember what they see. They tend to believe what they have experienced in their own lives; however, faced with new risks in an emergency, people must rely on experts. However, supposedly reputable experts may disagree regarding the level of threat, risks, and appropriate recommendations. The natural give and take among experts and their tendency to enjoy the peer review process could leave the general public with increased uncertainty and fear. The media will often augment this give and take with point/counterpoint discussions regardless of the validity of the differing views. Research indicates that, often, the first message to reach the listener may be the accepted message even though more accurate information may follow.

With this in mind, CERC principles stress that simplicity, credibility, verifiability, consistency, and speed are critical when communicating in an emergency. An effective message must be repeated, come from a legitimate source, be specific to the emergency being experienced, and offer a positive course of action.

DURING A DISASTER, WHAT ARE PEOPLE FEELING?

People experience a multitude of feelings. Each person may or may not face any or all of a range of emotions. Patterns do emerge in a crisis, however, and response officials need to expect these and understand why communicating in a crisis is different.

There are a number of psychological barriers that could interfere with the cooperation and response from the public. Many of them can be mitigated through the work of a leader with an empathetic and honest health risk communication style.

Fear, Anxiety, Confusion, and Dread

Chaos theory related to crises emphasizes that disasters taking a toll on human life are inherently characterized by change, high levels of uncertainty, and interactive complexity.[5] The majority of people will experience at least one traumatic event "outside the range of normal human experience."[18] How well someone may cope with those traumatic events will depend on the individual's level of personal resilience. Personal resilience is a person's ability to maintain equilibrium in the face of trauma and loss. Resilience is often described as the protective factors that foster positive outcomes and help humans to thrive after extreme disasters.[18] The following psychological resources protect victims of disaster: coping efforts, self-efficacy, mastery, perceived control, self-esteem, hope, and optimism.[19] In disaster situations, some people may feel a sense of dissociation and that the familiar normal world they knew is gone. These feelings may be mitigated with quick, firm directions for action.[20] Survivors' fear, anxiety, and despondency can be reduced to manageable levels by reducing situational uncertainty with information, by directing individuals or communities in activities that restore a sense of control, and by modeling optimistic behaviors.[1,13,20] These are all activities that can be achieved through mass communication mechanisms; however, the messages must be crafted carefully and acknowledge the emotional toll.

In a crisis, people in the community are feeling fear, anxiety, confusion, and, possibly, dread. The responsible official's job when communicating in a crisis is not to alleviate these feelings. If that were the goal, failure would be a certainty. Instead, these are the emotions that communications leaders should acknowledge in a statement of empathy. "We've never faced anything like this before in our community and it can be frightening."

Hopelessness and Helplessness

If the community, its families, or individuals let their feelings of fear, anxiety, confusion, and dread grow unchecked during a crisis, psychologists predict they will begin to feel hopeless or helpless.[21] A reasonable amount of fear is tolerable. Instead of striving to "stop the panic" and eliminate fear, help the community manage its fears and set it on a course of productive action. Action helps overcome feelings of hopelessness and helplessness. As much as possible, direct people to perform relevant actions – things that are constructive and relate to the crisis they are facing. Anxiety is reduced by action and a restored sense of control. This should be the primary objective for risk communication in a crisis.

The actions may be symbolic (e.g., put up the flag), or preparatory (e.g., donate blood or create a family check-in plan). Some actions must be taken in context. Care is necessary when instructing people which actions to take without telling them when to perform them. Phrase these preparatory actions in an "if – then" format. For example, "Go buy duct tape and plastic sheeting to have on hand, and if (fill in the blank) occurs, then seal up one interior space in your house and shelter in place."

The public must feel empowered and in control of at least some parts of their lives in order for officials to reduce fear and feelings of victimization.[21,22] Plan ahead and think of action messages that instruct people on activities they can perform, even if it is as simple as "checking on an elderly neighbor."

What About Panic?

Contrary to what is depicted in the movies, people seldom act completely irrationally or "panic" during a crisis.[7] While there are anecdotal reports that people have run into burning buildings, have refused to get out of a car stuck on the tracks with a train speeding toward them, and have gone into emotional shock and become paralyzed to the point of helplessness, the overwhelming majority of people can and do act reasonably and rationally during an emergency. How people absorb or act on information they receive during an emergency may be different than how they behave in nonemergency situations. One cannot predict whether someone will choose fight or flight; however, everyone's behavior will fall at some point on the continuum. Extreme "fighters" may resist taking most actions to keep themselves safe until the very last moment, and extreme "fleers" may take extraordinary additional steps to make themselves extra safe, well in advance of the threat. These normal reactions to a crisis, particularly when at the extreme ends, are often reflected in media reports and erroneously described as "panic." In actuality, panic behavior is defined as behavior counter to survival. Although officials responsible for getting a recommended response from the community may have the impression that people are engaging in extreme or maladaptive behavior, in reality, the overwhelming majority of people do not.[23] The condition most conducive to panic is not bad news; it is conflicting messages from those in authority. People are the most likely to panic (although still not that likely) when they feel that they cannot trust what those in authority are telling them or when they feel misled or abandoned in dangerous territory. When authorities hedge or hide bad news to prevent panic, they are likely to exacerbate the risk of panic in the process.

During the U.S. anthrax incident in the fall of 2001, the media reported local shortages of ciprofloxicin because people began seeking prescriptions anticipating the threat of anthrax. If an individual wants a prescription for ciprofloxicin even though that person lives on the other side of the country from where the exposures had occurred, is that really a panic behavior or one that is counter to survival? On the contrary, it is a display of the individual's survival instinct. If people hear a community leader saying, "don't panic," they may think that does not apply to them. By securing Ciprofloxicin prescriptions, individuals may think they are taking a rational step to ensure survival, and someone else must be panicking. If response officials describe individual survival behaviors as "panic," they will alienate their audience and render them unable to receive the public health message. Instead, officials should acknowledge people's desire to take protective steps, redirect them to helpful actions they can take, and explain why the unwanted behavior is potentially harmful to them or the community. Officials can appeal to people's sense of community to help them resist maladaptive actions aimed at individual protection.[24]

When people are overwhelming emergency hotlines with calls, they are not panicking. They want the information they believe they need and officials should have. As long as people are seeking information, they may be fearful but they are not acting helplessly; they are not panicking. Seeking information is an appropriate behavior during a crisis. Community leaders should share the information that is available and share but avoid pedantic or paternalistic tones. State what is and is not known in the situation using an honest and humble style and empower people as much as possible to draw solid health conclusions for themselves and their loved ones.

Uncertainty

Uncertainty will increase anxiety if there is a perception of danger or threat.[12] To reduce anxiety, persons will engage in information gathering and processing to look for options and to confirm or refute their beliefs. Individuals may believe information used in this process whether or not it is accurate. In fact, to improve coherence and reduce anxiety, persons may be selective about the data they absorb in the process of uncertainty reduction, thus discounting information that is distressing or overwhelming. People seeking information in dangerous situations will be more attentive to behaviors and language styles of persons in power.[12] They may choose a familiar source of information over a less familiar source, regardless of the report's accuracy. Persons less certain of their ability to process information involving complex situations may choose an advocate to collect and interpret information for them.

Early in a crisis, there are typically more questions than answers. The full magnitude of the problem is unknown. Perhaps the cause of the disaster is unknown, often including the cause of the disaster itself. Even actions people can take to protect themselves may be unclear. It is dangerous to promise an outcome outside of one's control, especially if one is in a position of responsibility. One should never utter a promise, no matter how heartfelt, unless it is in one's absolute power to deliver. Officials can hope for certain outcomes, but most cannot be promised. New York Mayor Rudy Giuliani cautioned, "Promise only when you're positive. This rule sounds so obvious that I wouldn't mention it unless I saw leaders break it on a regular basis."[25]

People can manage the anxiety about uncertainty if officials share with them the process they are using to obtain the answers.[7,24] "I can't tell you today what's causing people in our town to die so suddenly, but I can tell you what we're doing to find out. Here's the first step . . . " or "It's too early to declare that this is the pandemic we've been predicting – but this is still a serious health concern because the virus is transmitting between humans, and here are the steps we're taking next."

Remember, in a crisis, people believe any information is empowering. Tell them what is known now and, most importantly, tell them what is not known and explain the process being used to determine the answers.

So if people are not panicking, why can things seem so confused and challenging in a crisis, especially in the early stages? Just because an action a person chooses to take may be driven by survival instincts, it does not necessarily mean it is the best behavior for the community as a whole. There are a number of troublesome expected behaviors that can and do occur in major catastrophes. A leader should be aware of these behaviors and be prepared to confront them in communications to the public.

ACKNOWLEDGE PEOPLE'S FEARS

When people are afraid, it is counterproductive to pretend that they are not or tell them they should not feel fear.[1] Both responses leave people alone with their anxiety. (Mishandling people's fears goes hand in hand with over-reassurance, but it is conceptually different: "Everything is under control" versus "Don't worry.")

Even when the fear is totally unjustified, people do not respond well to being ignored – nor do they respond well to criticism, mockery, or statistics. These approaches are marginally effective even when the fear is warranted. Instead, officials should acknowledge fears while concurrently providing people the information they need to put those fears into context. Giving people permission to be excessively alarmed about a bioterrorist threat makes it far likelier they will actually be reassured.

Stigmatization

In some instances, victims may be stigmatized by their communities and refused services or public access.[26] Fear and isolation of a group perceived to be contaminated or a risk to close contacts will hamper community recovery and affect evacuation and relocation efforts. In a disease outbreak, a community is more likely to separate from those perceived to be infected.

During the severe acute respiratory syndrome outbreak, which was believed to have originated in China, cities around the world reported that the public avoided visiting Chinatown sections of their cities. The governor of Hawaii publicly had dinner in the Chinatown section of Honolulu at the time to help counter the stigmatization that was occurring. This is a good example of leadership modeling behavior desired by the public.

Response officials must be sensitive to the possibility that although unintentional and unwarranted, segments of their community could be shunned because they become "identified" with the problem. This could have both economic and psychological effects on the well-being of community members and should be challenged immediately. This stigmatization can occur absent any scientific basis and could come not only from individuals but entire nations. During the avian influenza outbreak in Hong Kong in 1997–1998 and during the West Nile virus outbreak in New York City in 1999, policies of other nations banned the movement of people or animals, absent clear science indications for those measures.

Perception of Risk

The perception of risk is also vitally important in emergency communication. Not all risks are created equally.[1,6] A wide body of research exists on issues surrounding risk communication, but the following emphasizes that the public accepts some risks more than others.

- Voluntary versus involuntary: Voluntary risks are more readily accepted than imposed risks.
- Personally controlled versus controlled by others: Risks controlled by the individual or community are more readily accepted than risks outside the individual's or community's influence.
- Familiar versus exotic: Familiar risks are more readily accepted than unfamiliar risks. Risks perceived as relatively unknown are perceived to be greater than risks that are well understood.
- Perceived origin of risk: Risks thought to be generated by nature are better tolerated than risks perceived to be intentional inflicted.
- Reversible versus permanent: Reversible risk is better tolerated than risk perceived to be irreversible.
- Statistical versus anecdotal: Statistical risks for populations are better tolerated than risks represented by individuals. An anecdote presented to a person or community, i.e., "one in a million," can be more damaging than a statistical risk of one in 10,000 presented as a number.
- Endemic versus epidemic (catastrophic): Illnesses, injuries, and deaths spread over time at a predictable rate are better tolerated than illnesses, injuries, and deaths grouped by time and location.
- Fairly distributed versus unfairly distributed: Risks that do not single out a group, population, or individual are better tolerated than risks that are perceived to be targeted.
- Generated by trusted institution versus mistrusted institution: Risks generated by a trusted institution are better tolerated than risks that are generated by a mistrusted institution. Risks generated by a mistrusted institution will be perceived as greater than risks generated by a trusted institution.
- Adults versus children: Risks that affect adults are better tolerated than risks that affect children.
- Understood benefit versus questionable benefit: Risks with well-understood potential benefit and the reduction of well-understood harm are better tolerated than risks with little or no perceived benefit or reduction of harm.

In any discussion of risk, the scientist may perceive one risk in 10,000 as an acceptable risk when the listener may anecdotally be familiar with that one adverse outcome and believe that the personal risk is much greater. Perception of risk is not about numbers alone. These and other risk perceptions must be considered during a crisis.

A blind spot for response officials is in measuring the magnitude of an event. Typically the magnitude of the event is measured by the number of people injured, ill, or dead, or the dollar amount and geographical spread of property damage. One must also consider the causative agent of the event. The principles of risk communication are vital when developing messages during an emergency. If it is the first emergency of its type – irrespective of etiology or magnitude – the communication challenges will increase, even if the severity of the crisis is not as great as previous events. Health officials must measure the magnitude of a crisis based on three things: the degree of physical and mental impact on people (i.e., ill, sick, or dead), the degree of property damage, and the emotional toll the crisis takes on the population based on its attributes.

ROLE OF THE SPOKESPERSON

The right spokesperson at the right time with the right message can save lives. The following emergency risk communication principles should be incorporated into messages.

- Acknowledge fears. Do not tell people they should not be afraid. They are afraid, and they have a right to their fears. Expert spokespersons should simply share reasons why they are not afraid (based on expert knowledge) and let people conclude for themselves why this expert is less concerned. Never follow with "so do not be afraid."
- Express wishes. "I wish we knew more." "I wish our answers were more definitive." An "I wish" phrase expresses empathy.
- Give people things to do. Offer a range of responses – a minimum response, a maximum response, and a recommended

middle response. (e.g., Do not drink the tap water; buy bottled water; boil the tap water.)

- Acknowledge the shared misery. Some people will be less frightened than they are miserable, feeling hopeless, and defeated. Acknowledge the misery of a catastrophic event and then help move people toward hope for the future through the actions of the organization and through actions that they too can take.
- Give anticipatory guidance. If officials are aware of future negative outcomes, they should let people know what to expect (e.g., side effects of antibiotics). If it is going to be bad, tell them.
- At some point, be willing to address the "what if" questions. These are the questions everyone is thinking about and wants answered by experts. Although it is often impractical to encourage "what ifs" when the crisis is contained and not likely to affect large numbers of people, it is reasonable to answer these questions if they could happen and people need to be emotionally prepared for them. If officials do not answer the "what if" questions, someone with much less expertise will likely answer them. If spokespersons are not prepared to address "what ifs," they may lose credibility and the opportunity to frame the "what if" questions with reason and valid recommendations.
- Be a role model and ask more of people. Many trauma experts agree that the psychological outcome of a community as a whole will be resilience. Perhaps the most important role of spokespersons is to ask people to bear the risk with them. People can tolerate considerable risk. If spokespersons acknowledge the risk, its severity, and complexity and acknowledge fears, they can then ask people to bear the risk during the emergency and work toward solutions.

Case Study: The Israeli Risk Communication Experience

During the past several years, Israel has suffered from several large-scale events that necessitated development of a robust risk communication program preparing the Israeli population to best protect themselves.

1) The War Against Terror
   a) Over a 6-year period beginning in September 2000, more than 5,600 civilians were wounded and more than 785 civilians were killed due to terror events in Israel.
   b) Most of the casualties occurred during 2002–2003, usually resulting from suicide bomber attacks.
2) The Second Iraqi War (Operation Iraqi Freedom)

   Israel had only a few months to prepare the population and to provide protection in case of a conventional or unconventional attack (2002–2003). Iraq fired 39 Scud missiles at Israel during the first Gulf War, all armed with conventional explosives. It was known that they possessed weapons of mass destruction.

3) The Second Lebanon War (2006)
   a) During the second Lebanon war, Hezbollah (an extremist Shiite Muslim organization in Lebanon) attacked the northern part of Israel with more than 4,000 rockets. This resulted in more than 4,300 civilian casualties (half of them with mental illnesses) and an additional 42 civilian deaths.
   b) The war started precipitously without any warning time to prepare the population and lasted 33 days.

Table 22.1: General Information on the State of Israel (at the time of this writing)

√ Seven million inhabitants, many being recent immigrants. From 1989 to 1996, approximately 670,000 people emigrated from Russia
√ Area – 20,770 km^2
√ Gross domestic product (GDP) – 179 billion dollars U.S.
√ Religion: 76.5% Jewish, 16% Moslem, 2% Christian, 1.5% Druses, 4% other
√ Only democracy in the Middle East
√ Israel is a single state with a single command structure (single national police force, fire department, and emergency medical system)
√ Multilingual – Hebrew, Arabic, English, Russian, and Amharic
√ High percentage of population with military service background
√ Population is well educated
√ Majority of hospitals are public
√ Has a "Home Front Command" (established in 1992). One of its main goals (by law) is to prepare the Israeli population and to instruct them on civil defense issues

Understanding Israel's basic infrastructure is critical to place the information to follow into context (Table 22.1).

Insights and Observations

OBSERVATION 1

Preparing a country's population requires extensive time and effort, willing and engaged decision makers, and a substantial budget. Preparations must be coordinated with all relevant organizations and should begin in advance and be revised during and after the event.

OBSERVATION 2

A country must identify and be prepared for legitimate threats. Using cost/benefit analyses, decision makers must set priorities because limited resources (including the public's time and attention) make it impossible to prepare for all hazards concurrently. As an example, in preparing for Operation Iraqi Freedom, Israel focused on mitigating both a conventional and unconventional missile attack through public education on the use of gas masks and how to prepare a shelter (Figure 22.2).

Figure 22.2. A child's gas hood. See color plate. *Source:* HFC.

OBSERVATION 3

The plan must be developed, tested, and evaluated in advance and be continuously updated. It should include roles for all relevant organizations and the media. Periodic exercises, some of which include the community, must be conducted to test the plan (Figure 22.3).

The plan should include

- Instructions for protective behaviors
- Emergency announcements
- Films that provide guidance to the public (these are labor intensive to prepare)
- Expert analysis and explanation via interviews. Simply having information is inadequate. Experts must also be able to clearly and honestly communicate their knowledge to the public
- Information centers
- Informational websites
- Information sheets (e.g., separate pamphlets or inserted into phone books)

The plan must be continuously reassessed. The situation is dynamic and therefore the plan must be adjusted to the changing environment.

Figure 22.3. WMD Drill. See color plate.

OBSERVATION 4
WORKING WITH THE MEDIA

The media is the key source of information for the public before and especially during events (Figure 22.4). Therefore, positive collaboration is essential. In Israel, the media are considered to be First Responders. Therefore, they must be educated and take part in exercises. They need to understand the threats and the needs of the population. For example, they must understand that a terror event is a double-edged sword. When the media brings publicity to a terror event, it may assist the terrorists in achieving their goals by bringing attention to their cause and creating societal disruptions. In today's information age, there are many opportunities for bystanders to transmit video or pictures from the event. For example, during the second Lebanon war, television studios broadcast real-time footage generated from third-generation cellular phones within minutes of events.

For an effective relationship with the media, it is useful to understand the characteristics they seek

- Timely news coverage, 24/7
- Up-to-date information
- Relevant material
- Newsworthy events
- Both breaking news and smaller stories with emotional appeal

During events, it is important to deliver the known information as soon as possible. The goal is to be first, be right, and above all to be credible. If officials do not provide information directly to the public, someone else might do so (and it might be the wrong information and also lead to rumor reporting). Once rumors are spread, it will be very difficult to change the public's mind and convince them to trust authorities again.

The media also provides critical information to emergency managers from the scene of an event, at times even before the traditional first responders arrive.

Figure 22.4. News screen capture. See color plate.

OBSERVATION 5
CONTINUOUSLY REASSESS THE PUBLIC'S NEEDS

To be effective, officials must assess the status of the public in real time. Providing guidelines is necessary, but not sufficient. In addition, the public requires instruction and support. Several methods are useful to assess the public's needs.

- Surveys – during crises times, daily surveys should be conducted. Ask the population the key questions that allow assessment of the effectiveness of preparedness or response actions. For example, in the War against Terror, officials learned that the public fully understands instructions and implements the protective actions they should take.
- Focus groups – Conduct focus groups to evaluate the effectiveness of plans. For example, focus group participants gave feedback on educational films or evaluated experts and spokespersons.
- Special officers trained in the psychosocial effects of war serve as observers throughout the country.
- Media – It is important to monitor and evaluate how the media present information to the public.
- Call centers – Officials have established call centers where the public can receive information. During times of crises, the volume of calls increases dramatically. For example, during the 33 days of the second Lebanon war, the Home Front Command received and processed 161,380 phone calls from the public.
- Interviews – Direct interviews with the public can provide useful feedback.

OBSERVATION 6

Public interest and awareness varies depending on the stage of event preparation.

During non-emergent times, the public is occupied with day-to-day problems and concerns. Therefore, it is nearly impossible to persuade them to prepare for something that might happen. However, when the situation is rapidly changing, the public immediately wants all available relevant information. Because it requires significant amounts of time to prepare this information, officials should prepare it in advance to the extent possible and use it at the relevant time.

Risk communications experts also use special methods to deliver important information during non-emergent times. For example, at a designated time each year Israeli officials conduct a "Day of Preparedness" in all the schools in the country. Children then bring home key preparedness information to their families.

OBSERVATION 7

Leaders must deliver an answer that satisfies the majority of the population.

In the words of Pareto, "20% of people consume 80% of your time." The Israeli approach, however, is to provide information to the entire public and not only to the majority. Children, older people, and people with disabilities have special needs. For example, when an alert is being announced, the same alert is sent to deaf people via a pager that was given to them in advance of the event.

OBSERVATION 8

A key principle is achieving resilience – life must go on as close as possible to "normal."

Those opposed to the state of Israel (both countries and terror organizations) believe it would be much easier to achieve their goals by fighting against the population than by fighting directly against military forces. The Israeli population has been educated about this concept. For example, Israeli citizens understand the goal of terror – "to kill one and to frighten thousands." To show resilience, the Israeli population continues its normal life, even after a terror attack (they keep going to the cinema, eating at restaurants and using public transportation, even minutes after a terror event). This is a good example of resilience and risk communication is an important tool to achieve it.

The same concepts apply to wartime scenarios. The goal is for the population to continue their normal lives as soon and as much as possible. Therefore, it is critical to provide the public with timely information. Although information about the threat can cause a rise in anxiety, when it is accompanied by guidance for feasible actions, it leads to preparedness, self-sufficiency, and lower fear levels.

OBSERVATION 9

Different people learn and are affected in different ways.

It is important to use a wide array of methods to communicate with the public.

The following are some of the techniques used

- Public exercises and training.

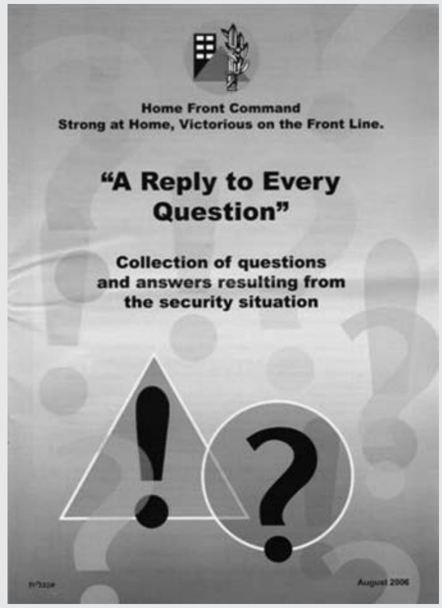

Figure 22.5. Leaflet in English. See color plate. *Source:* HFC.

- Media – television channels remain the principle way to address the public, with radio channels being the second most frequent.
- Internet – public officials should prepare and present important information in several languages and include pamphlets that the population can download from the Internet (see the Home Front Command web link: www.idf.il/oref).
- Written materials – during the Lebanon war in 2006, special information pamphlets were distributed through several methods (e.g, mail, newspaper delivery, at major food stores). These pamphlets provided key information regarding actions a family should take and how they should perform them before, during, and after an attack.
- School and workplaces – these are important sites for information distribution.

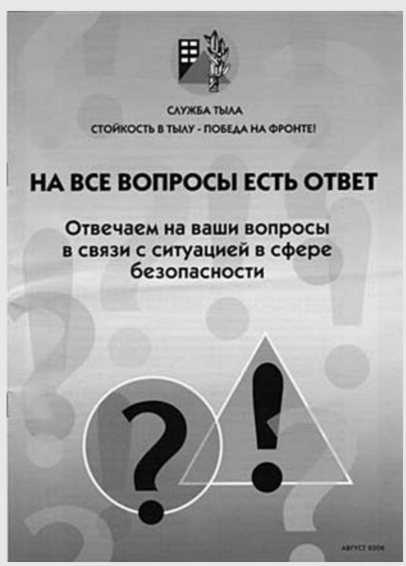

Figure 22.6. Leaflet in Russian. See color plate. *Source:* HFC.

Figure 22.7. Leaflet in Hebrew. See color plate. *Source:* HFC.

- Cell phones – major security announcements can be sent to cell phones via instant messaging.
- Call centers – a national call center provides standardized answers to the public's questions. This call center manages all issues regarding civil defense. At every local authority, there is also a call center. Coordination of the national and local call centers is critical to ensure that callers receive a single, uniform message.

OBSERVATION 10

Because Israel is a country of new immigrants, it is a multilingual society. For example, Arabic is one of the official languages. Therefore, risk communication messages must be prepared and delivered in several languages. It is essential to deliver comprehensive risk communication in Hebrew, Arabic, English, Russian, and Amharic (see Figures 22.5–22.7). In addition, tourists and foreign laborers may need information in other languages. Officials should take into consideration that they must adjust the message to different cultures. For example, the same pictures cannot be used for both orthodox and nonreligious audiences.

Summary

Risk communication is an essential tool to achieve preparedness. The Israeli experience provides valuable information, but it must be carefully evaluated and modified as appropriate before being applied to another system. Many challenges remain. Officials must strive to ensure clear, effective, and coordinated risk communication both before and during an event.

FIVE COMMUNICATION FAILURES THAT INHIBIT OPERATIONAL SUCCESS

Communication experts and leaders who have faced disasters have discovered that certain approaches will cripple or even destroy the success of their disaster response operations.[8,27]

- Mixed messages from multiple experts
- Information released late
- Paternalistic attitudes
- Not countering rumors and myths in real time
- Public power struggles and confusion

Mixed Messages

The public does not want to "select" from one of many messages in which to believe. During the mid-1990s, the Midwestern United States suffered a series of great floods. Response officials determined that the water treatment facilities in some communities were compromised and that a "boil-water" directive should be issued. A problem developed when multiple government and response organizations issued directions for boiling water and each of them was different. In the United States, people generally turn on the faucet and expect clean water. Few people know the "recipe" to boil water because they have never needed it. So for individuals under stress either directly due to an event or as a consequence of providing extensive care to a sick relative, simply "picking one" instruction for sterilizing water is unacceptable. Even healthy people do not like the thought of risking a bad case of diarrhea if they do not choose the right boil-water instructions.

When faced with a new threat, people want a consistent and simple recommendation to follow. They want to hear absolute agreement about what they should do and they want to hear it from multiple experts through multiple sources. Messages can be damaging even if they are not wrong. If they are inconsistent, the public will lose trust in the response officials and begin to question every recommendation.[1,8,27] Local, state, regional, and national response officials and their partners must work together to ensure messages are consistent, especially when the information is new to the public.

Information Released Late

Following the September 11, 2001 U.S. terrorist attacks many individuals wanted advice about whether or not to purchase a gas mask and requested information from the CDC. Three weeks after the attack, CDC had an answer on its website. During the 3 weeks that the CDC required to develop and vet its answer, a number of experts were willing to provide an answer; however, it was frequently not one that was scientifically valid. By the time the CDC issued advice to the public not to purchase gas masks, the "gas mask" aisles at the local Army-Navy Surplus stores were already empty. At the time, few U.S. officials could contemplate the consequences of such an attack. Subsequently, it became clear that officials must anticipate and create a process to quickly react to the information needs of the public. If one cannot provide people what they need when they need it, others will, and those "others" may not have the best interests of the public in mind when they offer advice.

As such, citizens will be vulnerable to receiving inappropriate advice from unscrupulous or fraudulent opportunists or even well-meaning people who do not have adequate expertise.

Paternalistic Attitudes

Imitating the American film actor John Wayne's swagger and ostensibly answering the public's concerns with a "don't worry little lady, we got ya covered" is ineffective in the information age.

People want and expect information that allows them to form their own conclusions.[28] As a response official, it is insufficient to satisfy one's own worries with copious bits of information and then state a bottom line message that is unsupported by the currently known facts. As difficult as it may be, one must help the public to reach the same conclusion by sharing with them what one learned to reach that conclusion. Response officials should determine what they learned that made them believe the situation was not worrisome and then share this information.

Treat the public like intelligent adults and they will act like intelligent adults.[7,21,29] Treated any other way, they will either reject advice from officials or behave in ways that seem illogical. It is ineffective for officials to instruct the public "do not worry." Rather, provide information to individuals that they need and allow them to reach the appropriate conclusion that they do not need to worry. By engaging the public in the process, they will follow.[21,30]

Not Countering Rumors in Real Time

During a pneumonic plague outbreak, an organization's drug distribution program will fail if rumors circulate that there are not enough drugs for everyone. A system is needed to monitor what is being said by the public and the media that permits rapid reaction to false information.

> Rumor management: Holding press conferences every time a rumor surfaces may actually serve to spread it. Instead, a press conference may be necessary if a rumor has been widely published. If the rumor is circulating on the Internet, post a response on the Internet and have a telephone information service ready to address the rumor. The media will report rumors or hoaxes unless officials can rapidly explain why they are false. Have an open, immediately available channel to the media for use when monitoring systems detect a troublesome rumor. Officials should not think "this is preposterous, and no one will believe it." In a crisis, the improbable seems more possible. Deflect rumors quickly with facts.

Public Power Struggles or Confusion

In an actual event, one state's governor held a press conference about a public safety crisis at the same time the mayor of the city was holding one. This set the tone for speculation about who was in charge and what was or was not true.

In the information age, it is easy to see how this could happen. Sometimes there may be a power struggle over jurisdictions or other issues. These issues should be resolved quickly and confidentially. It is disconcerting to the public to think that the people responsible for helping them are not cooperating with each other. All partners need clearly defined roles and responsibilities. When they overlap, make sure officials settle power struggle concerns out of public view so response officials are not confused. When all else fails, stay in the scope of one's responsibility and refrain from declaring authority over an issue without being certain that such authority exists.

Even if everyone attends the same press conference, officials could send the wrong message to the public. If people are jockeying for the microphone or looking back and forth at each other hoping someone will answer a reporter's question, the public will be left with the impression that there is confusion and that power struggles exist among the leadership.

Figure 22.8. Audience relationship to the event. See color plate.

Early in the sniper shooting incident in metropolitan Washington D.C., Montgomery County Police Chief Charles Moose formally requested involvement by the U.S. Federal Bureau of Investigation (FBI). Although there were concerns about what that might mean to local law enforcement, the chief chose to involve the FBI and did it quietly and apparently seamlessly, at least to the public. At no time did the public perceive a power struggle among the response agencies. This, however, was a community that had previously survived a terrorist attack at the Pentagon and an anthrax attack at the Capitol. It had learned the value of a united front with multiple jurisdictions working cooperatively for the good of the community. Interagency disputes need to end the moment a crisis begins. A good plan can help avoid such disputes from the start.

Content is Critical in an Emergency: Identify Audiences and their Concerns

The receiver of one's communication will be judging the content of the message, the messenger, and the method of delivery. Each of these aspects must be considered in planning for crisis and emergency risk communication. The public's awareness of government is heightened during a crisis. A lack of continuity, control, adequate resources, or full knowledge of the event can invoke fear and threaten social unity.[28] The public's needs can be judged three ways: 1) their relationship to the incident, 2) their psychological differences (e.g., fight or flight response and emotional versus adaptive coping), and 3) their demographic differences (see Figure 22.8).

Possible audiences for crisis and emergency risk communication are

1) Public within the circle of disaster or emergency for whom action messages are intended.

Concerns: Personal safety, family safety, pet safety, stigmatization, and property protection.

2) Public immediately outside circle of disaster or emergency for whom action messages are not intended.

Concerns: Personal safety, family safety, pet safety, and interruption of normal life activities.

3) Emergency response and recovery workers and law enforcement involved in the response.

Concerns: Resources to accomplish response and recovery, personal safety, family safety, and pet safety.

4) Public health and medical professionals involved in the disaster response.

Concerns: Resources adequate to respond, personal safety, family safety, and pet safety.

5) Family members of victims and response workers.

Concerns: Personal safety, and safety of victims and response workers

6) Healthcare professionals outside the response effort.

Concerns: Vicarious rehearsal of treatment recommendations, ability to respond to patients with appropriate information, access to treatment supplies if needed/wanted, and how to volunteer for service in the disaster area.

7) Local, state, and national civic leaders.

Concerns: Response and recovery resources, liability, leadership, quality of response and recovery planning and implementation; opportunities for expressions of concern; and trade and international diplomatic relations.

8) Congress or equivalent legislative body.

Concerns: Protecting and informing constituents, review of statutes and laws for adequacy and adjustment to needs, and opportunities for expressions of concern.

9) Trade and Industry.

Concerns: Business issues (loss of revenue, liability, and business interruption) and protection of employees.

10) National Community.

Concerns: Vicarious rehearsal, perceived personal risk, readiness efforts initiated.

11) International Neighbors.

Concerns: Vicarious rehearsal, perceived personal risk, readiness efforts initiated.

12) International Community.

Concerns: Vicarious rehearsal, perceived personal risk, and exploration of readiness.

13) Stakeholders and Partners Specific to the Emergency.

Concerns: Included in decision making and access to information.

14) Media.

Concerns: Personal safety, access to information and spokespersons, and deadlines.

Each of these audiences will desire a specific message. Response officials should prioritize the development of messages for each audience based on their involvement.

Remember the basics when creating messages. Audience segmentation and demographics remain relevant during a crisis. Consider the following

- Education
- Current subject knowledge and experience
- Age
- Disability (hearing or sight impaired)
- Language spoken/read
- Cultural norms
- Geographical location

How Audiences Judge Messages in a Crisis

Expect an audience to immediately judge the content of a message in the following ways.

- **Speed of communication**. Was the message timely? Research indicates that the first message received on a subject sets the stage for comparison to all future messages on that subject. If the public first hears that the world is flat, and then someone comes along and says "the world is round," that message may be less well accepted. Also, the speed with which one responds to the public can be an indicator of how prepared one is to respond to the emergency. More rapid responses can indicate that there is a system in place and that needed action is being taken. If the public is not aware that officials are managing the problem, the response is inadequate. The public may then lose confidence in the organization's ability, and it will need to commit further resources to convince the public that the response system is working.

First impressions are lasting impressions. If an organization fails to gain public confidence early, it will be nearly impossible to recover the public trust. This does not necessarily mean having all the answers; it means having an early presence so the public knows that the organization is aware of the emergency and that there is a system in place to respond. A great message delivered after the audience has turned their attention to other issues is a message not delivered at all. There are two important reasons to be the initial source of information in a crisis. First, the public uses the speed of information flow in a crisis as a marker for judging preparedness.[6] A perfect operational response may be irrelevant without concurrent health risk communication. Even when a hazardous materials team in the U.S. city of Atlanta responded within 2 minutes of a chemical plant fire and made all the correct decisions. The local news coverage was filled with sound bites from angry families. People saw the black smoke and wanted to know if they should evacuate, but were unable to receive rapid, practical information. Parents, gripping the hands of their small children, castigated the people who knew but did not tell them that they were safe. Living in the information age means being expected not only to save lives but also to tell people that lives are being saved at the same time as the event unfolds.

The second reason is a psychological reality. When people seek information, the first message they receive carries the most weight.[23] The tendency is for people to accept the initial information they receive. If they hear a second message that conflicts with the first, they start to weigh them against each other, but tend to give the first message greater value. This is especially dangerous if the first message is incorrect but sounds logical.

For example, the news media reports that health officials are swabbing the noses of congressional staffers for anthrax spores to establish if they need to take antibiotics. A member of the lay public is exposed to a white substance in the break room of the local factory, and thinks a nasal swab should be performed. In fact, a positive or negative nasal swab for anthrax spores is not a reliable way to determine if someone should be given antibiotics.

That determination is made with other data such as proximity to the exposure site and ventilation systems. Even so, reasonable people who were misinformed that nasal swabs were useful in making medical treatment decisions will expect to receive the same care as people in the news who they perceive as being more privileged.

It is better to expend resources and distribute an early correct message, rather than risking the need for excessive resources later to correct a faulty first impression.

- **Factual content of the message**. The public will listen for factual information, and some will expect a recommendation for action. It is important for officials to present the facts accurately, repeat them consistently, avoid the initial delivery of vague details, and ensure that all credible sources deliver the same message. Preparation is critical and consistent messages are vital. Inconsistent messages will increase anxiety and will quickly damage the credibility of experts.

Crafting the Best Messages

Consider the following when creating an initial communication to an audience:

- For the general public, present a **short, concise, and focused message** (6th-grade level). It is difficult in a heightened state of anxiety or fear to internalize copious amounts of information. Get the bottom line out first. In time, the public will want more information.
- In the beginning, provide relevant information only. Avoid starting with a lot of background information. Spending significant time establishing the identity of the spokesperson or the organization is not useful. One sentence should be sufficient.
- **Provide action steps in positives**, not negatives (e.g., "In case of fire, use the stairs," "Stay calm," are positive messages. Negative messages are "Do not use the elevator" and "Don't panic.")
- **Repeat the message**. Repetition reflects credibility and durability. Correct information is correct each time it is repeated. Reach and frequency, common advertising concepts, teach that the message is more apt to be received and acted on as the number of people exposed to the message (reach) and the number of times each person hears the message (frequency) increase.
- **Create action steps in threes or rhyme, or create an acronym**. These are ways to make basic information easier to remember, such as "stop, drop and roll" or "KISS – keep it simple, stupid." Three is not a magic number, but in an emergency, officials should expect the audience to absorb three simple directions. Research indicates that somewhere between three and seven bits of information is the limit for people to memorize and recall.[23] It makes sense in the stress of an emergency to ask the audience to remember fewer bits of information. (For example, anthrax is a bacterium that is treated with antibiotics. Anthrax is not transmitted from person to person. One should seek medical care if exhibiting the symptoms of anthrax: fever, body aches, and breathing problems.)
- **Use personal pronouns for the organization**. "We are committed to . . . " or "We understand the need for . . . "

Avoid

- **Technical jargon and medical terminology**
  - Instead of saying "people may suffer morbidity and mortality," say, "people exposed may become sick or die."
  - Instead of "epidemic" or "pandemic," say "outbreak" or "widespread outbreak."
  - Instead of "deployed," say "sent" or "put in place."
  - Instead of "correlation" say "relationship" (avoid using "cause").
- **Unnecessary filler** – background information (save for other outlets/times).
- **Condescending or judgmental phrases** – (e.g., "You would have to be an idiot to try to outrun a tornado." "Only hypochondriacs would need to walk around with a prescription for Cipro.") Most people are neither idiots nor hypochondriacs, and both ideas have crossed their minds. Insulting the audience by word or tone destroys your chance to influence behavior. That does not mean condoning the behavior; instead, validate the impulse but offer a better alternative and the reasons why it is better.
- **Attacks** – Attack the problem, not the person or organization.
- **Promises/guarantees** – Guarantee only what one can deliver; otherwise, promise to remain committed throughout the emergency response.
- **Discussion of money** – In the initial phase, discussion of the magnitude of the problem should be in the context of the health and safety of the public or environment. Loss of property is secondary. Also, a discussion of the amount of money spent is not a surrogate for the level of concern and response from an organization (what does that money provide?).
- **Humor** – Seldom is humor a good idea. People usually fail to understand a joke when they are feeling desperate. Humor is a great stress-reliever behind closed doors. Inappropriate humor is sometimes used as a coping mechanism during a crisis, but can be detrimental. One should be cautious not to offend others responding to an emergency, even behind closed doors, and be especially sensitive when speaking to the public.

KNOW THE NEEDS OF YOUR STAKEHOLDERS

Stakeholders are identifiable groups of people or organizations who can be reached in additional ways besides through the media. They self-identify as stakeholders. Response organizations do not determine whether these groups have something at stake in the crisis – the stakeholders do. They believe the organizations are beholden to them in some way and these groups expect to communicate with the organization directly and not only via the news media.

The highest level of respect toward a stakeholder group is demonstrated by an organization's leader willing to meet face to face with them. Organizations need to determine who, in a crisis, should be invited to meet with, be called by, or receive a hand written note or personalized e-mail from its leaders. The organization's leaders cannot do all of these things for all stakeholders, so they must delegate some of these activities. For example, Mayor Giuliani tried to attend as many funerals as possible for the firefighters, police, and government workers who died on September 11, 2001 in New York City. He tried not to delegate that task.

Stakeholders are people or organizations with a special connection to an organization and its involvement in the emergency.[21] It is wise to anticipate and assess the incident from the stakeholders' perspective. They will be most interested in how the incident will affect them. Stakeholders are expecting something from the organization. It could be as simple as information released through a website and e-mail or as complex as in-person meetings with key organization officials.

In crisis communication planning, the first step in responding to stakeholders is identifying them. Stakeholders may vary according to the emergency, but core stakeholders will be interested in every emergency and will expect a response from the organization.

Not all stakeholders are supporters of the organization; nonetheless, it is critical to identify unsupportive stakeholders and be prepared to respond to them appropriately. Stakeholders fall into three categories based on their responses in a crisis: advocates, adversaries, and ambivalents. The response to stakeholders will depend on to which of the three groups a stakeholder belongs. The key is to anticipate stakeholders' reactions based on their affinity for the organization and the way that similar groups have reacted in the past when this type of crisis has occurred.

An emergency or crisis may be an opportunity to strengthen an organization's partner and stakeholder relationships as they see it in action. A positive response will enhance the organization's credibility. Therefore, it is prudent to consider existing stakeholder controversies or concerns and how the ongoing relationship will color their attitude during this incident.

By planning ahead and identifying as many stakeholders as possible before the event occurs and the means by which to communicate with them, an organization can respect stakeholders by addressing their special needs for communication.

Expending energy on stakeholder communication during a crisis is valuable for at least two reasons other than one may owe them this attention. First, they may have information of value to the organization. They have points of view outside the organization. Few stakeholders will be shy about pointing out deficiencies. It is preferable for the organization to hear these criticisms directly rather than indirectly through the media. Stakeholders may also be able to help communicate messages for the organization. They may have credibility in circles where the organization lacks influence. If an organization is forthcoming with them, it may face fewer problems during the crisis recovery.

Research has shown that leaders and their organizations make five mistakes during a crisis according to stakeholders.[13,22,27] These errors include: inadequate access, lack of clarity, no energy for response to them, too little too late, and perceptions of arrogance. Most of these represent a lack of resources and planning directed at stakeholder communication.

The Town Hall Meeting

Facing a community in a town hall meeting or citizen's forum during a crisis may be the most difficult communication task asked of a response official. Nonetheless, response officials owe the community the opportunity to meet and discuss aspects of the response. In addition, officials will be held accountable.

However, convening a townhall meeting without preparation and practice is not advisable. A poorly managed meeting can lead to lack of community support. In addition, the people who come to a town hall meeting are not representative of the entire community. They are usually the most angry or frightened. The basic principles for a successful meeting are

- Let people talk. Do not allow experts to lecture. The more people talk, the more successful they will judge the meeting.
- Solicit questions. Listen to their questions before offering solutions. Officials may be surprised to find out that their issues, are in fact not the community's issues. The key is not to offer solutions to problems, rather empower the audience to discover solutions.
- Meet every person's input with respect. Praise people for being willing to offer ideas. Encourage participation.
- Tell the truth. Organizers should admit when they do not know something and follow up to obtain the information people are seeking.
- Do not express anger. Meeting participants may have been emotionally hurt, feel threatened by risks out of their control, feel they are not respected, or have had their fundamental beliefs challenged. Set aside irritation. Instead, strive to understand.

> Town hall meeting management: Sometimes people appear angry because they are advocates for a particular position on an issue. These people become "angry" when the cameras are focused on them. Sometimes people appear angry because they hope to litigate. Set ground rules and remind people that, in *this* town hall meeting, everyone must behave respectfully if they want to be heard. Do not allow hecklers to gain control. Remain calm and take a little more abuse than most people would expect. In so doing, the legitimately angry community members will soon come to the rescue, demanding that the hecklers behave.

Despite all the risks one faces in holding a town hall meeting, officials work for the people and should provide this opportunity. Setting realistic goals for the meeting is important, as it is not the responsibility of organizing officials to have everyone leave the meeting happy. Sometimes, the goal should be to simply listen. One should avoid promising what cannot be delivered, no matter how easy it would be to do so in the moment. In general, it is wise to under promise and over deliver.

Seldom has the approach of giving a lecture led to a change in anyone's mind or behavior. Lecturing is easy – the speaker can vent emotions and is not required to address others' points of view. A lecture, however, does not engage the audience. If people are upset, they want to be heard. Limit opening remarks to 5 minutes or less, because the audience will likely be thinking about what they want to say, rather than listening to someone else.

Providing instructions is easy, requesting input is more difficult. Asking questions is a deliberate action. It forces the process to slow down and forces everyone to stop and think before replying. Instead of attempting to persuade individuals or community groups to take an action, allow them to convince themselves through a self-discovery process. The key is to not provide the solution but to help the audience discover its own answers.

One can assist an audience discover its own answers by asking the right questions. Using feedback as a tool, ask the audience questions that will create awareness about the situation in such a way as to empower them to make difficult choices. As many therapists will attest, people who discover their own answers and say something in their own voices will take ownership of the idea. It is better to ask a leading, open-ended question than to make an interpretation. The right questions can help audiences to make the necessary connections between the information provided by experts and the best possible choices for them in the situation. This strengthens the audience's tendency to claim ownership for the insights.

For example, if a severe communicable disease outbreak were to occur, a challenge for officials in emergency response and public health is the possible need for temporary suspension of civil rights to control the spread of disease. An extreme case would be the need to quarantine individuals or communities. A population that understands the need for quarantine will be more likely to follow officials' instructions.

The following are questions to assist the lay public with taking ownership of protective public health measures

- Start with broad, open-ended questions.

Examples: "What challenges have (you or your community) faced that required consensus building to solve the problem? How did it go? What did you learn from those experiences? Were there difficult choices to make?"

- Then, ask questions to discover the explicit wants, needs, and desires of the audience.

Examples: "What is most important to (you or your community) when faced with a problem to solve? Consensus building? Putting the greater good for the greatest number first? Avoiding conflict? That the solution is fair and equitably distributed? Ensuring that everyone has a voice and is heard? That reasonable alternatives are fully explored?"

- Follow with questions that are more specific to the situation now being faced by the audience.

Examples: "What are the ramifications to (you, your family, your community, the nation) when faced with this current problem? What consequences are you hoping to avoid? What do you see as the worst outcome for (you or your community)? What courses of action do you believe could mitigate this outcome?"

- Then, ask questions that encourage audience members to state the benefits they would like to see result from a course of action.

Examples: "What benefits would (you or your community) expect if this disease did not spread further? Since you've brought up quarantine, what benefits would (you or your community) expect if you accepted quarantine as a course of action to reduce spread of disease?"

- Once the audience sees and expresses the benefits, it will be much easier to demonstrate how a particular strategy can solve the problem.

Examples: "From what I understand, you are looking for a way to protect (yourself, family, community) from more illness or death? If I can go ahead and explain how quarantine will meet those needs, are you open to implementing it? If you think quarantine would work in this effort, how do you see the quarantine being explained to the entire community and implemented?"

Allowing people to persuade themselves is not an easy process. Done poorly, it can seem condescending or manipulative. It takes practice and a great deal of empathy. It is worth the effort, however, because it is truly the most effective way to gain acceptance in thought and behavior.

RECOMMENDATIONS FOR FURTHER RESEARCH

Following the U.S. anthrax events in 2001 and the struggles the CDC experienced with communication, it developed key principles for use of CERC in future potential injury creating events. CDC successfully applied these principles in response to Hurricane Katrina and in preparation for pandemic influenza. There are vital areas of emergency risk communication that require urgent consideration and research such as those related to vicarious rehearsal and outreach to special populations.

Vicarious Rehearsal and Risk Communication

In an emergency, some recovery and specific health recommendations are directed at victims, those exposed, or those who are potentially exposed to the event. The communication age allows some people to participate vicariously in a crisis that is not an immediate danger to them. These people will mentally rehearse the crisis as if they are experiencing it and consider the courses of action presented, which, in reality are being presented to those directly affected by the crisis. Because these observers have the luxury of time to decide their chosen course of action, they may be much more critical about its value to them. In some cases, these people may reject the proposed course of action and choose another or insist that they too are at risk and deserve the recommended remedy (e.g., an emergency department visit or a vaccination). These concerned but unexposed persons may place an undue burden on already thin response and recovery resources. Research is needed to help determine the best way to manage the anxiety created by those who are vicariously involved in a crisis event and who then believe they also should be taking a mediating action. Perhaps alternate "action" messages are needed for people who are not really threatened but are vicariously feeling threatened and may be primed to take an action that is unnecessary. In addition, how should treatment messages be communicated to ensure that only those who should act on them do so?

Emergency Messages in Multicultural Settings

Can emergency communication reflecting a nation's dominant culture's perspectives appropriately influence behaviors of persons from minority groups? Research related to culture and crisis is inconsistent.[12] In crisis situations, development of event-specific messages is needed swiftly. Efforts to tailor messages could, however, slow information flow, creating additional problems regarding credibility and trust. In addition, if messages were culturally tailored in some crises, there may be potential for messages to be misinterpreted as "selective" or culturally biased, which could increase mistrust or create a perception of stigmatization. For example, because most cases of influenza H5N1 historically occurred in Asia, messages tailored by health officials specific to Asian Americans might be perceived by some in the population as focused on their differences and separateness, thus stigmatizing them.

If cultural differences in messaging are neglected during a public safety emergency, will it result in increased levels of illness or death among minority groups? Are people's information needs essentially the same when reacting to serious threats, thus obliterating cultural differences and rendering culturally attuned messaging unnecessary? When the entities communicating with these diverse populations are authoritative governments (i.e., local, state, and federal) that have the power to suspend civil rights, ration scarce pharmaceutical resources, and control information flow, will the absence of culturally appropriate messages complicate disaster operations? These questions should form the basis of crisis communication research to ensure equitable support to all members of the community.

In an international setting, differing cultural norms (e.g., collectivist versus individualistic societies), political structures, media practices, and aversions to risk make the use of CERC principles more challenging. An important area of future research is determining to what extent these principles are universally accepted across cultures and which must be adapted based on national and cultural differences. Zaltman's[31] research emphasizes the commonalities among all human cultures and suggests people are more alike than different. Can health risk communication mitigate inherently harmful behaviors such as the tendency for people to gather at the seashore to watch for the tsunami or discuss as a group whether to exit a burning building? Is there a difference between cultural adaptation for pre-event messaging versus messaging during the event?

The initial objectives for release of public information in a crisis are to prevent further illness, injury, or death; restore or maintain calm; and engender confidence in the operational response. With looming crises such as pandemic influenza, which will involve many national and cultural groups, additional research on these issues is urgently needed.

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23

Telemedicine and Telehealth Role in Public Health Emergencies

Adam W. Darkins

OVERVIEW

Telemedicine and Telehealth

Telemedicine involves the use of electronic information and telecommunications technologies to deliver medical care services in situations in which patients and providers are separated by geographical distance.[1] Telemedicine technologies enable consultations and/or care delivery to take place remotely. Telemedicine has a role in improving access to care, for example in rural and remote areas that are medically underserved. Worldwide, people are becoming increasingly connected by a variety of telecommunications technology platforms. Existing and emerging applications on these telecommunications platforms are rapidly transforming homes and workplaces as well as how services such as healthcare will be provided. Hospitals and clinics have been the main locations for healthcare provision but technology is now taking aspects of these services into the home and local communities.

Telemedicine is a subset of telehealth.[1] Telehealth[2] encompasses a wider use of information and telecommunications technologies to deliver other aspects of healthcare. In addition to clinical consultations and care, telehealth includes the remote monitoring of health status, providing multimedia-based education to staff and offering information to patients to foster informed medical decision making. The role for telehealth in providing healthcare services in public health emergencies should be considered within the context of a changing social environment created by emerging technologies.

Role for Telemedicine and Telehealth in Public Health Emergencies

A public health emergency creates rapid response requirements. General and specialist healthcare provider expertise is needed for immediate triage and treatment of the acutely affected population. Once this initial acute phase of a public health emergency abates, the need for healthcare expertise evolves into providing aftercare and monitoring the remaining at risk population. Healthcare providers must assess the significance of any changes in physical and mental health status of the affected population and provide accurate prognostic information about health risks to individual patients, their family caregivers, and the population at large. There is a wide spectrum of healthcare needs in a public health emergency. Meeting these needs involves the assessment of risk to both individuals and population subsets. Some of this assessment can be accomplished virtually or remotely. Thus there is a self-evident rationale for the use of telehealth in public health emergencies.

A vision for the vital role telehealth can play in public health emergencies follows.

Telehealth should be a vital adjunct to the public health emergency response to assist in saving lives, reducing avoidable morbidity and managing the care of patients with medically unexplained systems.

Patients who are concerned about an exposure, but not truly medically ill, can pose as much of a challenge to emergency responders as those with major injuries or illnesses resulting from a disaster. Among this group of patients are people whose health status may dramatically deteriorate some time later, for example, from an emergency that may or may not have been precipitated by the concurrent event. A good example of this would be a patient who has a myocardial infarction in the aftermath of a major disaster. Within this group are also those with psychological trauma related to concurrent events that may have long-lasting sequelae (see case study 23.1).

Telehealth can play an important technical role in assisting first responders as well as first receivers in remote hospitals, clinics, and shelters. One area in which telehealth can be particularly beneficial is in providing guidance to manage large numbers of patients who present with "medically unexplained symptoms." Healthcare providers can access specialist advice to distinguish between patients who are concerned about exposure and those who may be truly ill and require observation, treatment, and potentially further epidemiological surveillance. There are three main modalities of telehealth that are in routine use that can be used in emergency and disaster management.

- Home telehealth
- Telehealth via real-time clinical videoconferencing
- Store-and-forward telehealth

CASE STUDY 23.1[3,4]

During the morning rush hour on March 20, 1995 a cult terrorist group known as the Aum Shinrikyo placed containers of the nerve agent sarin in five of the carriages on three of Tokyo's underground railway lines. The release of this material resulted in alarms from 15 subway stations as people arrived with breathing difficulties, muscle weakness, and altered levels of consciousness.

Approximately 6,000 people were exposed to the chemical agent. Of these, 3,227 went to the hospital. There were 493 hospital admissions to 41 hospitals. Those seen in the hospital manifested classic cholinergic symptoms, with nicotinic effects predominating. Twelve people died in the near-term as a result of the incident and several developed permanent neurological sequelae. The majority of the victims, however, were acute psychological casualties – people who feared they might have been exposed to sarin vapor but had no real contamination. For at least 5 years after the attack many of those exposed continued to manifest symptoms of posttraumatic stress disorder, a condition that may have been mitigated if there had been earlier recognition and treatment.

Practical Technologies to Provide Telehealth-based Services

Clinical videoconferencing systems such as that illustrated in Figure 23.1, together with the requisite telecommunications connectivity, enable real-time videoconferencing that provides consultation and advice on clinical care. Although it is not currently possible to examine directly a patient when using these systems, there are emerging telehealth technologies, which will be discussed later, that suggest this will happen in the future.

Real-time videoconferencing for clinical purposes, also known as synchronous telehealth,[1] allows an expert clinician from any specialty to help manage patients who are in geographically distant locations (as close as several miles to as far as thousands of miles away). Clinicians providing synchronous telehealth can

Figure 23.1. Clinical Video Conferencing System. See color plate.

Figure 23.2. Home-Telehealth Device. See color plate. Used with permission from Kimberly Boltom.

1) Diagnose
2) Triage
3) Make treatment recommendations such as advise antibiotics and analgesic medications
4) Supervise procedures such as wound debridement and fracture reduction

Synchronous telehealth services can, therefore, supplement or provide otherwise unavailable on-site specialist expertise in the immediate aftermath of a public health emergency. Examples include

1) Management of burn patients requiring urgent access to plastic surgical specialty care
2) Provision of access to specialist assets such as infectious disease consultants to identify and manage an infectious disease outbreak and proactively assist in disease prevention throughout all phases of the emergency
3) Provision of counseling and therapy services to both the affected population and emergency responders with mental health needs secondary to the traumatic events they have witnessed
4) Protection of specialist emergency response healthcare personnel assets in a bioterrorism event by enabling clinicians to render advice from a distant location that does not expose them to contagious agents

Home telehealth[1] devices such as the one illustrated in Figure 23.2 are in routine clinical use. They enable the monitoring of patients with chronic diseases, such as diabetes and chronic heart failure, in their own homes and local communities. The telecommunications modalities used to support these technologies include regular telephone lines, wireless phone technology, and broadband Internet.

The routine recording of vital signs and use of interactive disease management protocols via home telehealth devices can rapidly alert a clinician who is remotely located to the deterioration in the patient's condition so that an appropriate response can be instituted. The appropriate response may vary from supporting patient self-management to providing advice, prescribing new drugs or adjusting medications, or initiating emergency hospital admission. If the clinician monitoring the patients needs further expert assistance, other colleagues can rapidly and easily assist in patient management via electronic systems. Once it is in place, the infrastructure of a home telehealth network readily lends itself to use in a public health emergency. Examples include

1) Quarantine of an exposed population (and isolation of an infected population) in the event of pandemic influenza or a bioterrorism event with a contagious agent such as pneumonic plague or smallpox
2) Monitoring the definitely exposed and those at risk from possible exposure to a pathogen after a bioterrorism incident

In events such as these, the challenge for emergency and disaster responders may be the sheer numbers of people, who by virtue of being at risk, threaten to overwhelm a limited healthcare response capacity. These victims require management in ways that limit the spread of a contagious pathogen. Home telehealth offers a surge capacity[5] that may otherwise be much more costly or even impossible to provide.

The acquisition, storage, retrieval, and forwarding of digital clinical and radiological images, known as store-and-forward or asynchronous telehealth[1] provides simple mechanisms for obtaining remote advice from expert clinicians who can report on digital images, radiographs, echocardiographs, and ultrasound studies. This resource makes it possible to deploy general and lesser skilled personnel to the site of the public health emergency who can receive advice on the triage, immediate care, and ongoing management of those they assess and treat.

Despite compelling reasons for the use of telehealth in the management of public health emergencies that have been recognized for over a decade, it remains an underutilized resource. Its lack of adoption by mainstream emergency and disaster management teams is likely attributable to the following challenges.

1) Lack of standardized clinical pathways
2) Noninteroperability of information technology and telecommunications networks
3) Immaturity of the vital business and management processes that are required to support and sustain telehealth-based services
4) Conservatism of those currently providing emergency services in the absence of compelling evidence of the clinical effectiveness and efficacy of telehealth as compared to traditional practice

These challenges can be summarized as follows:

> Underutilization of telehealth in public health emergencies is the result of a lack of a compelling vision of telehealth as a means of saving lives and reducing avoidable morbidity associated with public health emergencies and translating this into clear strategies and operations guides for its use.

Operations guides for implementing telehealth into the emergency response need to cover clinical, technical, management, and business requirements. Although these operations guides can be created at the local level, ultimately professional organizations, technology panels, standard-setting bodies, legal/regulatory entities, and most importantly government must be fully engaged to make these guides valid and useful. Until this wider collaborative approach to standardizing the role of telehealth in the emergency response is embraced, telehealth networks cannot reach the necessary critical mass to transform public health emergency management. The technologies used by telehealth are already being used in other aspects of the emergency response, such as the remote assessment of physical damage and ongoing risk after disasters.[6]

The four challenges described previously to delivering services via telehealth in public health emergencies are similar to those limiting its growth in routine healthcare delivery. Early adopters who advocate the use of the telehealth response in public health emergencies often suggest developing unique telehealth solutions[7] that are used exclusively for this purpose and not used in routine healthcare operations. A pioneering application of telehealth to provide support in a public health emergency (the Spacebridge project) suggests an alternate strategy (see case history 23.2), that of building on existing systems that are used in nonemergency situations.

One of the reasons for Spacebridge's success was undoubtedly the long-standing expertise of both the U.S. National Aeronautics and Space Administration and the Soviet Space Agency in the remote monitoring and managing of people (astronauts and cosmonauts) as part of their respective space programs. A recurring theme that surfaces when using telehealth in any widespread fashion to manage a public health emergency is that its success is more likely when building on existing systems rather than creating separate, stand-alone networks. Intuitive sense and experience, such as the subsequent use of Spacebridge, illustrate the value of deploying an existing telehealth network that provides routine care delivery during an emergency. In this manner, the technologies have been previously implemented and evaluated by an existing pool of clinicians with documented skill sets. Routine operations guides ensure that these clinicians are comfortable with telehealth technologies and familiar with the practicalities of using them to deliver care. The following issues must be addressed to achieve success.

1) Use of standardized clinical processes
2) Use of reliable, user-friendly, robust technologies
3) Ensuring adequate telecommunications bandwidth
4) Management of legal and regulatory issues, for example, patient privacy issues
5) Addressing business and management aspects
6) Consideration of psychosocial issues

Telehealth and Systems Reengineering

To address the issues that make telehealth deployments successful, there has to be an associated business case that justifies embarking on telehealth implementation. For telehealth to be a serious proposition as a standard part of the routine emergency response, there must be clear clinical and economic justifications for its widespread implementation. Supplementing existing routine and emergency healthcare delivery systems with telehealth is a sophisticated process. Widespread deployment of telehealth requires major reengineering of current healthcare delivery systems. Redesigning a system involves more than merely adding telehealth technologies and their supportive information technology platforms to deliver essentially a duplicative version of current services. A "provide the technology and they will use it" approach to technology implementation without strategic direction is likely to fail. Rather, fundamental changes in clinical and

CASE STUDY 23.2[8,9]

On December 7, 1988, an earthquake measuring 7.2 on the Richter scale struck Spitak, Armenia killing 50,000 people. The Soviet Union took an unprecedented step in allowing international relief workers to provide aid to the homeless and injured. With town and surrounding community hospitals destroyed, there was an urgent need for medical services. One element of this response was an offer from the U.S. National Aeronautics and Space Administration to the Soviet Government to provide telehealth support. This project was called "Spacebridge" because it was established under the auspices of an existing 1987 agreement between the United States and the Soviet Union that allowed for the joint exploration of space for peaceful purposes. The aims of Spacebridge were to provide consultations to a hospital in Yerevan in the Soviet Union from U.S. medical centers in Utah, Texas, Maryland, and the Uniformed Services University of the Health Sciences in the specialty areas of rehabilitation, plastic surgery, mental health, rehabilitation, public health, and epidemiology.

Technical issues that needed resolution before implementing the project were

1) Establishing terrestrial and satellite-based telecommunications links
2) Harmonizing technology protocols and procedures to enable video, voice, and fax communications to support remote consultations
3) Agreeing on common telehealth and staff training procedures
4) Finding suitable translation services to accommodate different languages
5) Ensuring patient privacy for telehealth consultations

The outcomes of the project were that 400 clinicians from the Soviet Union and United States provided expert consultations to 253 of the injured. The Spacebridge was deployed again on two further occasions with similar success. The first was following a train collision outside Ufa Russia when 300 people were killed and many burned following a gas explosion. The second was to help trauma victims following the political uprising in Moscow in October 2003.

business processes are necessary to reengineer healthcare services to develop and sustain telehealth networks.

Creating telehealth networks that can provide support in public health emergencies will radically transform emergency preparedness in both developed and developing parts of the world. This endeavor requires investment in technology, clinical change management, and associated organizational development. The widespread investment to implement these changes, i.e. those required to sustain the clinical, technology, and business processes for telehealth networks, has not yet been made. Decision makers should carefully consider this investment before implementation. Once such changes are made to incorporate telehealth into standard practice, they will likely need to be sustained for daily operations. For example, hospitals that have adopted picture archiving and communication systems to replace the use of x-ray film in routine radiology services do not anticipate reversing the process.[10] Resources to reverse implementation of this system would include recreating x-ray film archives, reemploying staff, reinstituting radiology storage rooms, and then investing in additional equipment and staff training. This brief description of the business process reengineering that accompanies the implementation of picture archiving and communication systems illustrates how telehealth implementation requires a systems approach, one that usually creates multiple interdependencies. Risk management strategies associated with telehealth require the clinical, technology, and business components parts of the new system to be documented, managed, maintained, and updated. Creating an initial telehealth project or program is complex and the long-term support of a new program must include systems maintenance. The vital roles of training and maintenance/support are often neglected when considering implementing a telehealth system.

The benefit of connecting local hospital sites and their associated clinicians with the site of a public health emergency is well described.[11] This chapter assumes general familiarity with such point-to-point approaches to telehealth in public health emergencies[12] and will therefore concentrate on the systems approach to create interoperable telehealth networks. The magnitude of public health emergencies and the challenges they present require telehealth to provide a sizeable, consistent, and reliable resource that deals with the substantive and often acute problems that must be addressed efficiently, effectively, and consistently.

The will, financing, and focus involved in undertaking a widespread radical systems reorganization to implement a telehealth program requires that decision makers embrace change. Which of these drivers is the eventual vehicle varies according to circumstances. In the case of implementing technology-based telehealth solutions, the pace of change typically depends on the baseline level of sophistication of technology within the organization.[13] In regard to telehealth's role in supporting emergency preparedness, there are currently some early innovators, but a preponderance of traditionalists remain who resist these programs. Given a general resistance to organizational change and a comfort with the traditional emergency response, there is currently no overarching driver at the operational, policy, or political levels that supports the changes involved in creating and then sustaining telehealth networks. Understanding how these systems will eventually evolve and creating the accompanying clinical, technological, and business systems is neither a conceptual exercise nor a question of fashionable technology. It must be based on practical considerations of underlying patient care needs in population terms coupled with appropriate support systems. This needs-driven approach to shape systems that support care requires a service-oriented architecture[14] in an organization, something that will be discussed later.

Health Needs as Drivers of the Implementation of Telehealth into Emergency and Disaster Management

Whether voluntarily adopted in the short term or imposed out of necessity in the future, developing telehealth networks to support public health emergencies requires a clear understanding of population-level patient needs. Telehealth must function to

1) Manage these needs more effectively than can be done by the elements of the traditional emergency response
2) Manage these situations at lower cost
3) Protect healthcare workers

Meeting these stipulations raises the following questions: what are the challenges confronting traditional management of public health emergencies that telehealth can meet and can telehealth offer itself as a viable solution to these deficiencies? A case for creating telehealth networks to systematically support emergency services requires more than embracing new technology. The successful creation of telehealth networks to support public health emergencies depends on ensuring they support clinical processes that management personnel can readily apply at the scene in real-time situations. The system must provide a useful adjunct for management and treatment of the acutely ill and injured population. It is the ability of a technology to resolve a clinical need in this way that ultimately drives its adoption into mainstream healthcare usage. What are the needs of patients and staff associated with public health emergencies that telehealth can fill?

By their very nature, public health emergencies and disasters are unpredictable. They are unpredictable in terms of their causation, timing, occurrence, location, and the damage and disruption that they may cause. RAND defines public health emergency preparedness as[15]

> The capability of the public health and health care systems, communities and individuals to prevent, protect against, quickly respond to and recover from health emergencies, particularly those whose scale, timing or unpredictability threatens to overwhelm routine capabilities. Preparedness involves a coordinated and continuous process of planning and implementation that relies on measuring performance and taking corrective action.[16]

The chief mission for the field of public health emergency preparedness is, therefore, to provide an anticipatory response to unpredictable events. Ideally this response prevents, proactively manages, and adapts to the changing way in which most public health emergencies unfold. The traditional emergency preparedness approach has been based on trying to manage this unpredictability by creating systems that seek to impose elements of certainty. Such certainty includes

1) The range of possible eventualities that an emergency preparedness response team might have to face has been fully determined
2) Clear procedures and processes have been formulated to deal with these situations
3) The logistics in terms of people, equipment, supplies, communications, and transport that will be needed to manage likely eventualities have all been determined
4) The command and control structures are in place to manage the initial response and subsequent activities

This traditional approach to preparedness of defining certainty in relation to public health emergencies is essentially an exercise in Newtonian physics. Newtonian physics theory takes a linear view of systems, one in which knowledge of the constituent parts of a system allows its behavior to be accurately predicted thereafter. The reality of public health emergencies is that they are anything but certain. The only thing that is predictable is that the disaster response will not be implemented precisely according to the plan. Yet, if responders use a basic command and control infrastructure, the event can be managed well. The emergency response attempts to bring order, predictability, and ultimately levels of control to disaster management. Information technologies have fostered new approaches to the logistics and management of situations from industrial production to military conflict by enabling just-in-time systems to operate. This creates a more flexible and adaptable response, one that replaces the Newtonian view of events and their management with one in which situations are seen as part of a complex adaptive system. This changed approach is relevant to the role of telehealth networks in providing flexibility and adaptability of healthcare services in an unfolding public health emergency.

Telehealth offers a way in which population needs for healthcare services can be addressed dynamically. The traditional Newtonian approach has its merits in that it is necessary to have an armamentarium of services. The complexity of a public health emergency does not result from unidentified healthcare needs. Usually, the resources to meet these needs are ones that have been considered and are potentially available. It is the logistics of making sure the right care is available at the right time in the right place that is the main challenge. Telehealth offers this “just-in-time” flexibility to supplement the traditional physical response to a public health emergency or to provide urgent support in areas of healthcare delivery that have been neglected. As with the delivery of routine healthcare services, the main benefit of telehealth in emergency and disaster management is that it allows for the re-engineering of clinical processes. Telehealth does not necessarily generate innovative new programs of care. It does facilitate creativity and improvisation that is often the hallmark of success when the unpredictable happens.

Emergency response encompasses a wide spectrum of primary, secondary, and tertiary healthcare needs. Such a response will typically involve governments at the local, state, and federal levels. It necessitates these bodies work collaboratively with nongovernmental organizations and volunteers. A wide range of professional and allied staff may be involved at various stages of a public health emergency. This staff includes, but is by no means limited to, engineers, aid workers, volunteers, law enforcement, water and sanitation workers, and transportation and healthcare professionals, including public health. The public health emergency response includes much more than healthcare services alone. Healthcare services, whether delivered physically or via telehealth, must be considered within the context of the wider response. The information technologies, videoconferencing capabilities, and telecommunications bandwidth that is necessary to support telehealth is equally applicable for nonhealthcare professionals use in other aspects of assessing and managing the emergency response. The current discussion will be limited to the healthcare services response to public health emergencies but recognizes that this is only one component of a broader system.

The effectiveness of the public health emergency response depends on the adequacy of logistics and communications. Detailed plans must provide sound and effective strategies for managing the variety of situations that may be encountered

Table 23.1: Basic Management Elements for the Response Phase of the Public Health Emergency

1	Ongoing surveillance/monitoring to detect the threat to the public health
2	Verifying the existence, associated location(s) and determining the extent and cause of a public health emergency
3	Mobilizing the appropriate local, state, federal, nongovernmental organization, and voluntary responses to the emergency
4	Ascertaining the legal milieu and enforcing laws and regulations to protect health and ensure public safety
5	Instituting existing policies and plans that verify, manage, and contain the emergency
6	Informing the public about the emergency and the appropriate actions they need to take
7	Providing the appropriate triage, preventative, curative, palliative, and investigative services to protect and treat people and animals affected by the public health emergency
8	Depending on risk and exposure related to the nature of public health emergency, evacuate, quarantine, or shelter in place the affected/exposed population
9	Transitioning from the initial emergency response to routine operational management to deal with the aftermath of the immediate emergency situation
10	Reviewing the outcomes, opportunities for improvement, and need for revision of laws, regulations, policies, and procedures

through the phases of a public health emergency and these must include allowances for unexpected contingencies. Embedding telehealth within current healthcare services systems can be accomplished by introducing it directly into existing strategies and programs. For example, the breakdown of routine transportation services during a public health emergency can be mitigated either temporarily or permanently by implementing a telehealth program.

The example of using telehealth in situations where there are transportation difficulties is one of many possible scenarios. Telehealth use for a variety of needs, array of situations, and differing responses associated with a public health emergency creates endless combinations and permutations of how it might be incorporated into an emergency response. In August 2005, Hurricane Katrina illustrated how a sudden loss of critical infrastructure could rapidly render inadequate the ability to deliver healthcare to the population. Telehealth was deployed[17] during Hurricane Katrina, but without a coordinated approach for incorporation into the traditional emergency response. Telehealth can assist with the provision of basic emergency response elements as shown in Table 23.1.

Mounting an effective emergency response with telehealth is dependent on attention to detail. Assessment of the disaster response to Hurricane Katrina and the Indonesian tsunami[18] is prototypical of all such responses. It suggests there could be better coordination of agencies and assessment of needs in the local community to ensure the resources deployed are appropriate, clinically effective, and cost effective. As with nonemergency healthcare, progress is being made to standardize the elements of the response to a public health emergency.[19,20] Since the destruction of the World Trade Center in New York on September 11, 2001 and the anthrax attacks in its aftermath, the need for an effective response to public health emergencies in the U.S. has come under the spotlight politically and in the public consciousness. As a result, new funding opportunities have arisen and with them have come the accompanying expectation of enhanced safety and security for the public. With increasing accountability for a return on investment in emergency preparedness, the issues of dealing with unpredictability and uncertainty rise to the fore.[21] For example, the elusive search for a solution to containing the threat of pandemic influenza has sharpened the attention of governments on the financial accountability of emergency preparedness systems.[22] As the telehealth emergency response scenario below shows, managing the consequences of pandemic influenza is a concrete example of how telehealth should be applied within this framework of financial awareness.

Telehealth Emergency Response Scenario

In the event of a high virulence pandemic, there will likely be widespread contagion and loss of life without an effective vaccine for protection. In the evolving public health emergency, engagement of national governments and international collaboration will be necessary to mount a humanitarian response of unprecedented complexity. From a practical perspective, there will be insufficient hospital capacity to care for infected patients and it would be better to manage many of the victims in out-of-hospital locations. Home and community settings (e.g., community centers and hotels) would probably be used to house those affected and segregate those who have been exposed but have not yet become ill. Home telehealth devices offer one option for monitoring people and helping to manage their treatments remotely, such as via telephone. By using telehealth, fewer healthcare professionals would be needed to monitor and manage a population of patients (100 or more patients can be managed by each nurse). In the event of a pandemic, healthcare professionals will also become infected, thereby reducing the workforce. Home telehealth-based quarantine systems, if adequately designed and appropriately engineered from a clinical and technology perspective, offer a solution to the lack of surge capacity. Figure 23.3 depicts a healthcare professional managing a population of patients who are being monitored on home telehealth systems. The monitor provides population-level data that are viewable on a simple Internet browser–based application that enables expanded viewing to the level of individual patients.

The most significant benefit that telehealth brings to healthcare delivery, whether in providing routine care or emergency care, is that patients can receive attention at their location and need not be transported to a specialist. Healthcare decision-making often takes place in hospitals. Telehealth makes it possible to move the locus of healthcare decision making from the hospital to home or a local community setting. When the physical locations of patient and practitioner are changed through

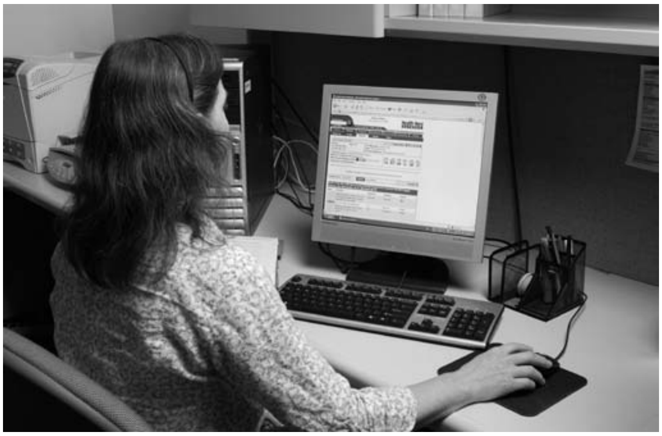

Figure 23.3. Population Management via Home-Telehealth. See color plate. Used with permission from Kimberly Boltom.

the use of telehealth, it is particularly important to pay close attention to the continuum of care. The purpose of monitoring a patient at home in the routine delivery of care is to facilitate treatment in the home or arrange for care in a more appropriate setting. Logically such monitoring activities lend themselves to providing supportive care during public health emergencies.

Individuals who are being managed for injuries sustained in a public health emergency may have existing medical histories that impact how, where, when, and even if they should be treated. After the initial patient assessment at the disaster site(s) and real or potential health-related problems are detected, patients begin a journey of care. They may need ongoing monitoring and if so, it is important to have medical information available for clinicians to compare any change in patient status with the baseline. If the patient has to be evacuated and subsequent care is undertaken at a different location by another clinician, information about the preceding treatment regimen, such as medications or surgeries, needs to be available. Telehealth enables the virtual management of patients across the continuum of care. Telehealth is a safe and effective addition to the delivery of care, provided the elements of this continuum are recognized and the necessary processes are in place to coordinate clinical care. Otherwise it may result in further fragmentation of care and make it less safe. Although aspects of a written patient record can be verbally communicated, sent by fax, or physically attached to the patient, the optimal way to support patient management across the continuum of care using telehealth is to implement an electronic health record (EHR). In the absence of an EHR there are major limitations to how widely telehealth can be used.

It is difficult to build a viable business case for telehealth in the absence of an EHR.[23] Many telehealth applications have rudimentary EHR systems that can support continuity of care but fall short of a comprehensive EHR. These limited software packages lack the advantages of well developed systems, including applications to link with laboratories, operating rooms, and emergency departments. The creation and implementation of EHRs into healthcare systems is a major socioeconomic issue for any nation and has implications for payment systems as well as privacy and confidentiality of personal healthcare information. Implementation of EHRs is proceeding to varying degrees, at variable paces, and with differing success rates in healthcare systems worldwide. The EHR is vital to the creation of telehealth networks; the two systems are synergistic in public health emergencies. An EHR provides more than just a tool for the management of individual patients. Aggregated information from an EHR can offer valuable data for assessing needs, planning services, and patient monitoring and evaluation. If data were available from those who are triaged and assessed, this would transform the management of public health emergencies. Real-time data on the needs of the population would allow a more dynamic response with coordination of healthcare services within a wider emergency management context at the local, national, and international level. This would help manage the logistics of evacuating casualties to local/regional/national or even international medical facilities. The EHR also could facilitate the ongoing epidemiological surveillance of those affected by a public health emergency. Regarding the sarin incident in Tokyo, for example, if an EHR had existed to assist with victim management, it would have been much easier to understand how long-term symptoms related to initial exposure.

The Electronic Health Record and Telehealth

In the routine delivery of healthcare services, the use of information technology to coordinate care has been recognized at the policy level.[24] A health information system is a clear prerequisite to providing safe and effective consultations via telehealth. The success of organizations such as the U.S. Department of Veterans Affairs (VA) in implementing telehealth is, in part, attributable to the presence of an EHR. The EHR facilitates the ability to change the location of care. In public health emergencies, there is a critical health information need to support 1) monitoring, surveillance, and planning; 2) managing the care of those with health problems resulting from the emergency situation; and 3) caring for patients with existing health problems that may have been exacerbated or compounded by the emergency situation.

The EHR offers tools to manage patients across the continuum of care associated with emergency and disaster response, just as it does in routine healthcare delivery. It enables changes in the location of care because it allows the process of healthcare decision making to move closer to the patient. It removes the necessity for the patient to travel to large capital assets such as traditional hospitals to receive expert assessment and care. EHRs and telehealth enable a much more flexible approach to the delivery of care. Major changes in both healthcare and emergency and disaster management often follow what happens on the battlefield. The Korean War introduced the concepts of rapid evacuation and the mobile army surgical hospital, which persisted as standard operating procedure throughout the Vietnam War and until the end of the first Gulf War. The acute management of the combat wounded totally changed with Operations Enduring Freedom and Iraqi Freedom. Initial triage and stabilization now take place closer to the site at which the injury occurred and definitive treatment may happen in another country or even on another continent. Patients need only be "stabilized" prior to transport rather than "stable."

The value of an EHR in a public health emergency was exemplified by the evacuation process for patients in the New Orleans VA who were relocated to other VA centers in advance of Hurricane Katrina in 2005. The EHRs for these evacuated VA patients were available nationally within 48 hours.[25] Impressive examples such as this show the value of the EHR when used for routine care delivery in emergency situations, both for patients affected by the acute event as well as those who require ongoing care for existing health conditions. In a population that is aging and suffering from an increasing burden of chronic disease, public health

Table 23.2: Recommendations for Implementing Information Systems Nationally and Internationally

Ensure information technology system can support the individual, organizational, and institutional needs of users
Avoid simultaneous implementation in an entire large country in one overarching project
Avoid implementing state-of-the art technology with unskilled professionals
Limit the number of project components
Ensure clear ownership of the project and buy-in by users
Ensure compatibility of systems and collaboration among participants

emergencies affect the ongoing care of these patients in ways that can be life-threatening, such as the separation of diabetic patients from their insulin supply. Many other areas of human activity, such as commerce and industry, already use information technology systems to communicate, coordinate, and evaluate complex undertakings. These systems resolve logistical problems in analogous ways to the emerging use of the EHR and telehealth in healthcare.

Although an EHR is of particular importance to telehealth, it must be kept in perspective and viewed cautiously to avoid overzealous and uncoordinated efforts to introduce such systems. It is a considerable challenge to implement hardware and software components of an EHR. Implementing an EHR with the associated training, information technology support, cyber security, interoperability, and other modular components it requires (e.g. laboratory and blood transfusion packages), is a colossal undertaking. To succeed, an EHR project must be well planned, particularly in developing countries. Key principles for the implementation of information technology systems in developing countries to support routine operations[26] are listed in Table 23.2. These same principles apply to projects in developed nations and to telehealth systems.

Basic requirements for an EHR are even more complex than for other systems. Therefore, even if there were unanimous support for an international EHR system to coordinate emergency responses, the challenges of implementing an integrated system offering public health benefit would severely impede its creation, even in developed countries. Nascent elements of a future solution can be seen in projects like the common alerting protocol, which is an attempt to standardize alerts in the event of disasters.[27] The rudimentary nature of the information systems that can be deployed widely in a developed country was shown by the experience with KatrinaHealth in the U.S.[28]

Telehealth logically builds on health information systems for two reasons. First, the EHR provides necessary information that is needed for continuity of care and assists both the referring practitioner and the teleconsulting practitioner in making appropriate treatment decisions. Second, the telecommunications infrastructure required for distributing an EHR helps provide the business case and routine operational telecommunications backbone for a telehealth network. The routine exchange of an EHR on the local area networks and wide area networks (WANs) of healthcare organizations sustains the network and ensures basic interoperability, cyber security, and privacy requirements. These same items apply directly to other systems on the network, such as telehealth. If the organization's information technology infrastructure is not sophisticated enough to implement the requirements of an EHR, it will restrict the development of a telehealth network. An adequate telecommunications infrastructure is as important to the development of telehealth services, as water is to a hydroelectrical power generation project.

Telecommunications Technology Support of Telehealth

Telecommunications technologies are changing the lives of people worldwide. Developing nations that lack impediments to innovation from vast legacy systems, such as public telephones that use copper wire, are leapfrogging over developed nations in their use of new technologies for commercial, leisure, and entertainment purposes. The legacy that current telecommunications systems impose on developed countries means that developing nations may lead the way over developed nations in creating the preeminent technology-based healthcare delivery systems of the future. These nations may also decide how these systems will participate in the emergency response to public health emergencies.

The availability of traditional telephone service and integrated services digital networks (ISDN) as well as cellular, radio, and satellite communications are the basic building blocks for data exchange that can support telehealth services. The ability to use standard telephone service, ISDN, broadband, or satellite communications to connect a patient at one point with a clinician at another site is known as point-to-point telehealth. This will be described in more detail later. Given access to the necessary finances and political willpower, it is possible to purchase the equipment and telecommunications bandwidth necessary for establishing a telehealth project that can support routine healthcare delivery almost anywhere in the world. The step-by-step addition of new participants on point-to-point telehealth networks is unlikely to create systems of the size and complexity needed to assist in routine healthcare delivery, much less support services needed during public health emergencies. The reason for this relates to the nature of telecommunications networks and fundamental systems requirements that can be traced back to the development of the telephone.

After its invention, the telephone was of limited use to the general population because the connections were all point-to-point. The worldwide network of telephone services that is now supported by standard telephone service, wireless, satellite, and the Internet was made possible by the development of telephone exchanges and common dial planes that allow direct dialing. The key developments needed so that telecommunications infrastructures can support telehealth depend on similar technology solutions and standards to ensure they are interoperable. It is outside the scope of the current discussion to describe international efforts associated with telecommunications standardization; however, there are efforts underway to standardize the emergency response to public health emergencies. Although telecommunications needs have been recognized, telehealth is not yet a supported application.

Telehealth and the Standardization of Support Services for the Emergency Response to Public Health Emergencies

The Sphere project is an attempt to define a Humanitarian Charter and Minimum Standards for Emergency Response.[29] It lists contingencies to consider when managing disaster situations, from monitoring clinical conditions such as goiter to logistical issues such as burials. However, it only references telecommunications and does not mention telehealth. Telecommunications are a vital part of disaster relief. By their very nature telehealth services are based on a telecommunications infrastructure. A robust interoperable telecommunications network is a prerequisite for telehealth. The need to develop this telecommunications network for emergency and disaster relief has long been recognized at the international level, but it has been slow to evolve. The Tampere Convention[30] was unanimously adopted on 18 June 1998 by the delegates of 75 countries. Its elements require countries to facilitate the provision of prompt telecommunication assistance in the event of a disaster. The convention covers the deployment of reliable, flexible telecommunication services. Regulatory barriers that impede the use of telecommunication resources for disasters are waived during a public health emergency. This waiver includes licensing requirements for allocated frequencies, restrictions on the import of telecommunication equipment, and mobilization of humanitarian teams. The Tampere Convention also eased restrictions for the use of life-saving telecommunication equipment but did not aid its standardization. The relative inertia in attempts to harmonize telecommunications platforms globally is due to commercial and political considerations coupled with the relative inflexibility of large legacy systems. These issues lie outside the current discussion of the role of telehealth in public health emergencies; however, as a consequence of this lack of standardization, there are problems with interoperability of communication systems, including telehealth. The functional continuity of function of telecommunications systems is vital if they are to support the delivery of health and other services in public health emergencies, as illustrated in Case Study 23.3.

The vulnerability of telecommunications networks to disasters was exemplified by this situation in which it took 48 hours to restore paging services to the areas most affected by Hurricane Katrina.[31] Rescue attempts during Katrina were plagued by problems with nonoperability of telecommunications systems. To help rectify this deficiency in the U.S., part of the telecommunications spectrum has been dedicated to emergency and disaster management services.[32] Considerable work remains to secure land-based telecommunications infrastructure and standardize it in ways that are necessary to support the safe and robust networking services needed for widespread telehealth expansion.

Satellite-based services provide the most reliable and consistently available telecommunications systems in the event of a public health emergency. A disaster such as an earthquake, hurricane, flood, or cyber terrorist attack can disrupt land-based telecommunications systems. Despite the theoretical back up and redundancy of telecommunications fiber in WAN topographies, there are often situations where critical points of failure can occur with damage at a single site. Any design for telecommunications systems that support telehealth should contain back-up arrangements that involve a contingent WAN based on satellite communications.

The need to have a contingent WAN applies to both the routine delivery of healthcare and to telehealth networks that support public health emergencies. The value of using telehealth to provide services at a distance is that existing care delivery systems are redesigned to make care more accessible. Usually the physical provision of certain services can either be reduced or completely curtailed because telehealth offers care more economically and effectively. The end result is that information technology–mediated services replace services that were once delivered directly and in situations where the ability to physically provide services may not be possible. This makes it vital to ensure that telecommunications back-up and redundancy plans exist in the event of failure of the primary technology. Telehealth-based services will likely never replace the need to provide direct care during a public health emergency, but telehealth should be considered part of the emergency response armamentarium, with the aim of providing a flexible and adaptive response. In mounting this flexible and adaptive telehealth response, a critical issue is determining how clinicians and responders at the scene(s) will be connected via telehealth networks. This will require the development of a common telecommunications dial plan[33] for telehealth services, whether limited to the emergency response or applied to telehealth provision generally.

Telephone and cell phone networks have a standardized system to assign numbers and support connections between individuals on the basis of dialing the requisite number(s). This organized system of interconnectivity is known as a "dial plan." A dial plan to connect telehealth clinicians over telecommunications networks must have a standardized structure and must link remote healthcare responders into a prioritized telecommunications infrastructure. It would be pointless to have a widespread network of clinicians available to respond urgently to a public health emergency and then rely on a publicly available telecommunications system to support them. Questions related to the dial plan and access issues emphasize the need for improvement in the human aspects of telehealth networks and how they are organized.

Telecommunications standards for video functions that connect clinical workstations are rapidly changing as point-to-point services are evolving toward multipoint services. The H.320 video protocol[34] for point-to-point over ISDN is evolving to the H.323[35] protocol that allows multipoint connections and many individuals to connect into a videoconference. The future of video services over large telecommunications networks is Internet Protocol[36] (IP) based. There are constraints on the expansion of web-based services to support IP video on the scale that large telehealth networks will require. These should be resolved with the newest version of IP – Internet Protocol Ipv6. The use of IP as the basis for telecommunications connections raises the possibility that large telehealth networks may assemble from smaller existing systems as a network of networks and not as a separate undertaking.

CASE STUDY 23.3

On August 29, 2005 Hurricane Katrina made landfall in southeast Louisiana and Mississippi. As a consequence of the hurricane and subsequent flooding, 1,577 people died in Louisiana, Mississippi, and Alabama. Hundreds of thousands of people were left homeless and a massive humanitarian relief effort was mounted. The event was a severe test of emergency preparedness in terms of logistics and readiness. It took 48 hours to restore even the most basic telecommunications services on a widespread scale.

Clinical Care Networks to Support a Telehealth Response to Public Health Emergencies

A single provider who personally knows the on-site clinician and is linked by satellite-based videophone can improve care and decrease mortality. A relationship-based initiative like this illustrates a benefit of telehealth, but it is not readily scalable beyond a certain size. A systems approach to telecommunications networks is necessary to support large-scale public health emergencies. Emergency managers must assemble and connect the various components of the clinical care network that provide such support. This network is likely to constitute a core of practitioners that have competencies in

1) Trauma and orthopedics
2) Emergency and critical care
3) Neurosurgery
4) Plastic surgery
5) Infectious disease
6) Public health
7) Pediatrics
8) Psychiatry
9) Care of burns

In the event that such a network must be assembled rapidly, it might be possible to use on-the-spot volunteers. The planning and processes necessary to construct a reliable telehealth network require that the appropriate systems are already in place to

1) Verify that staff (volunteer or otherwise) are trained and fit to practice
2) Establish a registry of staff that identifies their appropriate credentials, their clinical specialties, and contact details
3) Ensure that staff have access to equipment that is compatible and interoperable and can link via the necessary telecommunications bandwidth
4) Develop operations guides for staff that focus on explicit processes and communication
5) Train staff in the systems and ensure they are aware of the limitations of telehealth and the support on which they can rely at the patient site
6) Develop and implement quality assurance and outcomes measures as well as the systems to monitor them postevent
7) Construct the necessary systems within emergency response teams to manage and coordinate a telehealth-supported healthcare initiative

The processes 1–6 all currently exist in healthcare but must be adapted to the emergency response. To support the clinical and technology arrangements that make telehealth possible, associated business processes are needed.

Business Processes that Support of Telehealth Networks

Healthcare systems vary worldwide in terms of management style and reimbursement or funding allocation strategies for care. Telehealth facilitates the provision of healthcare irrespective of how it is delivered. The two main approaches to the provision of care are dedicated services and service lines.

Dedicated services are implemented through traditional hierarchies that are professionally based and represent distinct silos, for example orthopedic surgery, emergency medicine, physical therapy, and occupational therapy. This construct bases the delivery of care on the expertise of those providing it rather than on the patients who receive it. Telehealth can readily fit into this arrangement, assuming the clinical activity can be coded on associated information systems and the workload captured by individual professional discipline and subspecialty.

A service line arrangement is one in which the services provided dictate the managerial arrangement. An example is mental health services. Telehealth itself can be managed as a separate service line. This pattern of service delivery is more reflective of the care given to patients. In this arrangement of services, telehealth can be coded for workload purposes as its own entity.

The workload supported by telehealth services is accurately captured, whether delivered as a dedicated service or a service line. Telehealth is distinctly different from other healthcare practice in that there are two separate episodes of care associated with each telehealth encounter. The first is the support of the patient at the site and the second is the consultation services of the clinician who is providing advice from a distance. This duplicative coding requirement can present challenges in some healthcare systems in which the concept of two separate episodes of care occurring simultaneously at two separate sites is anathema.

The arrangements for reimbursement or supplemental funding after a public health emergency is complex and variable within and between nations. The ability to systematically code for telehealth activity means that it is possible to accurately capture workload data and thereby ensure that an accurate reckoning is made for the costs of providing services. Telehealth relies on electronic technologies and it is possible to automate the process of capturing workload activity by using standard codes. One example is the use of Health Level 7 generated by the technologies instead of relying on manual coding of information by clinicians. The ability to track clinical activity and associated costs of telehealth encounters is a vital part of developing telehealth-based services. The nature of large networks that rely on electronic technologies is that they need a stream of high-volume low-cost applications to sustain them. Telehealth networks are sustainable up to a certain size by the variable types of grant funding and barter that often typifies the development of innovative new services in healthcare. However, to achieve a critical mass of permanently sustainable funding, the processes of workload capture, clinical coding, and financial recompense should be as clear and explicit as the clinical and technology processes associated with telehealth.

CURRENT STATE OF THE ART

Introduction

The current state of the art with respect to the use of telehealth in public health emergencies is varied and somewhat rudimentary. Within the wider healthcare arena, telehealth is an innovation that is emerging but lacks the information systems necessary to support it in ways that will transform it into a full-fledged healthcare activity. In many situations, telehealth activities are fragmented and it is difficult to gauge its effectiveness. It is typically a separate endeavor undertaken within an existing clinical service in an informal way, not supported and coordinated at the enterprise level.

Although the current role of telehealth in public health emergencies is limited and variable, there are several telehealth modalities in use, including

1) Real-time clinical videoconferencing
2) Home telehealth
3) Store-and-forward
4) Public telephone systems
5) Amateur radio
6) Web-based information

State of the Art for Real-time Videoconferencing Applications

The Telemedicine Information Exchange[37] provides information on telehealth activity worldwide with sections on

- Africa
- Antarctica
- Asia
- Australia and New Zealand
- Canada
- Caribbean
- Central/South America
- Developing countries
- Eastern Europe
- France
- General Europe
- Germany
- Global
- Greece
- India
- Italy
- Middle East
- Netherlands
- Scandinavia
- Spain/Portugal
- Switzerland
- United Kingdom
- United States

Therefore, expertise from all these countries is potentially available to assist in the event of a public health emergency. The current status of telehealth deployment in emergency preparedness situations is largely that of a single or small group of clinicians providing variable support. There are organizations seeking to develop a clinical network of physicians who can offer humanitarian assistance via telehealth. Humanitarian Emergency Logistics & Preparedness (HELP)[38] is one such organization. It maintains a website[39] through which it strives to mediate ISDN- and IP-based video consultations. This initiative and others like it are works in progress. These are grassroots efforts that are attempting to develop an international network of telehealth providers. There is a tremendous willingness and enthusiasm among individual clinicians to participate in humanitarian assistance via telehealth. Despite this enthusiasm, there are logistical issues that limit implementation. The goal of voluntary, governmental, and international agencies is to harness the volunteerism of clinicians into telehealth networks. Progress by such agencies toward achieving this goal is hampered by the lack of interoperable registries to certify the credentials of these volunteers and the cost of satellite communications, which provide the only current assurance of telecommunications operations continuity.

Satellite Communications for Synchronous Telehealth in Emergency and Disaster Management

There are upward of 150 communication satellites that could be used for telehealth.[40] However, at the time of this writing, the cost of satellite communications is approximately 7.50 USD/minute for only 64 kbit/second transmission (Inmarsat Airtime by KVH). The costs of satellite bandwidth make it prohibitive to use in third world situations where the total per capita annual expenditure may amount to 15 minutes of satellite time.

Despite these constraints, when the United Nations Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space[41] met in 2007, it noted the programs that were contributing to the increasing availability and use of space-based solutions to support disaster management. These included

- Italian-Argentine Satellite System for Emergency Management (SIASGE)
- RADARSAT-2 to reinforce the ability to detect potential disasters
- Use of IRS images
- Indian National Satellite System (INSAT)-based communications and telemedicine services for postdisaster relief operations
- Advanced Land Observing Satellite ("Daichi") of Japan
- ISRO satellite-based search and rescue network (this helped save 30 crew members on board the ship *Glory Moon* in 2006)
- International Satellite System for Search and Rescue (COSPAS-SARSAT) mission control center of Nigeria, which had been supporting search and rescue operations in aviation-related disasters

Although the U.S. military is similarly bound by cost considerations regarding satellite usage, it participated in the Pakistan earthquake relief effort in 2005. The military demonstrated that a robust consultation service for infectious disease, trauma, pediatrics, and dermatology could be established via satellite communications.[42]

Land-based Communications for Synchronous Telehealth in Emergency and Disaster Management

The PROACT[43] system (Preparedness & Response On Advanced Communications Technology) is a synchronous telehealth project based at the University of Kentucky. It was established to bring public health, medical, and other experts together from anywhere within the U.S. via interactive videoconferencing. Its aim is to supplement other elements of the emergency response by

1) Bringing the regional coordinators together on a regular basis
2) Delivering disaster preparedness and response educational programming to communities
3) Engaging communities in statewide planning and response efforts

4) Reaching out across state lines to other PROACT-like networks for regional and national disaster response
5) Providing a channel to connect victims of disasters with specialists from anywhere in the world, including the U.S. Centers for Disease Control and Prevention in Atlanta

The activities of PROACT mirror those outlined by the Southern Governors Association. This group called for the inclusion of telehealth in emergency preparedness[44] and seeks to develop a network of networks to evolve telehealth capacity for emergency preparedness.

Bandwidth, logistics, regulations, and other constraints mean that the status of real-time clinical videoconferencing (and store-and-forward telehealth) has been relatively unchanged since the Telemedicine Spacebridge to Armenia.[10] During operations between March and July 1989, the use of Spacebridge resulted in more appropriate diagnoses being made in 26% of the patients seen. Anecdotal experience repeatedly shows similarly improved outcomes when telehealth is used in this sporadic way. Proponents of telehealth see its value in public health emergencies and call for the development of the telehealth networks that are necessary to support its widespread operational deployment. Opposition to creating these telehealth networks stems from the lack of scientific evidence to support them. Telehealth use in public health emergencies is therefore in the classic dilemma that besets many new innovations in healthcare. Delay in creating the networks that will demonstrate the widespread benefits of telehealth are the norm until scientific evidence for improved outcome can be shown.

To show the benefits of telehealth and provide evidence of effectiveness, telehealth network simulations have been developed.

Real-time Simulations Using Synchronous Telehealth

1) Operation Strong Angel.[45] The United States Navy Third Fleet organized this simulated humanitarian response in Hawaii in June 2000. It took place within the umbrella of the concurrently occurring Rim of the Pacific Exercise[46]
2) North Carolina Domestic Training Exercise.[47] This training exercise took place in June 2002 at Camp Lejeune Marine Corps Base in Jacksonville, North Carolina. It used existing telehealth networks supplemented by rapidly deployable systems like satellite to show how telehealth could enhance the traditional emergency response to a disaster
3) Shadow Bowl.[48] In January 2003, the U.S. Super Bowl sporting event was used as the backdrop to a simulated homeland security exercise that examined community readiness and medical response. Telehealth was used as part of this medical response

There is a commonality of findings from all these simulations. The first and most important is that it is possible to mount an effective telehealth response within the wider emergency response. Even with the advantages of forewarning and planning, it is a complex undertaking to develop the telecommunications infrastructure to support telehealth. Integrating the telehealth response and the use of information technologies into the existing emergency response is challenging. Operational details that reflect the clinical, technical, and business considerations highlighted in the overview section can be problematic. Telehealth networks should be based on realistic simulations.

State of the Art for Home Telehealth Applications

Patient monitoring and telemetry has been featured in simulation exercises but the use of home telehealth technologies to manage public health emergencies has not occurred in real events. Home telehealth technologies have the potential to provide surge capacity, such as during pandemic influenza. The current status of home telehealth services and networks is at an early stage and needs to evolve. Currently relevant issues for the development of home telehealth networks and the provision of surge capacity are

1) The home telehealth industry is an emerging one but still in its infancy, although rapidly increasing in sophistication and interoperability of technology
2) Strategy for technology distribution
3) The telecommunications capacity needed to support such networks
4) Where the necessary clinicians would be situated
5) What protocols and procedures these clinicians would use
6) How home telehealth services would interface with other services
7) How staff would be trained and retrained
8) Whether the necessary patient self-management and family/community caregiver tools could be developed

Without resolution of these issues, the use of home telehealth will likely be sporadic and show limited benefits. In the aftermath of Hurricane Katrina, the care provided to veterans via telehealth in areas not devastated by the hurricane continued uninterrupted. The only exception was the need to transfer support for this remote care from clinicians at hospital sites that were destroyed to other hospital sites.

State of the Art for Store-and-Forward Applications

The Swinfen Charitable Trust,[49] a United Kingdom–based charitable organization, has provided routine medical services to third world countries and shown the great value of store-and-forward technologies. However, such initiatives are fixed in terms of the "people networks" on which they depend. They rely on relationships that are not easy to expand in a complex public health emergency unless the necessary practices, processes, and procedures have been detailed in advance and embedded in the emergency response.

There is increasing use of informal telehealth modalities to provide support in emergency and disaster situations. Examples include the use of e-mail and transfer of digital images over a variety of telecommunications platforms, including cameras in cell phones. These activities are usually ad hoc, poorly documented, and use the general public telecommunications systems. They are, therefore, vulnerable to failure if these networks cease to function. Instead, they need to function as part of dedicated networks to support emergency and disaster management.

The current status of store-and-forward technologies is, therefore,

1) Sporadic and mostly informal
2) When formal, part of the real-time videoconferencing response
3) Subject to the vagaries of telecommunications support
4) Lacks access to accompanying health record systems

5) Has major privacy and cyber security deficiencies in its informal usage

State of the Art for Public Telephone Systems

By definition, there is ubiquitous use of telehealth in both routine healthcare and emergency and disaster operations when the public telephone system is accessed. However, this resource is subject to disruptions from network damage and to inadequate capacity due to sheer call volume in a public health emergency. Despite its limitations, the public telephone system is a mainstay in healthcare delivery. Its use is routine and understood and cell phone technology makes it mobile. It does not lock individuals to set locations in the way that the old copper-wired systems did. The telephone system is often the way in which telehealth systems are deployed that involve clinical videoconferencing. Important initiatives in relation to an expanded role for the telephone in providing healthcare are: 1) to work toward prioritization of users on public telephone systems to ensure that emergency responders get priority and 2) to use the telephone and telephone call centers as sources of public information and epidemiological surveillance.[50]

The Current Role of Amateur Radio Networks in Providing Telehealth

There is a danger with telehealth, as with all new innovations, of not recognizing existing capabilities. An invaluable part of telecommunications support in public health emergencies has been amateur radio.[51] Amateur radio users are often trained and skilled communicators. The emergency management community recognizes these competencies when discussing the Amateur Radio Service. Amateur radio users are a resource that can act as a conduit to help agencies exchange information. They may not understand the medical and health terminology, but the ability to transmit the information accurately makes them an invaluable communications bridge.

The Current Role for Web-based Information

The use of the Internet to provide web-based information and resources is a worldwide phenomenon. The volume of health-related information on the Internet that may be pertinent in the event of a public health emergency is so great that it could not all be synthesized and verified.

The Internet may itself be a target of a terrorist or hacker-induced event. The effect of this could be local, national, or conceivably worldwide. If a patient's EHR were purposely altered, this could lead to a well-meaning telehealth provider inadvertently administering a fatal treatment. In addition, ongoing access to the Internet requires electricity services that despite generators, batteries, and solar energy can be finite. Furthermore, bandwidth capacity might be inadequate to accommodate large numbers of users simultaneously. Thus, a total reliance on posting information on the Internet is unwise and written materials that are published or printable are needed as a backup.

The veracity of Internet information is a critical issue. There have been large purchases or liquidations of stock and other financial instruments triggered by planted rumors on the Internet. The propagation of misinformation in the form of urban legends is well known. Web-based information sources must be credible, authoritative, accessible, and usable by those with disabilities, such as visual impairment.

Examples of credible information sources valuable to emergency responders and the public are the sites for the the U.S. Armed Forces Institute of Pathology Anthrax Education and the Center for Disaster and Humanitarian Assistance Medicine. The anthrax education web site[52] provides information about the pathogenesis and imaging of inhalation anthrax. It is intended to improve the understanding and recognition of inhalation anthrax by diagnostic professionals. The content represents the combined efforts of the Armed Forces Institute of Pathology and the American Registry of Pathology, Washington DC and INOVA Fairfax Hospital, Fairfax VA. The Center for Disaster and Humanitarian Assistance Medicine is supported by the Uniformed Services University of the Health Sciences, Bethesda, MD. Its web site is a resource[53] intended to provide information about chemical and biological warfare and terrorism. Information contained on the site is derived from the organizations' 25 years of instruction on management of weapons of mass destruction events.

Using the web to distribute information requires resources and expertise to maintain the data and keep it scientifically correct and valid. There is also concern that by publicly posting information about the emergency response on the Internet, one may be providing information to terrorists as well as the intended audience.

Web-based resources that provide information to the general public at the local, national, and international levels are currently grossly inadequate with regards to content and quality. Web-based training modules are increasingly providing information for emergency responders. This information, however, is often parochial to individual organizations and not linked with common standards and the operational policies and procedures of other organizations.

Recommendations for Further Research

In the previous sections of this chapter, it has been stressed that the use of telehealth in public health emergencies is at a rudimentary and formative stage. To move forward and use telehealth as a tool to transform elements of the healthcare response, the following areas of research, investigation, and development are important.

1) Policy considerations
2) Organizational strategic considerations
3) Networks of networks
4) Research on the clinical effectiveness of telehealth in public health emergencies
5) Robustness, standardization, and interoperability of technology
6) Understanding that telehealth is a complex adaptive system[54]

Recommendation 1 – Policy Considerations

Central governments and healthcare services should consider telehealth in formal policy terms.

The role of telehealth has not yet been formalized into policy in terms of the routine delivery of healthcare services, let alone for public health emergencies. Governments and health services are notoriously reactive when it comes to policy development in healthcare. The EHR and telehealth are simultaneously transformative and disruptive technologies and organizations. Healthcare professionals worldwide are reluctant to embrace the EHR and telehealth for these reasons. The crisis that affects the delivery of both routine and emergency healthcare services in terms of access equity requires a focus on the patient. Telehealth is a technology that benefits patients by taking services from healthcare facilities to the home and local community. Lack of support from hospitals and the existing healthcare infrastructure is a powerful barrier to change.

ORGANIZATIONAL STRATEGIC CONSIDERATIONS

Similar reservations exist in healthcare and emergency response organizations to adopting telehealth in their approach to managing public health emergencies. In part, this is because healthcare organizations do not plan ahead in a strategic manner and consider the impact of new technologies. This strategic approach requires incorporation into the broader consideration of health informatics and telecommunications implementation and mandates innovative new methods for reimbursement.

RECOMMENDATION 2

Telehealth should be part of the emergency and disaster management strategies for all healthcare organizations.

NETWORKS OF NETWORKS

Healthcare organizations develop their own intranets based on evolving information and communication technologies. Business, technical, and privacy/confidentiality/cyber security considerations make these intranets self-contained offering limited access to the Internet and connectivity with other healthcare entities. Access to the breadth and volume of healthcare services needed in a public health emergency requires that networks of networks aggregate and self-assemble in an organized and cohesive way to offer integrated and interoperable services.

RECOMMENDATION 3

International agencies, central governments, and healthcare organizations should link telecommunications networks and clinical services that provide both routine services and emergency and disaster management.

Research on the Clinical Effectiveness of Telehealth

The use of telehealth in public health emergencies must be based on scientific evidence that it is clinically effective and cost effective. Although there is accumulating evidence for the effectiveness of telehealth in certain areas,[55] such evidence is currently lacking for its application in public health emergencies. A research agenda should be developed and should include ethical dilemmas in disaster research. There are special research considerations in a fast moving technological area like telehealth.[56] For example, the approach of the traditional randomized controlled trial is rarely appropriate.

RECOMMENDATION 4

A comprehensive research agenda should be developed and funded at the international and national levels to generate the evidence necessary to support the use of telehealth networks for emergency and disaster management.

Robustness, Standardization, and Interoperability of Technology

Telehealth in general, and the home telehealth industry in particular, is an emerging enterprise. The future use of telehealth depends on creating robust technologies that are standardized and interoperable. The experience of cellular technologies in public health emergencies shows the dangers of nonoperability. The electronic components required to support telehealth must be engineered to exacting specifications and developed under the necessary standards for interoperability. Wherever possible these new assets should be compatible with existing technologies to maximize the function of older systems (backward compatibility).

RECOMMENDATION 5

Governmental bodies and international/national technology standardization agencies must develop robust and interoperable telehealth technologies that enable the widespread deployment of these assets in public health emergencies.

Telehealth Requires a Complex Adaptive System

The implementation of telehealth by emergency and disaster management in ways that can improve response to contemporary threats and address risk security[57] need to embrace rather than deny uncertainty. Telehealth should be developed within the context of building networks of organizations committed to a process of continual inquiry, informed action, and adaptive learning. This approach is one that recognizes complexity and is different from the traditional anticipatory response to emergency and disaster management that is linear. The emergency response to a public health emergency is, above all, a logistical response. Using a scientific approach to logistics management, investigators are beginning to examine the emergency and disaster response.[58] By considering the key participants, phases, and logistical processes of disaster relief, the parallels with business logistics are identifiable and each can learn from the other. Information systems are key to both.

RECOMMENDATION 6

Organizational development should encompass both linear and complex adaptive approaches as appropriate in developing and implementing telehealth networks.

Conclusion

Telehealth has many applications in the management of public health emergencies. With technologic advances, heightened emphasis on efficient allocation of scarce resources and cost-effectiveness, and protection of emergency responders, telehealth will become an increasing important tool for the emergency managers of the future.

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Complex Public Health Emergencies

Frederick M. Burkle Jr.

INTRODUCTION

Public Health Emergencies

The term "public health emergencies" denotes disasters that adversely impact the public health system and its protective infrastructure (water, sanitation, shelter, food, and health) thus resulting in both direct and indirect consequences to the health of a population. When this protective threshold is destroyed, overwhelmed, not recovered or maintained, or denied to populations through political violence, war, conflict, or other disasters, classic consequences, all preventable, emerge. Outbreaks of communicable disease, food shortages leading to undernutrition and eventual malnutrition inevitably result in worsening vulnerability and insecurity, population displacement, loss of livelihoods, and poverty.

Public health emergencies occur more often in developing countries where public health infrastructure, adequate numbers of health sector workers, and basic medications and equipment are lacking or nonexistent. An exception occurs in developed countries when urban environments become more populous and dense, commonly with migrants experiencing low socioeconomic status and increased vulnerability. Urban occupancy for the disadvantaged is often limited to unfavorable disaster-prone areas with poor or absent infrastructure. Such a combination of factors results in high risk for a major public health emergency to occur if additional essential infrastructure loss were to occur with an earthquake or tsunami. Similar public health emergencies happen whenever the protective public health cover is breached in large-scale disasters such as Hurricane Katrina and the Indian Ocean tsunami. Two years after Hurricane Katrina, a 47% increase in mortality was reported in New Orleans.[1] This uncomfortable outcome of the public health impact of the disaster results from system resources and infrastructure deficiencies that are similar to the familiar and prolonged woes common to countries at war in Asia and Africa. Additionally, large-scale epidemics, pandemics, and other biological, chemical, or radiation disasters have the potential to cause unprecedented public health catastrophes. By definition, public health emergencies result in dire health consequences and share similar health indices such as increased mortality and morbidity, which remain the most sensitive indices of short- and long-term impact and outcome.

Complex Humanitarian Emergencies

The focus of this chapter is the prototypical public health emergency commonly referred to as complex humanitarian emergencies (CHEs). Descriptively, "complex" is added to define a worsening or absent, political, economic, governance, security, and social system that either catapults or accelerates a deteriorating public health environment and severely curtails its recovery.[2] The political violence and warfare commonly grows so severe that it requires international humanitarian assistance and UN peacekeeping or peace enforcement assets to protect the civilian population. CHEs have also been called "complex political emergencies" favored by some to emphasize the pervasive political violence that is at the core of these tragedies.[3]

Additional public health emergencies are covered elsewhere, but because they may differ in cause, all are conceptually linked by similar consequences brought about by the disruption in the protective cover that public health provides to a population. CHEs have been defined by the U.S. Centers for Disease Control and Prevention (CDC) as "situations affecting large civilian populations which usually involve a combination of factors including war or civil strife, food shortages, and population displacement, resulting in significant excess mortality."[4] The twentieth century is known for cross border wars such as WWI and II, the Korean War, and the 1991 Persian Gulf War, yet few understand that during that time more people were killed by war, conflict, and its consequences within their own country rather than from outside forces.

CHEs represent the most common human-generated disasters of the past three decades. Internal crises are often catalyzed by longstanding social and sex inequities, poverty, judicial injustices, cultural incompatibilities, ignorance, racism, oppression, tribalism, and religious fundamentalism, all of which adversely influence public health and access to it.[2] In the past two decades, the agricultural and protective public health infrastructure has declined while hunger in the world (defined as without food

Figure 24.1.1. Refugee camp conditions in northern Iraq 1992. Camp demographics are critical in determining requirements and vulnerability. As Kurdish men were killed by Saddam's Iraqi forces, or were fighting to keep their own territory safe, the fleeing Iraqi Kurds were primarily children (50%) women (30%) and the elderly (20%). Logistics and health care in the precarious camp tents placed on the side of mountains had to adapt to unique needs. (Burkle, 1992). See color plate.
All photos were taken and are owned by me. I give permission for their use. Frederick M. Burkle, Jr., MD, MPH, DTM.

for basic health) has climbed 18% to 850 million people.[5] The chronic, smoldering political violence adversely affects access to and availability of health facilities and services, leading to increasing mortality and morbidity rates among the most vulnerable populations (e.g., women, children, elderly, and disabled). Such data go uncounted, unnoticed, and without political attention from the outside world. While the number of CHEs has declined over the last decade, the few that remain are more complex, longer lasting and more insecure. The number of crisis-affected countries and territories across four continents at risk for deadly conflict remains unchanged.[5] Politically, these are commonly referred to as "failed" or "fragile states."

CURRENT STATE OF THE ART

Measuring the Human Cost of CHEs

Characteristically, CHEs are initially confined within nation-state borders and result in massive numbers of internally displaced populations (IDPs). Political violence and its direct effects on individuals occur first, resulting in death and injury.[3] In time, IDPs begin to experience the consequences of being separated from essential public health services and mortality and morbidity from indirect causes begin to escalate. Most CHEs risk effecting neighboring countries with escaping refugees and in spreading, over time, the political turmoil and the conflict itself across borders.

Without epidemiological studies the short- and long-term impact of various forms of political violence would remain elusive. Studies performed in the early 1990s highlighted the dominance of public health consequences and the preponderance of civilian victims. Epidemiological studies detect and verify continued health problems, confirm whether victims are benefiting from aid operations, and often catalyze major alterations in the direction and strategies of the international relief community and governmental donors. The additional lack of local and nation-state capacities in governance, economics, public safety, communications, and transportation work against an efficient and effective recovery and normalization to predisaster health indices.

Data analysis suggests that CHEs have changed substantially over the last three decades, especially in the overall levels of insecurity.[6] At the time of this writing, in Iraq, for example, security assessments and relief strategies have not yet evolved effectively to deal with worsening security, especially as it impacts civilians and the relief community.

The humanitarian community relies on use of specific direct and indirect indices to 1) assess consequences including severity of the conflict, 2) measure the impact or outcome of interventions in declining mortality and morbidity, and 3) identify the most vulnerable of populations requiring care. The most common baseline health indices followed are

- Mortality or death rates
- Morbidity rates
- Nutritional status
- Aid program indicators to ensure predicted impact and outcome
- Age and sex-specific mortality and morbidity rates critical to determine population vulnerability
- Attack rates and case fatality rates crucial during outbreaks and epidemics

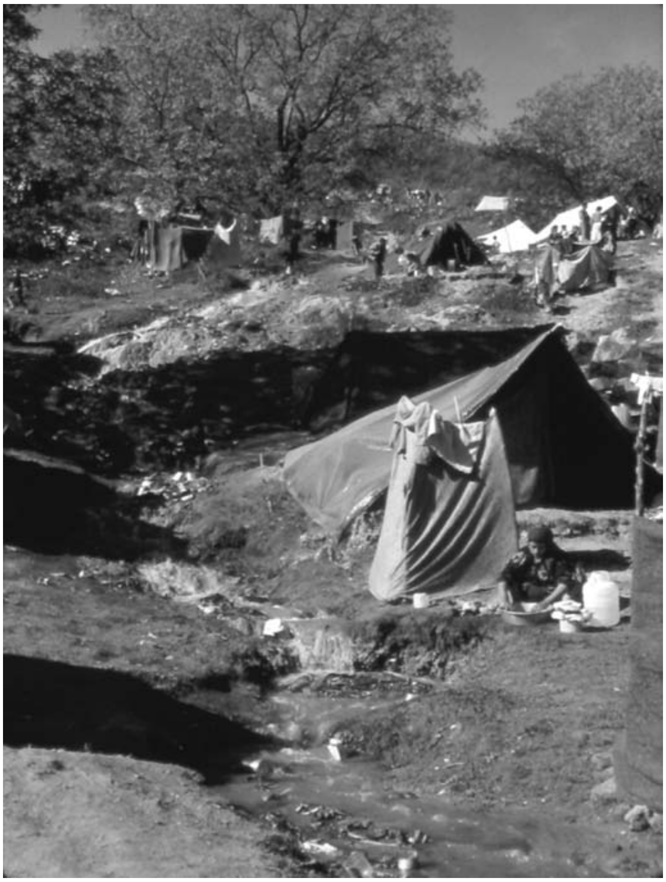

Figure 24.1.2. This Figure illustrates camp conditions that contributed to the 80% of childhood deaths resulting from diarrhea and dehydration secondary to common waterborne bacteria and viruses. Water from melting snow that ran through the camp was polluted by makeshift toilet facility run off and the washing of soiled laundry. (Burkle, 1992) See color plate.

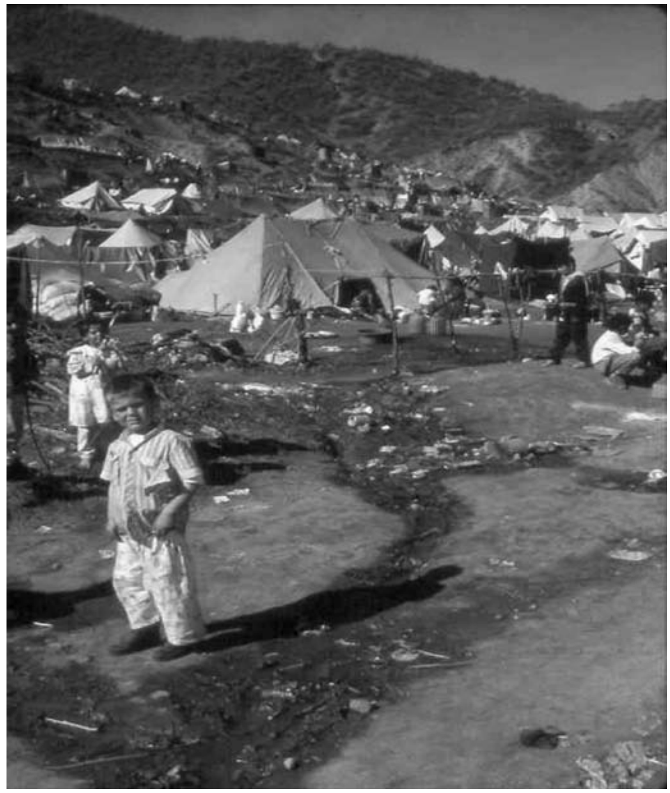

Figure 24.1.3. Mountain streams ended up as stagnant and polluted pools at the base of the camp where children played. Simple and easily corrected public health solutions must be sought to prevent outbreaks. (Burkle, 1992) See color plate.

Direct Indices

Direct effects of political violence result in death, injury, and disabilities, including psychological, as well as the direct consequences resulting from a lack of protection from, and respect for, international humanitarian law. Direct effects are quantitative in nature, subject to organized attempts to measure (i.e., population based cluster sampling), and easier than indirect effects to find and for which to hold people accountable.

Intervention from outside agencies and organizations is initially driven by reports of battlefield and civilian deaths. Assessment teams use both direct observation and rapid assessment tools to measure the consequences of the conflict on essential public health parameters such as access to and availability of food, water, sanitation, shelter, health, and fuel. Initial assessments focus on measurements for crude mortality rates and "younger than age 5" mortality rates. As the humanitarian community becomes more established, follow-on surveys include population-based cluster samplings and studies that further disaggregate the crude mortality rates to determine age and sex vulnerability (i.e., infant and maternal mortality and morbidity rates). Ongoing surveys and surveillance ensure that management responses meet SPHERE (Humanitarian Charter and Minimum Standards in Disaster Response) and other essential public health standards.[7]

The assumption is that low-cost humanitarian aid, if properly performed and managed, will reduce the direct indicator rates to pre-war/conflict levels or better within 4–6 months.[6] As the direct effect mortality rates decline however, so does outside interest and relief aid from donor agencies and governments, often giving a false assurance of success.

Indirect Indicators

It is the indirect collateral damage effects of conflict resulting from population displacement, disruption of food supplies, destroyed health facilities and public health infrastructure, and consequences, such as poverty and destroyed livelihoods that will ultimately account for 90% or more of overall mortality and morbidity. Women and children are the most common victims, as are the elderly and those with disabilities. No existing datasets, however, measure indirect death tolls, and except for a few countries, the humanitarian community has no idea how to gauge the worldwide extent of indirect deaths.

In contrast to direct indices, indirect deaths are rarely measured, are more functional and abstract in nature, frequently require qualitative or semiquantitative measures, and their accuracy is difficult to confirm. In CHEs the health system and public health infrastructure is the first to be destroyed and last to recover or be rehabilitated. In the postconflict phase the risk of continuing death and disability from environmental, communicable, and noncommunicable diseases related to the lack of this recovery may continue to decay up to 10 years postconflict and the effects may far exceed the immediate loses from the war itself.[8,9] Similar consequences are found in countries contiguous to the conflict.

Despite the cessation of hostilities, subtle and rarely counted mortality and morbidity result from those now out-of-work and despondent, demobilized soldiers, and IDPs who are more likely to suffer suicide, depression, and alcohol and drug abuse. A sensitive marker of the continued community decay and economic and physical insecurity is an increase in sex-based violence among intimate partners.[10] In developing countries experiencing residual postconflict insecurity, families struggling to recover economically will frequently delay reenrollment of their children to school, usually females – a factor that subtly correlates with high child mortality rates. Over the past decade, humanitarian assistance has moved from insecure rural Africa and Asia to overcrowded urban areas.[11]

Urban aid is predominantly focused on protecting single or widowed mothers with young children seeking some semblance of security, education, and essential public health and social services once their rural economies are destroyed. Many have been forced to resort to prostitution to avoid abject poverty, only to succumb to the ravages of sexually transmitted diseases. The increased density of urban populations has rapidly outstripped the fragile and poorly maintained public health infrastructure. Few urban conclaves have safe water and sanitation. More than 2.6 billion people, almost one of every two people in the developing world, do not have adequate water and sanitation.[11] In areas where the vector exists, outbreaks of dengue fever serve as a marker of economic decay and worsening governmental services resulting from increased breeding of mosquitoes in the stagnant water of failed public rubbish collections.[12]

Achievement Indicators

Achievement indicators refer to the completion of a certain humanitarian-related missions, such as emergency delivery of military rations and rebuilding of clinics and hospitals. Coalition military and private contractors prefer to use achievement indicators rather than outcome indicators in measuring effectiveness of their interventions. Achievement indicators do not necessarily result in improved outcomes or guarantee the functional return of the health and public health infrastructure. Whereas these functions are critical to the relief process, claims of success in humanitarian aid and reconstruction must be viewed with caution when achievement indicators alone are used.

Epidemiology of CHEs

CHEs can be divided into: developing; smoldering or chronic country; and developed models, all with differing data presentations.[2,4] Models are valuable in predicting priorities for immediate aid, even before confirming field level assessments. There are overlaps in these three models, especially when developed country conflicts persist with failed public health infrastructure resulting in failing indices similar to those seen in developing countries. Iraq once enjoyed stable health indices indicative of a developed country. In 2007, after 4 years of war and a worsening public health infrastructure, the infant mortality rate equaled that of Afghanistan and Sierra Leone.[13] A common element of CHEs is that acts of genocide, ethnic cleansing, and torture have been universally reported in all models.

Developing Country Model

Developing country CHEs primarily occur in central Asia and Africa and are characterized by a health profile that exacerbates preventable diseases, such as infectious diseases and malnutrition, resulting from lack of protective levels of food, water, sanitation, shelter, and healthcare (Table 24.1).[14] This results in high crude mortality rates, the majority coming from deaths from children younger than the age of 5 years. Seventy-five percent of the world's epidemics occur during CHEs.[2] Outbreaks only occur from unprotected endemic diseases. The major causes of mortality and morbidity are diarrhea and dehydration; malnutrition and micronutrient diseases such as vitamin A, C, and B6 deficiencies; complications from childhood vaccine-preventable diseases such as measles and tetanus; and complications from acute respiratory infections; and malaria.

CHEs result in people attempting to flee the war and conflict. If they flee their homes but are unable or unwilling to cross the country's border they are termed IDPs. With international law they remain under the authority of the host country, even though national forces may be attempting to find and kill them. This contradiction remains a dilemma for the international community, a well-known illustration being the forced abandonment

Table 24.1: Developing Country Health Profile

- 90% of deaths are preventable
- Outbreaks of communicable diseases
- Malnutrition and micronutrient diseases
- Absent protective public health infrastructure
- Major deficiencies in WHO childhood vaccine protection
- Mental health consequences are most often unmeasured and untreated
- Internally displaced and refugee populations
- Weaponry, usually small arms and machetes, accounts for 4%–11% of deaths
- High crude mortality rates range from 7–70 times normal baseline
- Higher mortality rates in orphaned and unaccompanied children
- High case fatality rates

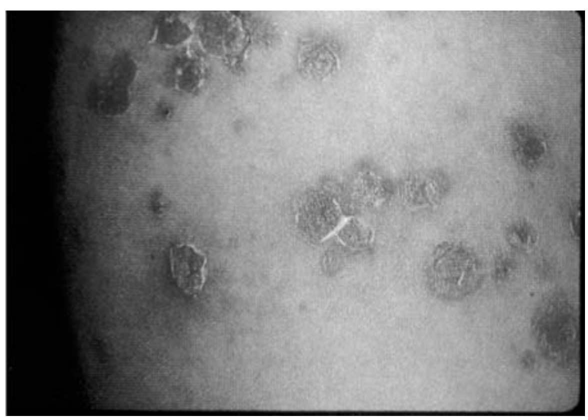

Figure 24.1.4. Although considered a common and treatable problem in the western world, impetigo patients are triaged as urgent in refugee camps and among internally displaced populations, especially if the victims are malnourished. Impetigo can progress rapidly from a minor skin infection to septicemia when micronutrient deficient and severe malnutrition exist. (Burkle, 1990) See color plate.

Figure 24.1.5–7: Scurvy, or Vitamin C deficiency and other micro-nutrient deficiencies (especially A and B l) must be suspected in prolonged war where malnutrition exists. These cases, seen in Viet Nam in the 1960s presented as minor bruising, severe pain when the limbs were moved and fragile tongue lesions that easily bled. Similar cases were seen in East African camps in the 1990s when the waste diet given to refugees lacked micronutrient supplements. Vitamin C serves as a co-enzyme in the metabolic reaction of clotting. Once paraternal Vitamin C was administered, the pain from bleeding under the periosteum ceased rapidly. (Burkle, 1968) See color plate.

Table 24.2: Smoldering or Chronic Country Model Health Profile

- Many years of chronic violence
- Social and political unrest
- Poor maintenance of basic public health infrastructure
- Environmental degradation high
- Little or no access and availability of health and education
- Below-sustenance-level economy
- Chronic malnutrition and stunted growth
- Children grow up knowing only a culture of violence
- Few indigenous healthcare providers
- Lack of basic reproductive health services
- Organized mental health services generally nonexistent
- Incidents of violent surges, resulting in peaks in death rates from direct violence and sudden-onset consequences of chronic conditions (i.e., acute malnutrition and dehydration in children with chronic malnutrition)
- Primarily small arms deaths and wounds, advanced weaponry increasing
- Violent surges increase internally displaced and refugee populations

of fleeing Tutsi civilians by UN peacekeeping forces in Rwanda. Characteristically, IDP mortality and morbidity rates are among the highest and nongovernmental organizations (NGOs) struggle to gain access to them, often one dangerous step ahead of menacing national or rebel forces. Populations who cross borders to flee death and prosecution are allowed refugee status under international law and the protective UN Agency benefits, both physical and political, that these provisions provide. Once international programs are in place in refugee camps the health indices begin to improve and in time may prove better than the neighboring country housing the camps. Crucially, similar aid programs must benefit the surrounding countryside to prevent resentment and new hostilities from erupting.

Required expatriate healthcare assets are those with primary care, public health and preventive medicine, and infectious disease, obstetrical, and emergency medicine skills.[15] Immediate international assistance comes in the form of World Health Organization (WHO) Emergency Health Kits that provide basic health supplies for a population of 10,000 for 3 months. Additional surgical and safe birthing kits are available.

Smoldering or Chronic Country Model

Countries such as Sudan, Haiti, and Gaza have experienced high levels of conflict for many decades, resulting in a distressing health profile (Table 24.2) with characteristics of a country

Figure 24.2.1-2. Examples of dehydration and malnutrition are common in complex emergencies, especially in Africa and Asia. Severely dehydrated children exhibiting extreme loss of skin turgor. (Burkle, 1968) See color plate.

suffering both developmental failure and ongoing requirements for all basic public health services (food, water, sanitation, shelter, health, and fuel) essential for survival. Absent or poorly maintained public health infrastructure results in chronic and untreated survivors of preventable diseases. Expatriate health workers and NGOs frequently serve as the rudimentary public health system for the country but are often prevented by insecurity from providing care to persecuted and minority groups. Communicable diseases within these countries, other than the ravages of human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS), are similar to those seen in the developed world in the early 1900s.

Because of chronic high vulnerability, these countries are more prone to adverse consequences of disasters. Haiti has suffered from increased deforestation and lack of tree–root

Figure 24.2.3. A Kurdish child with severe dehydration from diarrhea. The diagnostic "old man facies" occurs with severe loss of body water and electrolytes. Further examination was not allowed. Confirmatory laboratory tests are rarely available. These cases are usually field managed as isotonic losses with oral rehydration. With clinical improvement the family trusted the physician to complete the physical examination. (Burkle 1992) See color plate.

Figure 24.2.4. The majority of resupply in complex emergencies is through local logistical networks such as these rehydration salts, from UNICEF, being trekked through jungle trails along the Burmese border to a refugee camp run by the International Rescue Committee. (Burkle, 1993) See color plate.

Table 24.3: Developed Country Model Health Profile

- Occur in baseline populations who are relatively healthy
- Demographic and disease profiles similar to western industrialized countries
- Excess trauma deaths from war-related advance weaponry and small arms
- Excess age and gender related deaths increase during times of ethnic cleansing
- Few epidemics
- Excess mortality from untreated chronic diseases
- Significant rates of elderly with undernutrition
- Rape, abductions, and psychological traumatic exposures common

structures that normally protect other countries from worsening floodwaters. In recent years, uncontained floodwaters resulted in more than 3,000 preventable deaths from mudslides and drowning. A dilemma for the international community has been the frustration of responding to an emergency situation within a country that chronically suffers smoldering environmental decay. The environment suffers incrementally with each added conflict or environmental insult (e.g., drought, famine, posthurricane flooding). Do disaster terminology semantics accurately describe the problems that exist? As with Haiti and Sudan, is it appropriate to describe these events as emergencies or as developmental crises? Indeed, they fit a category that exposes the inability of the international community, mainly restricted by existing international sovereignty laws, to intervene on the behalf of innocent civilians who may never see a sustainable life style at any time in their life.

This model results in a chronic excess of "younger than age 5" death rates. Rebel force violent surges result in an increase in adult direct death rates that often represent ethnic cleansing. A return to the chronic epidemiological picture occurs when the fleeing refugees again suffer from the ravages of preventable deaths and morbidity in barren desert conclaves and hastily built refugee camps.

Required professional expatriate assets are similar to that following an acute emergency in a developing country.[15] Without emphasis placed on stable governance and long-term nation-state development, including education and training of indigenous healthcare workers, these countries risk repeating similar emergency crises over and over again.

Developed Country Model

Prior to recent warfare, the former Yugoslavia, Chechnya, and Iraq enjoyed health profiles similar to that of Western industrialized countries (Table 24.3). As with the previous two models, worsening political violence results in internally displaced populations and also refugees seeking permanent asylum in willing countries. Characteristic of this model is the dominance of advanced-weapon-related deaths. When these weapons are fired in an indiscriminate manner, the resulting deaths by the age and sex epidemiology should reflect their representation within the baseline population demographics; however, epidemiological studies in Kosovo showed excess death rates in patriarchal males and young adult males of military age. This study became pivotal in Hague war crime trials as evidence of targeted ethnic cleansing.[16]

Figure 24.3.1. Bubonic and septic plague and other endemic infectious diseases are common when the public health infrastructure is destroyed in war and conflict. This figure illustrates an auxillary bubo. Grain stained confirmed Gram negative bipolar rods. (Burkle, 1968) See color plate.

In the former Yugoslavia the elderly population resisted displacement and often showed rapid decline in health due to undernutrition, stress-related mental health conditions, and exacerbation of chronic diseases such as diabetes, hypertension, and cardiac disease as violence separated them from sources of their medication. Ethnic cleansing methods resulted in rape, abductions, and assassinations. Interestingly, epidemics are uncommon in this model, in part because the educated population is aware, even in the worst of conditions, of the need for some semblance of basic hygiene including hand washing.

With worsening security, attacks against civilian and military targets include increasingly lethal improvised explosive device attacks and landmine detonations. Victims exhibit unprecedented multiorgan high-velocity blast effects. Fragile civilian health systems lack the capacity to manage complicated resuscitations for multiple organ failure, multiple limb loss, acute respiratory distress syndrome, and traumatic brain syndrome and the specialized care required for prolonged recovery and rehabilitation.

With the emphasis on traumatic casualties, the international requirements for aid include emergency medicine and surgical and anesthesia specialties.[15] Such services and resources rarely arrive from outside the country before 3 days time. The best programs are those that use previously educated and trained indigenous healthcare providers. These local personnel assume augmented responsibilities for emergency healthcare and stabilization during and immediately after the traumatic event, with delayed surgery, intensive care, evacuation, and other interventions coming from the international community. It is essential that outside interventions include more skill training provided by the international resources so that the level of competency remains improved even though the international "experts" leave.

Communicable Diseases in CHEs

Connolly et al., found that communicable diseases, alone or in combination with malnutrition, account for most deaths in

Figure 24.3.2. The humanitarian community must be sensitive to cultural beliefs that are not dismissed as modern medical care is added. In this toxic and comatose child, an inguinal bubo was surrounded with a lime substance believed to prevent spread. A paste material was placed over the umbilicus with "Chinese medical" writings as petitions to the "evil spirits" that caused disease. Onion flakes were placed in the hair for fever. The child had a febrile seizure immediately after this photo was taken. The mother, thinking that I had provoked an evil spirit within her child with the foreign instrument (camera) I held in my hand, fled with her child. The mother only agreed to return the child for treatment if I was removed as the health care provider. This being impossible, I managed the case from a distance through locally trained assistants. (Burkle, 1968) See color plate.

Figure 24.3.4. Vaccine preventable diseases are common. Tetanus arising from a foot lesion caused severe "lockjaw" in this 10-year old male. Hyperventilation with nasal flaring resulted in secondary tetany. This child survived with parenteral penicillin and antitoxin. (Burkle, 1969) See color plate.

CHEs.[17] Disease transmission is promoted by poor and dense population conditions common to refugee camps. Refugees fleeing the slaughter from small arms and machetes in Rwanda rapidly crowded makeshift camps across nation-state borders. A camp at Goma, in the former Zaire, surged to a population of more than 300,000 in 5 days. Crowding contributed to outbreaks of dysentery and cholera that killed thousands more. Whereas effective interventions are often possible in camp settings, populations covering large and poorly accessed geographical areas or entire countries pose a greater challenge. Health workers, at a minimum, must have an operational understanding of communicable diseases and the management in austere environments of diarrheal disease (watery, bloody, and nonbloody) and dehydration, acute respiratory infections, measles, tetanus, malaria, meningitis, tuberculosis, HIV/AIDS, viral hemorrhagic fevers, cholera and dysentery, and trypanosomiasis and leishmaniasis.

Standard case definitions for these diseases are critical to reduce variability in reporting. Epidemiological studies confirm, for example, that control of diarrheal diseases occurs through provision of clean water, simple hygiene practices, and sanitation systems, distribution of soap, training of clinical staff and indigenous health workers in aggressive rehydration therapies, and improved basic health services and disease detection. Western medical and nursing resources generally lack education and training in tropical disease diagnosis and management, and lack experience with the manner in which HIV/AIDS, tuberculosis, and malaria first present with advanced complications in a resource poor environment. Management of region-specific

Figure 24.3.3. Flea bite over cervical bubo resulting in highly contagious plague. (Burkle, 1968) See color plate.

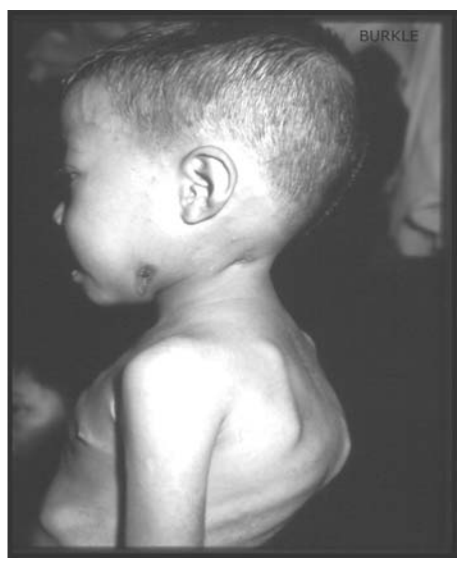

Figure 24.3.5. Tuberculosis is commonly seen and may result in many secondary cases in crowded camps. This child exhibits both Pott's disease and a scrofula lesion of the neck. (Burkle, 1969) See color plate.

Figure 24.4.1. Makeshift tents for women on the left and infants on the right. Kurdish fathers objected to the resuscitative measures taken on their ill infants claiming that death was dictated by religious beliefs. The humanitarian community must recognize cultural, religious, and ethnic restrictions and develop a dialogue that both addresses and balances health requirements and local values. (Burkle, 1992) See color plate.

pharmaceutical resistance must be researched before deployment with special attention to malaria resistance, and to the less frequent clinical presentations of tropical diseases such as dengue fever and Japanese B Encephalitis (Southeast Asia), and leprosy (Sudanese refugees).

There are three key elements to humanitarian interventions in communicable disease.[17]

1) Prevention and control of communicable disease
   a) Adequate campsite planning and shelter
   b) Water and sanitation
   c) Immunization
   d) Vector control
   e) Epidemic preparedness and response
2) Case management
   a) Use of standard treatment protocols
   b) Simplified and efficient drug regimens
   c) Syndromic management protocols for acute respiratory diseases and sexually transmitted diseases are often necessary where diagnostic facilities are lacking
3) Assessment, surveys, and surveillance
   a) Rapid health assessments and an initial overview of immediate consequences and needs
   b) Surveys which consist of intermittent, focused assessments that gather population-based health data
   c) Surveillance consisting of ongoing, systematic gathering, analysis, and interpretation of health data

Trends and baseline epidemiological information are critical for program and mission interpretation and as measures of long-term effectiveness and postconflict recovery and rehabilitation.

Malnutrition and Micronutrient Diseases in CHEs

Food shortages may be generalized across the entire population, limited to the most politically and economically vulnerable within certain ethnic, religious, or minority groups, or found only in IDPs and refugees. The most vulnerable in these populations are children, especially infants and children younger than 5 years of age and those unaccompanied or orphaned, women both pregnant and lactating, the elderly, and the disabled. Mortality and morbidity are most often the result of communicable diseases and malnutrition or a combination of the two. Death due to measles is rare in a nonmalnourished population. In CHEs, deaths from the complications of a simple and preventable childhood disease, such as measles, highlight the inherent threat to the immune system that results from malnutrition and micronutrient disease. Micronutrient diseases such as vitamin A deficiency, even without other manifestations of malnutrition, inhibit biochemical and cellular protective processes essential to infectivity and pathogenicity of an infectious agent.

Malnutrition is best appreciated as a combined threat of protein, energy, and micronutrient deficiencies referred to as protein-energy malnutrition. It is characterized by four therapeutic elements, all of which must be addressed in every malnourished victim.

1) Malnutrition itself is rapidly assessed first by mid-upper arm circumference in both children and adults, followed by surveys using more specific weight-for-height measures, and are continued long term through surveillance-based Z-scores.
2) Micronutrient deficiencies, especially vitamins A, C, and B6, are common and assumed to be present in severe malnutrition, but additional deficiencies should be assessed based on

Figure 24.4.2. "Collateral damage" goes beyond injury and death. The fragile and superficially placed piping seen in the foreground was the main water artery to this village in Iraq. Public health infrastructure may be different than the normal standard for civilian contractors, the military, and aid workers. Public health "indirect" deaths are more prevalent than direct deaths from weaponry and violence. (Burkle, 1992) See color plate.

known regional and geographical deficiencies such as iron and iodine. Prevalence in the population of disorders such as scurvy, beriberi, pellagra, and xerophthalmia give cause to assume that all those with severe malnutrition suffer these deficits until proven otherwise.

3) Assume all those who are malnourished are either harboring an infectious disease or are susceptible to one and its complications. Severely malnourished are often unable to rally fever, positive skin tests (TB), or leukocytosis as indications of an occult infectious disease. Even when skin tests are positive, it is unclear whether this is the result of prior Bacille Calmette-Guérin (BCG) immunization rather than acute tuberculosis infection. This is especially challenging since WHO recommends BCG vaccine be given at birth to patients in the developing world.

4) Assume all malnourished children to be dehydrated. Hydration must be addressed immediately with determination of whether dietary supplementation alone or hospital-based therapies are required. Rarely does the international community provide parenteral rehydration, even in cases of cholera. Studies suggest and clinical experience confirms that oral rehydration is as effective or better than parenteral rehydration even in the most severe cases.[18] International workers must gain experience and confidence in oral rehydration techniques and rehydration salts designed for austere environments.

Figure 24.4.3. This child soldier was a self-designated "general" in the rebellion against the Taylor regime in Liberia. Threatening and unpredictable, he also demonstrated childlike behaviors and needs. Originally from Sierra Leone, he was abducted at the age of eight and knew nothing but war and killing. (Burkle, 2003) See color plate.

Children entering a camp setting are assumed to be vitamin A deficient with no immunity to measles. Progress in humanitarian assistance requires immediate measles immunization, vitamin A supplementation, and possible prophylactic antibiotic coverage. Humanitarian relief efforts in developing countries are directed toward support of breast-feeding with extra rations and micronutrient supplementation to mothers, identifying those infants and children requiring wet nurse supplementation, and supplementary and therapeutic feedings (with hospitalization) for those most severely ill and malnourished. Women in developed countries at war (e.g., former Yugoslavia) more often than not have adopted many developed country habits such as bottle-feeding while working outside the home. Rates of breast milk substitute use of 60% or more provoke a crisis when outside supplies cease as the war escalates. The humanitarian community in the former Yugoslavia and other developed countries in crisis had no option but to reorganize rapidly the logistics system to supply and distribute breast milk substitute and weaning foods.

Psychosocial and Mental Health Problems

Assessment instruments and interventions developed in western countries are medically focused (emphasizing diagnosis and treatment of selected individuals) and rarely assess their cross-cultural impact or accuracy. Individuals suffering from psychosocial and mental health problems often present differently in different environments and require interventions adapted to their situation and culture. Many interventions promoted over the last three decades are not based on sound scientific evidence or best practices, and they have not been evaluated for their feasibility or effectiveness in the contexts in which they are being used, especially among multicultural populations.[19]

Current thinking recommends interventions that promote unity of psychosocial, mental health, and public health approaches while equally emphasizing community and medically based programs along with traditional multicultural and family-centered structures. This approach helps in clarifying that extreme human rights abuses, so prevalent in humanitarian crises, will no longer be simply medicalized. It forces an appreciation that a broader psychosocial, mental health, and public health services approach is necessary to address the variety of cultural, religious, and political factors that threaten well-being among these populations.

Culture can be considered, in part, to be a collection of coping mechanisms or behaviors shared by a group of people. These behaviors are learned ways of navigating the world safely, and having been developed and refined over centuries, these behaviors are often recognized as defining a culture and its strengths. CHEs, especially those resulting in displacement, involve upheaval to the extent that many of these behaviors are no longer appropriate or possible. Psychosocial programming in the immediate period after a crisis should include approaches aimed at making as many of these behaviors as possible appropriate and possible once more.[20,21] This consists of reestablishing many of the physical and social structures that existed prior to the disaster.

- Reconnecting families
- Reconnecting communities
- Reestablishing security

Risk Factors

CHEs produce risk factors that increase both individual and population risk for developing psychosocial and mental health problems and compound the problems for persons with existing psychological conditions.[21–23] Behavior of neglected and abused mentally ill in a refugee camp setting can lead to an erosive impact on the fragile social fabric of displaced communities. Additional factors include, but are not limited to

- Poor health and nutrition
- Separation from family and caregivers
- Suboptimum perinatal care, neglect, and understimulation of children
- Exposure to chronic communicable diseases that affect the brain
- Risk of traumatic epilepsy
- Exposure to extreme and repeated stress and sleep deprivation

War, conflict, and camp conditions often place those with existing problems at greater risk for

- Abuse, including gross dereliction, stigma, ostracism, sexual violence
- Child abduction, youth violence/death
- Family separation and displacement
- Neglect or abandonment by family and caretakers
- Exploitation
- Destruction of supportive institutions and services, including psychiatric facilities and medications
- Life-threatening physical illnesses and suicide
- Conditions that foment hatred and revenge
- Unremitting conditions that lead to worsening disability and premature death, especially among the elderly

Interventions

Common guiding principles and strategies for the humanitarian community in developing interventions for populations exposed to extreme stressors include[21–24]

- Contingency planning before the acute emergency
- Assessment before intervention
- Inclusion of long-term development perspectives
- Collaboration between agencies
- Provision of treatment in primary care and community settings
- Access to services for all in need
- Training and supervision
- Monitoring indicators, including project impact

Immediate psychosocial interventions should focus on supporting public health activities aimed at reducing mortality and morbidity, mitigating the burden on the community of managing the seriously mentally ill who need specialized psychiatric care, and mobilizing community-based resiliency and adaptation to new circumstances affecting people during the emergency. These immediate interventions may mitigate more serious mental illness in a large portion of the affected population.

The challenge for the humanitarian community is to support the population in the displacement camp. Humanitarian agencies and UN agency organizations usually have limited resources and are faced with displaced populations with overwhelming needs. Experience has shown that projects imported to deal with behavioral and mental health problems frequently are lacking in cross-cultural sensitivities or benefits and may prove detrimental. Such programs and their inexperienced personnel have no place in these critical situations. Indigenous and expatriate mental health professionals with specific skills should be properly identified and vetted to provide the best value-added expertise to a community-based approach. In doing so, they will provide care where most needed. Psychiatric, psychological, and social work practitioners trained in developed countries may play a critical role in training, providing consultation, supervision, and specialized care to the most seriously mentally ill, and in providing assessments and evidence-based investigations, preferably through a culturally sensitive partnership with the local population, indigenous healers, and caregivers. Limited resources must

Figures 24.5.1. The picture of mental health problems brought about by war depicts an elderly and overtly psychotic woman abandoned by her family to US military forces believing that the US held magical powers to cure her mental illness. (Burkle, 1992) See color plate.

Figure 24.5.3. A preadolescent male who built a mine to kill "occupying forces" accidentally triggered the device sustaining these severe injuries. More visible hemorrhage was prevented by massive vasoconstriction physiologically available as a last measure before death in children. With anesthesia this hormonal protection ceased and he rapidly lost what remained of his meager blood volume. In this case, the surgical team was aware of this risk and instituted protective blood, fluids and venous access before anesthesia was begun. Decoding of vital signs looking for fragile stroke volume losses are a required skill when Western monitoring technologies are unavailable. (Burkle, 1968) See color plate.

be directed to improve capacity of family basic survival needs through a community-oriented approach.

Psychosocial and mental health services need to be provided through both primary healthcare and community settings. Presentations tend to fall into three categories[24]

1. Severe psychological reactions to trauma

Figure 24.5.2. The last remaining survivor of her families' bunker destroyed in an air raid, this child was mute and refused to be held or receive care within the hospital wards. (Burkle, 1968) See color plate.

2. Significant problems in individuals who may be able to cope and adapt once peace and order are restored (this subgroup generally represents the majority of the population)
3. Disabling psychiatric illnesses (new or exacerbation of existing illness)

THOSE SUFFERING FROM SEVERE PSYCHOLOGICAL REACTIONS TO TRAUMA

Displacement from home and familiar cultural and religious surroundings may cause cognitive and emotional disorganization in the displaced population. This is often catalyzed by some degree of "experienced brutality" (e.g., rape, physical and mental torture, witnessing of killings of family and friends), which because of fear of possible reprisal and stigma may not be easily or readily revealed to healthcare workers. Beyond the physical suffering that occurs, displaced people are often deprived of their livelihoods and suffer a loss of identity, purpose, and community. Displacement camps are frequently crowded, poorly designed, and inadequately serviced. When war and conflict damage traditional ways of life, cultural bereavement, along with individual bereavement, can be key determinants of psychological distress. It is not uncommon that once the displaced population witnesses success in the ethnically relevant community programs for the severely mentally ill the same programs may see increased numbers presenting with acute trauma-related symptoms. This suggests that the initial barriers of stigma and suspicion tend to decrease with time.

Options for programing include both population-based interventions and conventional, "western-oriented," one-on-one therapies. Mental health problems common to displaced populations without a history of mental illness but with history of trauma exposure (including problems of children and adolescents), include several of the psychiatric diagnoses defined in the *Diagnostic and Statistical Manual of Mental Disorders IV*.

Figure 24.5.4. All resources are scarce and must be efficiently used without wastefulness. In this Figure multiple burn patients received care using the contents of a single surgical pack. This pack was also aged and contained WW II era sulfa powder. (Burkle, 1968)

- Situational depression and major depressive disorder
- Drug and alcohol abuse
- Somatization
- Anxiety
- Posttraumatic stress disorder (PTSD)
- Comorbidity of depression and PTSD

Claims of large populations experiencing PTSD have limited evidence; research suggests that only a minority of those exposed to mass violence suffer from this disorder, with numbers varying from 4% to 20%[22–24] A purely medical model of intervention that focuses on PTSD to the exclusion of other diagnoses is problematic in that it may fail to address other problems that present in the population; however, epidemiological evidence indicates that symptoms commonly associated with both PTSD and depression are identified in most cultures. Ethnographic assessments that recognize culturally determined language for relevant symptoms may help identify individuals suffering from these disorders.

THOSE PRESENTING WITH SIGNIFICANT PSYCHOSOCIAL AND/OR BEHAVIORAL PROBLEMS WHO MAY BE ABLE TO ADAPT AND COPE ONCE STABILITY IS RESTORED

Complaints presenting in this group generally differ in degree and these persons often demonstrate a greater ability to cope and adapt. Culture and community cohesiveness determines, to a large extent, how war, trauma, and displacement are experienced and what coping mechanisms are used. Programatic emphasis can be placed on community-based programs that focus on strengthening family and kinship ties, promoting indigenous healing methods, facilitating community participation in decision making, fostering leadership structures, and reestablishing spiritual, religious, social, and cultural institutions and practices that restore a framework of cohesion and purpose for the whole community. The goal is to encourage and strengthen pre-event coping and adaptive capacities of the population. Program strategies are developed to reduce stress and encourage normal activities and active participation of those displaced.[24] Examples are

- Establishing cultural and religious events, including funeral ceremonies and grieving rituals involving spiritual and religious practitioners
- Restarting formal or informal schooling and recreational activities
- Promoting adult and adolescent participation in relief activities, especially those that facilitate the inclusion of social networks of people without families
- Organizing community-based self-help support groups, especially focused on problem-sharing, brainstorming for solutions and effective ways of coping, and mutual emotional support and community-level initiatives
- Economic redevelopment initiatives such as microcredit or income-generating activities

The psychosocial and mental health response in the immediate post disaster period often emphasizes this type of approach. In addition, a program commonly called Psychological First Aid can be introduced.[25] It is an assessment strategy and an intervention that entails basic, nonintrusive pragmatic care with a focus on listening but not forcing talk, assessing needs and ensuring that basic needs are met, encouraging but not forcing company from significant others, and protecting people from further harm. With this approach many of the "symptoms" of mental health disorders may resolve, increasing the likelihood that those who continue to have symptoms have specific disorders requiring specific treatment.

THOSE SUFFERING FROM DISABLING PSYCHIATRIC ILLNESSES

Psychoses and severe mood disorders (including *Diagnostic and Statistical Manual of Mental Disorders IV*–defined diagnoses of major depression and bipolar disease) cause considerable disability in every culture worldwide. How these disorders are conceptualized, recognized, and managed across cultures and in a conflict or postconflict situation may differ considerably. Although it may be possible to diagnose psychotic disorders that were present prior to the event after a crisis occurs, providing sustained and effective treatment may be difficult. This places considerable stress on the families of those with severe illness and may exacerbate the ongoing stress to the camp population especially if their behaviors are disruptive. For anxiety and mood disorders that existed before the disaster, it is often impossible to distinguish the symptoms of these disorders from normal responses to an overwhelming crisis event.

Although emergency health services are usually void of mental health personnel, including psychiatrists, some promise has been found among programs that utilize local psychiatric nurses and community volunteers to provide services. Whenever possible, psychiatric interventions should be included as part of the established primary healthcare system, but even these resources may be severely lacking.

For the severely mentally ill, the impact of treatment is frequently dramatic with reintroduction of antipsychotic medications and supportive community follow-up that can include rehabilitation in traditional family structures. In camps, community volunteers can provide outreach services, family education and support, and links to other agencies that can assist with rehabilitation. Basic needs of patients in custodial psychiatric hospitals must be addressed if the crisis becomes protracted.

Newer psychotropic medications, often those familiar to foreign aid workers with experience in psychiatric treatment, are both scarce and prohibitively expensive. Aid workers must advocate for what is best for the populations they are attempting to serve and coordinate these requirements with the ability of local healthcare workers to sustain any medications from outside resources.[20]

Measuring and Monitoring Effectiveness

In general, the key psychological and psychiatric functional indicators based on SPHERE standards for interventions are[7]

- Individuals experiencing acute mental health distress after exposure to traumatic stressors have access to psychological first aid at health services facilities and in the community
- Care for urgent psychiatric complaints is available through the primary healthcare system
- Individuals with known psychiatric disorders continue to receive relevant treatment, and harmful, sudden discontinuation of medications is avoided

The International Response to CHEs

The UN Charter was launched at the end of WWII in 1945 to deal with cross border wars. Charter language does not adequately address internal conflict and the genocidal actions that dominate modern day emergencies. Sovereignty of individual nation states is steadfastly protected under the present Charter and severely limits the UN from entering any sovereign country to protect a minority population from ethnic cleansing and outright genocidal acts. The Charter Article II, Part 7 right of sovereignty reads[26]

> Nothing contained in the present Charter shall authorize the United Nations to intervene in matters which are essentially within the domestic jurisdiction of any state.

Only the UN Security Council has legal authority to respond militarily. The peacekeeping and peace enforcement actions allowed under Security Council Resolutions to cease internal nation-state conflicts are often too little and too late in protecting these populations. Operational successes occurred in the Kurdish crisis of Northern Iraq, the Balkans, and East Timor, but little changed the overall course of conflicts in the poverty stricken, remote, and austere environments of Rwanda, the Democratic Republic of the Congo, and the prolonged debacle in the Sudan and Somalia.

The UN-led humanitarian response community, made up of NGOs, the Red Cross Movement (resources from both the International Committee of the Red Cross and the Federation of Red Cross and Red Crescent National Societies), UN agencies such as UNICEF, WHO, and UN High Commissioner for Refugees, and others, has worked to protect civilian populations both within conflicted countries and on their borders. Over the last three decades, however, this traditional UN-led multinational response system has been criticized for being ad hoc, unprepared, underresourced, and overwhelmed by legal restrictions of an ill-equipped UN system. Without a major reform of the UN Charter that would favor human rights over exclusive sovereignty and include a standing UN Task Force of their own, the role of the UN in addressing any internal conflicts will remain limited in the future.

With increasing insecurity in places such as Iraq and Afghanistan, the political preference by western-led coalitions has been to bypass the UN-led system and traditional humanitarian community in favor of a non-UN military force. The humanitarian relief and reconstruction operations have been led by military resources and private contractors. Claims that these partnerships have succeeded when the UN-led humanitarian community has failed are in doubt.

Globalization has strengthened many Asian countries that have become economically interdependent with western industrialized countries. When the Indian Ocean tsunami occurred, a western-led consortium of military assets (from the U.S., India, Australia, Japan, Canada, and others), the World Bank, like-minded NGOs, and private contractors stepped in with the goal of ensuring rapid economic recovery. The consortium referred to the tsunami disaster as a CHE because two affected countries, Aceh Province in Indonesia and Sri Lanka, have ongoing rebel insurgencies. Less economically developed areas of the world remain dependent on the conventional, underfunded, and underresourced UN-led humanitarian community that is driven by rights-based humanitarianism. Whether either of these models will persist in the midst of donor country and international organization political change remains to be seen.[27,28]

Judt suggests that future coalitions of the willing will be powerless to respond appropriately to large-scale "natural disasters, famine, droughts, floods, resource wars, population movements, economic crises, and regional pandemics . . . " and "will have to act through others in collaboration, cooperation, and with little reference to separate national interests or boundaries . . . " The UN and its Agencies, such as WHO, UNICEF, and UN High Commission for Refugees have mature and tested "international early-warning, assessment, response, and coordination mechanisms for when states fray and collapse." The UN works best in handling crises "when everyone acknowledges the legitimacy of its role."[29] Major power political interference and influence currently impedes the opportunity for the UN to fulfill leadership in a consistent and predictable manner. In the meantime, it is not known how the world will manage future complex humanitarian and other large-scale public health emergencies.

RECOMMENDATIONS FOR FURTHER RESEARCH

As stated, even though the absolute number of CHEs has declined, the list of countries in crisis has remained long with little information on the impact of these crises being available for monitoring and evaluation. The world community must find new ways to prevent instability in fragile countries and apply resources that emphasize political and economic sustainability. Furthermore, a professional civil–military approach is desirable to many of these crises, but political competition, relevant education and training, funding, and lack of a modern day UN Charter, among many other factors, have stopped these good intentions in their tracks.

Research critical to conflict studies remains unattended, especially in topic areas concerned with: vulnerable populations, advances in international law that address access and protection, public health priorities, and sustainability. Awareness driven by globalization, especially Internet access to information, has led the world's population to expect equity, transparency, and accountability in global health and humanitarian assistance. Populations have little tolerance for responses that are imperfect, ad hoc, and politically motivated. There are concerns that disaster management issues, especially those resulting from public health emergencies, if not fully addressed will further complicate the widening rift between the world's haves and the have-nots. Recent events suggest that disasters occurring in countries economically interdependent with economic powers will receive robust relief that is directed at rapidly recovering the economy. In contrast, disasters in economically poor countries will be left to depend on fragile UN-, UN agencies–, and Red Cross/Red Crescent Movement–led responses that have limited funding and resources. Such inequities are apt to foment additional political unrest. Furthermore, a previously unrecognized public health overlap between conventional disasters and CHEs has been described. Conventional disasters and CHEs can occur during or following either event and epidemics commonly occur during CHEs. Unlike the findings in CHEs, the data do not support the often-repeated assertion that "epidemics, especially large-scale epidemics, commonly occur following large-scale conventional disasters." This emphasizes that training and tools are needed to help bridge the gap between the different types of organizations and professionals who respond to conventional disasters and CHEs to ensure an integrated and coordinated response.[30]

Public health is no longer relegated only to issues of healthcare and prevention. Rather, public health is being redefined to include transportation, communications, public safety, judiciary, good governance, and many other critical entities that are necessary for a village, a nation, and the global community to function. Public health and health indices have and will always be one of the most sensitive measures of the recovery process and its ultimate success or failure. Indeed, despite all the attention and resources that CHEs have received over the last three decades, the state of health of women and children, especially in disaster prone areas, has declined. Public health and agricultural infrastructure in both developing and developed countries have not expanded with population and maintenance demands. CHEs which were first considered "water wars" in some resource areas of the world must now be seen as public health (infrastructure and system) wars in deprived areas that lack the buffer capacity to respond to the insults that disasters provoke. Public health must take precedence over politics and must not be driven by political motives. Disasters keep nation states and the global community honest by revealing vulnerabilities in the public health system and infrastructure. Through immediate recognition that public health systems and infrastructure play a monumental role in the consequences and recovery of large-scale disasters, public health will be seen in a new light. This involves focusing on strategic and security issues that deserve heightened attention including an international monitoring system and international law protections. If this does not become a priority, public health emergencies will continue to increase as a pivotal challenge for future disaster managers and the global community.

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25

Patient Identification and Tracking

Darlene A. Gidley and Michael Ciraolo

OVERVIEW

Each year, many countries experience disasters including earthquakes, floods, fires, storms, and tornadoes, among others. These disasters vary in scope and magnitude and help shape the field of disaster management across these countries. Disaster planning previously based on limited experience and supposition is transitioning to planning based on evidence acquired from these actual catastrophic events. For the United States, at the time of this writing, the event that has most tested preparedness, response, and recovery is Hurricane Katrina along the Gulf coast in 2005. Hurricane Katrina provided disaster planners with first-hand experience in the challenges that arise after a major disaster that destroys significant infrastructure components of multiple communities.

One of the key issues illustrated by the study of Hurricane Katrina is that families and loved ones can and do get separated. In some instances, rescue workers sought to transport children to safety first, expecting that they would be reunited with parents within a brief period of time. Instead, confusion arose as to who was taken to which shelter. The same held true for hospitals evacuating patients or transferring patients to other locations. This created as much, or more, anxiety among hurricane victims than the destruction and loss of their property. As one news agency reported, "A centralized patient-tracking system did not exist. Without automated systems, it was almost impossible to know where evacuees were. Also, the federal government did not have a firm grasp on how many evacuees there were, and family reunification was difficult. . . . Data was spotty at command centers that state officials and organizations like the Red Cross set up."[1]

The National Center for Missing and Exploited Children estimated that approximately 5,000 young people were reported missing or displaced. Concerned parents did not know which agencies to contact for assistance in locating their children. No registry was automatically assigned the responsibility of reunifying families. In some cases, children were separated from their families for months before they were reunited.[2]

Hurricane Katrina destroyed much of the New Orleans healthcare system. Hospitals and skilled nursing facilities were damaged and thousands of doctors, nurses, and other healthcare workers were displaced. People lost access to their primary healthcare providers. This particularly impacted individuals with acute exacerbations of chronic conditions. According to U.S. government officials, 2,500 patients in Orleans Parish alone were evacuated.[3] In addition, dialysis centers across Louisiana with caseloads of between 3,000 and 3,500 patients were destroyed, and only half of these patients could be located several weeks after the storm made landfall.[4]

Identifying a patient's location may be very difficult, if not impossible, immediately after a major mass casualty event or disaster occurs. Most sick or injured persons will triage themselves to the closest healthcare facility with which they are familiar, particularly if the disaster is widespread and it is not possible to phone for emergency assistance. For large events in single locations, it is more likely that victims will be triaged by emergency medical services (EMS) first responders. In this case, multiple first responder agencies may be involved, large numbers of ambulances from various companies (and possibly other jurisdictional areas) may be on scene, buses may be used, and many receiving hospitals may be utilized. Although each entity will probably document the care they provide, there may not be a single entity that amasses all patient encounter data in real time.

For typical emergencies requiring EMS assistance, determining a patient's location is generally not difficult. Communications systems exist – in one form or another – that allow EMS field personnel to notify receiving hospitals of a patient's impending arrival. Although patient names are not communicated over the radio or telephone, determining where an individual was transported may only require a phone call to the area's EMS provider. Furthermore, under most circumstances, the following conditions exist

- Family members, friends, or colleagues are often with the sick/injured person and field personnel advise them as to the receiving hospital
- Individuals can call family/friends and inform them of their location
- Hospital personnel can notify next-of-kin when the patient arrives and patient information is obtained
- The receiving hospital is not likely to transfer the patient to another facility, but if a secondary transfer is

necessary, detailed information is maintained by the sending facility
- The incident location is known
- The telecommunications infrastructure is functional

This relatively informal system for tracking (finding) a patient seems to work sufficiently well, even in large cities and counties. As the number of patients, EMS response agencies, transport units, paramedic base hospitals, and receiving hospitals increases, however, the chances of losing track of patients also increases.

In a disaster, a number of factors are altered that make it difficult, if not impossible, to utilize the day-to-day informal system. Consider an earthquake scenario as an example

- A large number of injuries and fatalities may occur, instantly stressing or exceeding capacity of the emergency medical system
- Hospitals are not getting detailed (if any) information about the patients they are receiving
- There are multiple incident locations
- There are multiple jurisdictional EMS providers converging into the affected region to provide mutual aid
- Sick/injured patients may depart the incident location, leaving EMS personnel with no record of the patient's origin or destination
- EMS personnel may transport patients to alternate care sites rather than hospitals
- Family members may be unable to contact one another because of telephone/cellular site failure
- Medical receiving centers may be too overwhelmed to communicate patient location information to family members (at least in the immediate aftermath) or the telephone/cellular system may be inoperable or overloaded
- Hospital facilities may themselves be damaged and undergoing their own patient evacuations
- Medical records of patients treated and released may not be complete and computer systems might be inoperable
- It may be necessary to transfer patients to medical receiving centers in other cities/counties/states/countries, depending on the magnitude of the disaster

Several victim-tracking systems designed for different populations are in various stages of development with the common goal to ensure the timely reunification of family members following a disaster. A notable system is found on the American Red Cross' "Safe and Well" website, which allows individuals to register themselves on the Internet.[5] The U.S. National Disaster Medical System (NDMS) uses a system referred to as TRAC2ES, which tracks patients who are transferred to various NDMS hospitals throughout the country. U.S. EMS systems are exploring options for tracking sick and injured patients that would not be in the Safe and Well or TRAC2ES databases.[6] This chapter will focus on the considerations that should be given for tracking victims who are not already easily located and identified through existing systems.

CURRENT STATE OF THE ART

Components of a Patient-tracking System

There are two components of a patient-tracking system. The first part is the initial collection of data and entry into a system. This could occur at the incident site where the EMS first responders record the data or at a healthcare facility or other alternate care site. The second component is the data portal that will receive, aggregate, and disseminate data that EMS or healthcare personnel collect.

In selecting or designing each component of a patient-tracking system, the following factors should be considered.

- For what groups is the "system" being designed? Is it strictly a local system, or is it meant to collect and share data with multiple communities, the state, national, or international levels? Who are the stakeholders?
- What local systems (if any) are already in place? Are these systems compatible with others that exist within the larger jurisdictional area?
- What information does the jurisdictional area deem critical? What are the basic data elements that must be collected and what are the additional elements that are desirable but not mandatory?
- What are the budget constraints?

System design should also consider the following functions.

- Provide a unique identifier for every patient entered into the system. (An approach is needed to prevent using the same unique patient identifier twice. The main approaches are to use location-specific accession numbering or to develop unique patient identifiers based on a combination of patient-specific data, such as date of birth, name, and sex.)
- Use a process of tagging or affixing the unique identifier to each patient so it is easily displayed.
- Collect at least some, if not all, of the following patient data: last name, first name, date of birth, sex, race/ethnicity, unique identifier number, triage tag number (Figure 25.1), social security number or equivalent, home address, and phone numbers (e.g., mobile, home).
- Track patients lacking complete identification information (e.g., unconscious female without her wallet).
- Enter patient data at multiple points in the sequence of care (i.e., the EMS response; field assessment and treatment sites; field triage; emergency department triage; inpatient wards and units; intermediate care facilities; postdischarge; and medical examiner/mortuary care).
- Enter patient status data, which could include time-stamped triage status, time-stamped location, and time-stamped patient disposition (with the ability to track sequential locations).
- Update patient status data by multiple users, while preserving previously entered data unchanged.
- Plan disposition for patients.
- Capture additional patient status data such as Glasgow Coma Scale score, chief complaint, or baseline vital signs (desirable but not required).
- Track multiple patients at multiple locations for multiple incidents simultaneously without compromising data integrity or system performance.
- Update and view the same data at multiple locations simultaneously.
- Perform inquiries using multiple parameters, such as searches for individual patients, all records of patients with specific characteristics, and all records of patients at specific locations.

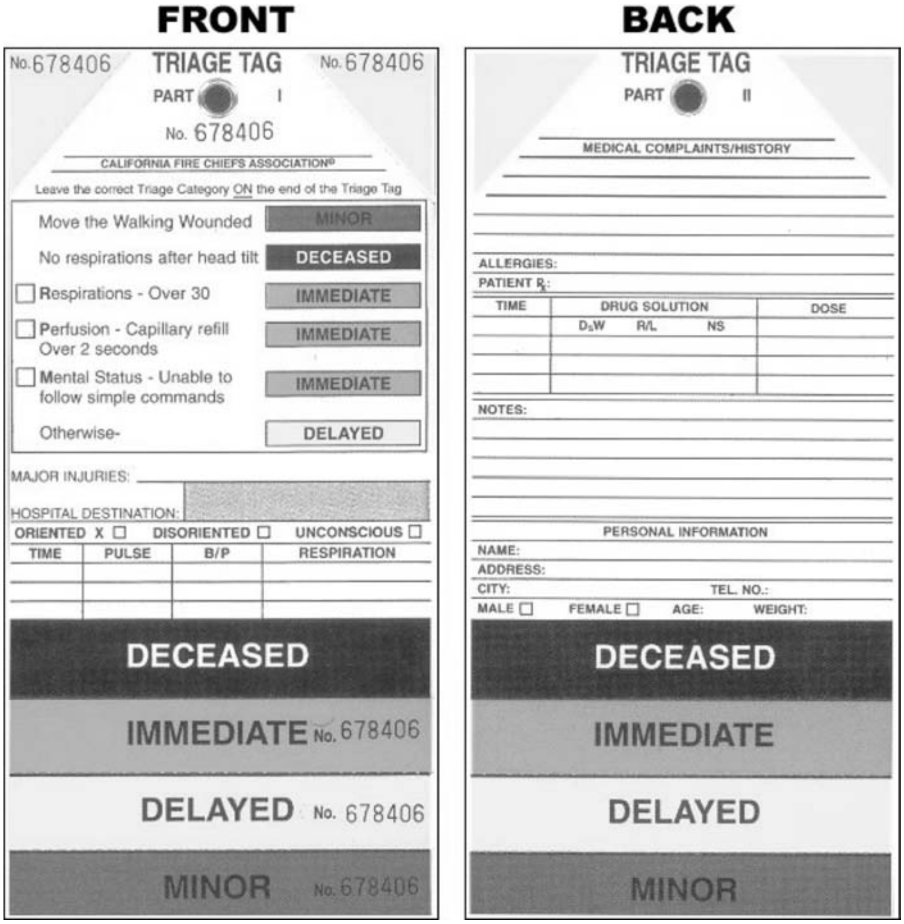

Figure 25.1. Original triage tag, with unique numeric identifier but no barcode. Copyright California Fire Chiefs Association. Reprinted with permission. See color plate.

- Allow users at multiple locations to view data in real-time (to the extent that real-time data are entered).
- Protect the privacy and confidentiality of patient data, in compliance with the health authority requirement, for example, in the U.S., the government's *Health Insurance Portability and Accountability Act* guidelines.[7]
- Secure data (e.g., with password protection and encryption) on any device where protected patient information is stored.
  - Any system relying on radio transmission, regardless of active or passive technology, must protect against threats to data interception, such as radiofrequency identification (RFID) "skimming." This practice involves the unauthorized use of a radiofrequency identification reader to interrogate any RFID chips in the vicinity, with the goal of recovering data from these elements. RFID devices are used as triage tags and contain patient-specific data.
  - Patient information stored on laptop computers must contain provisions to secure data against information theft should the laptop be stolen (e.g., encryption within the database).
- Ensure that all data collected by the system are handled and stored in a manner that protects them from corruption, even when the system is deployed in rugged, primitive field conditions. (Any system relying on radio transmission, regardless of active or passive technology, must protect against threats to data manipulation or corruption).
- Comply with health applicable authority standards, for example, in the U.S. the capability of managing data for at least 500 patients per million population per the U.S. Department of Health and Human Services guidelines for mass casualty care.
- Maintain the ability to export data in a common industry format, such as .csv or HL-7.

Who Should Be Included in a Patient-tracking System

Although an ideal system would track all patients who present to a medical facility following a disaster, this may be impractical because of the burden of data entry. From a pragmatic standpoint, the most important patients to track would be those who might otherwise be difficult for families to locate following a disaster. If however, government officials or researchers want to use the tracking system for quantifying the medical effects of a disaster, this would require that all patients be entered into a data system. Essential elements of a national, statewide, or regional patient-tracking system include all patients

- transported via the EMS system to a hospital or other medical treatment site
- admitted to a hospital who had illnesses/injuries/medical conditions that were a direct or indirect result of the disaster
- receiving care at a field treatment site
- evacuated from a hospital or skilled nursing facility

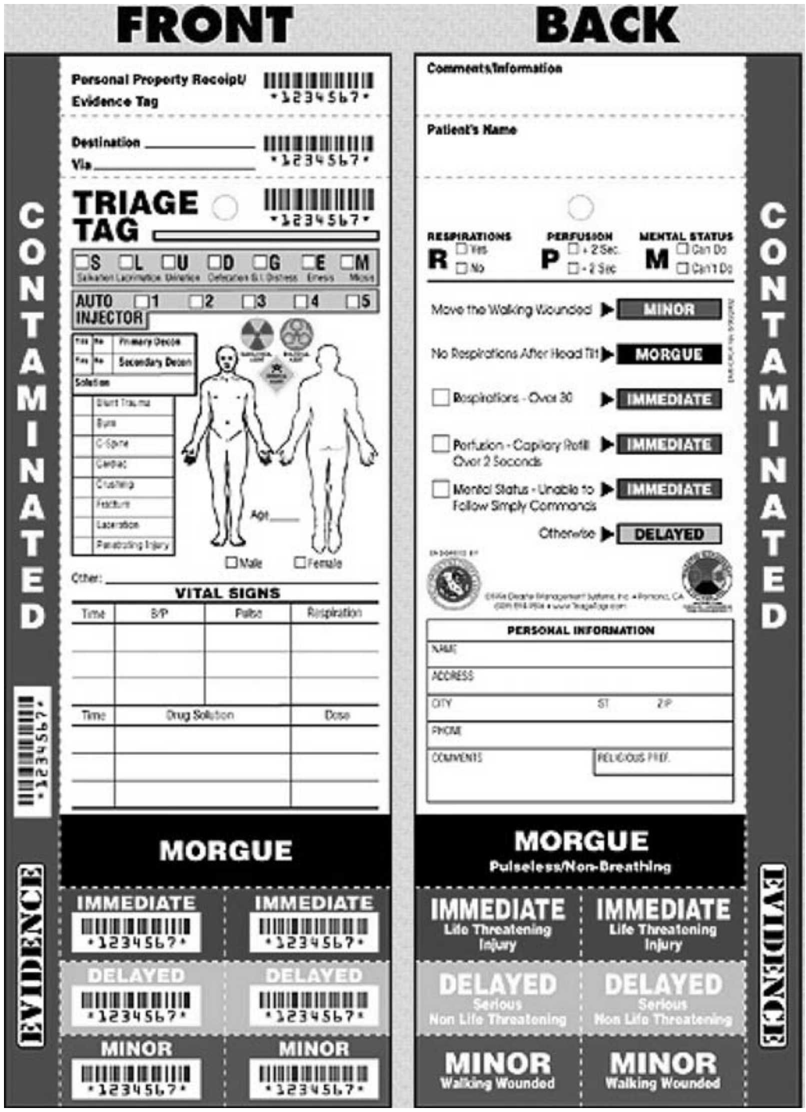

Figure 25.2. Medical all risk triage tag – Note the “1-d” barcode on the front. Copyright California Fire Chiefs Association. Reprinted with permission. See color plate.

- transferred from one facility to another
- received or transferred through the U.S. NDMS or equivalent in other countries
- who died (either on arrival to a medical treatment site or subsequently)

Additionally, it would be desirable to include all individuals in a disaster patient-tracking system who sought medical care at a clinic. This is based on the assumption that following a disaster, clinics might provide care to patients who would normally have presented to a local hospital. From a practical standpoint, however, clinics could be operating with fewer staff members caring for excess numbers of patients and, therefore, be unable to accomplish the necessary data entry. If a new tracking system is being implemented, it may be prudent to focus on perfecting a system that tracks more critically injured or ill patients seen at the other venues. Clinic patients could be added once a system has been thoroughly tested and perfected in exercises.

Where Data Are Entered

Every system has points of entry for patient data. Ideally, the entry point is the first place where the patient receives medical care. This could be at the incident location, at an alternate care site, clinic, or hospital. If a very basic patient-tracking system is adopted that only tracks EMS-transported patients and those patients admitted to a hospital, data entry could be initiated at the hospital site only. This would likely limit recorded patient information to data relevant to their current location only. It would not lend itself to tracking a patient’s previous locations. Within the U.S., patients treated and released, without hospitalization, could be encouraged to register on the Red Cross’ Safe and Well website.

Some jurisdictional areas may desire a patient-tracking system with capabilities that exceed the “basics” described previously. In this case, patient tracking could be initiated by EMS responders at incident locations. The tracking system could then “follow” the patient to the hospital and through discharge.

Although this would be a more comprehensive tracking system, it would require additional training and equipment.

How Data Are Entered

An initial patient record could be created by completing the information on a standardized triage tag such as the one adopted by the California Fire Chiefs Association (Figure 25.2).[8] The basic patient identification information and patient location can be entered manually into a database and the barcode on the triage tag scanned. If scanning equipment is not available, staff can also manually enter the triage tag's corresponding unique numerical identifier. This number acts as an important identifier for tracking the patient throughout the course of hospitalization and possible secondary hospital transfers. Alternatively, a patient's location could be physically tracked by activating an RFID tag. Although this is useful for locating a patient within a hospital or at a field treatment site, it is less effective in identifying a patient's location in a wide geographical area.[9] In addition, the cost of such a strategy is significant.

Existing systems such as EMTrack, ReddiNet, and WebPCR (already in place in California) have specific data entry requirements and will create local databases.[10,11] It is important that data do not reside solely at the local level because, in a disaster, patients may be transferred out of local jurisdictional areas. The challenge for local systems will be to develop a process that transfers the information from local databases (such as hospital sites) to a regional/state/national portal that aggregates the data and makes them available to system participants. The regional/state/national data portal must allow patient tracking by unique identifiers regardless of where they are physically located.

The Regional/State/National Data Portal

Assuming each jurisdictional area should have the flexibility to select or maintain an existing system that best meets its respective needs, then the statewide or regional (or national for smaller countries) patient-tracking system must have a secure Internet portal that can collect, aggregate, and disseminate a large amount of data from a variety of sources. One strategy is to identify and explore data systems already in place in a state or region to determine whether they can be expanded to include patient tracking.

Who Performs Data Entry

A critical element to the success or failure of a patient-tracking system is the data entry itself. All systems require human interface. It is unrealistic to expect that healthcare providers will assign staff to data entry functions when their resources are severely stretched following a disaster. The likelihood of cooperation increases if the data can be easily collected, are limited in volume, and the function of data entry can be assigned to trained volunteers.[12] The following are essential considerations.

1) Do not require real-time data because this would be too labor intensive. Rather, require update of information every 24 hours.
2) Limit data collection to easily obtainable information such as
    - Name
    - Sex
    - Date of birth or age
    - Most current address/telephone number
    - Present location
    - Location to which patient is being transferred (if applicable)
    - Triage tag number (if available)
    - Initial diagnosis
    - Patient permission to share information with persons seeking to find the individual[13]

    Possible additional information could include

    - Treatment date (arrival date)
    - Status (inpatient vs. outpatient)
    - Initial diagnosis
    - Patient condition
    - Admission note
    - Date of departure from hospital
    - Disposition
    - Transportation
    - Contact information
    - Social Security number or equivalent
    - Home zip code or postal code
3) Ensure that any data entry requirements are as simple as possible so that anyone can be assigned the responsibility and perform the task with little or no training in a minimal amount of time.
4) Consider training and using hospital volunteers or members of established organizations (e.g., in the U.S., the Disaster Service Workers and the Medical Reserve Corps) to perform data entry functions to minimize the workload of already overburdened staff. Volunteer availability would likely be higher following a traumatic event than a biological or radiological incident, when individuals might perceive a greater risk to their personal safety.

Driven by federal mandates and the experience of hospital evacuations associated with the Northridge earthquake and hurricanes Katrina and Rita, more patient-tracking systems are emerging in the U.S.[14,15] This marketplace is well developed with many patient-tracking-specific vendors using proven technologies, as well as veteran system integrators. There is, however, a lack of overall standardization or consolidation of vendors. Characteristics of this current marketplace include

- A lack of standardization regarding data interchange or even basic agreement on a minimum data set (patient name and date of birth vs. social security number vs. driver's license data vs. medical condition information and field treatment activities)
- The strong presence of vendors with previous experience in the tagging/identification/inventory markets, as well as system integrators
- Many vendors with few proven systems. Few fully deployed and tested patient-tracking systems exist from which to generate a track record for each vendor
- Reliance on public or nonproprietary technologies (discussed later)

Overall, the science of patient tracking is in its infancy and suffers from ambiguity over the very concept of patient tracking.

As is often the case in market-driven rather than purely evidence-based initiatives, different offerings are defined by the vendor, so that one vendor's version of patient tracking may be very different from their competitors. This underscores the importance of emergency managers with purchasing authority diligently researching and understanding their own specific requirements, goals, and systems issues. Government agencies have also initiated development of recommendations for patient tracking that are more evidence based, such as those found in the 2009 publication from the U.S. Agency for Healthcare Research and Quality.[16]

Despite a lack of standardization, there are some common components to patient-tracking systems, with shared technology platforms. Planners should consider four technology-related areas when procuring a patient-tracking system

- The tagging, or identifying technology
- Field data tools, both for data capture and for interfacing between the tagging technology and a database
- The field data communication technology (or technologies, as many vendors use multiple infrastructures for redundant systems) by which the field data tools pass information to a database
- A main application comprising the following: 1) a database (the "back end"); 2) some form of user interface viewable in many locations (the "front end," typically a web-based interface); and 3) a network to link viewers of the data (typically the public Internet). Additionally, consideration must be given for user access permission structures, interfaces for data exchange, disaster recovery, security, and privacy protection

Tagging

Approaches to tagging include triage tags with machine-readable numbers (requiring an optical character recognition system), or more commonly, a tag that utilizes a barcode. Barcodes have two configurations; an older generation "1-d" format (familiar from most Universal Price Codes), and the newer "2-d" format (which resembles a square composed of many irregularly spaced dots). The 2-d format contains more information; it is being used on driver's licenses in some U.S. states to capture nearly all of the information printed on the driver's license. Barcodes may be scanned quickly, rendering data entry fast, easy, and reliable. To avoid losing them, such tags may be affixed to a patient's wrist in a bracelet similar to those used in hospitals.

RFID devices are also being used as a means of tagging patients. These are radio transponders containing an antenna and the integrated circuitry necessary to produce identifying information (such as a tracking numbers). Automated highway toll tracking devices and inventory tags are common applications, and RFIDs have already found use in healthcare. RFID systems are frequently used in hospital systems for tracking assets such as supplies, pharmaceuticals, and medical devices. Similarly, RFID systems have used bracelets to monitor and track patients in settings such as nursing homes or psychiatric facilities where elopement is a potential problem. RFID technology has also been used to track the locations of personnel such as physicians and nurses.[17]

RFIDs have the advantage that staff can record the data they contain at a greater distance than the barcode information on a conventional triage tag (up to approximately 1 m). Their disadvantages include cost and the illicit tracking of RFID information, a practice called "skimming." The cost of an RFID tag is less than $1.00 U.S. per item, but this does not compare favorably with the cost of paper triage tags in the range of $0.01 U.S. per item. Skimming is easily accomplished and poses significant security and privacy concerns. This unauthorized retrieval of RFID information involves the use of an RFID radio receiver and a laptop computer to capture and read available data from any RFID within range, generally for nefarious purposes. How great a risk this poses to patient-tracking systems depends on the data contained on a patient RFID tag and the extent of security and encryption for related data communications. For example, a simple RFID (containing only a patient identification number) coupled with unencrypted data sent over a marginally secure WiFi connection would pose a risk to patient privacy.

A third approach to tagging avoids assigning the random (or sequential) number of a triage tag, and instead seeks to capture information directly from the patient. At least one system uses a field barcode scanner to capture information directly from a patient's driver's license via optical bar code scanning. This technology is limited to use for patients who have their driver's licenses in their immediate possession and it does not solve the challenge of tracking others who may not have readily available identification, for example, children in many countries.

Field Data Tools and Field Data Communication

Field data tools must serve as data entry devices and communication devices to perform data capture and data entry. Some will also provide access to the database, acting as field command post tools. At the simplest level, these data tools must scan, read, or otherwise collect identification information (e.g., via bar code scan or receiving the RFID signal), and they must permit the addition of other supplemental data. This might include an automatic time stamp or manual data entry option for patient name, medical condition, or other parameters.

The technology to do this is typically a durable mobile computer equipped with the appropriate scanning device and telecommunication system, e.g., the Symbol 9000 or MC50. Originally designed for warehouse and logistics operations that include scanning barcodes or reading RFID tags and sending the data to a local computer, these devices are well adapted to the inventory-related needs of patient tracking. Durable laptops may also be used in the field for data entry, data display, and command-and-control functions.

Most of these field data collection tools rely on various public infrastructures to transmit information back to a database, and many are enabled for multiple technologies. One system, for instance, offers wireless radio communication, satellite telephone, and transmission over the IEEE standard 802.11 b and g (commonly known as local area "WiFi"). These systems are all quasipublic infrastructure; they may be privately owned but during a disaster will be heavily stressed. In one strategy, the city of San Francisco, California is piloting a system that uses all three modalities in a tiered approach: if unable to establish a cellular telephone or WiFi connection, then the more expensive satellite telephone call is placed. All three technologies have limitations due to their use of the radio spectrum. The problems with cellular radio are familiar: dropped calls, areas where the signal does not reach, and saturation of a given cell due to overuse (a likely scenario in a disaster). WiFi – wireless access to the Internet – is far from ubiquitous. Few cities – and no rural or mountainous regions – have wide area WiFi coverage. Furthermore, availability

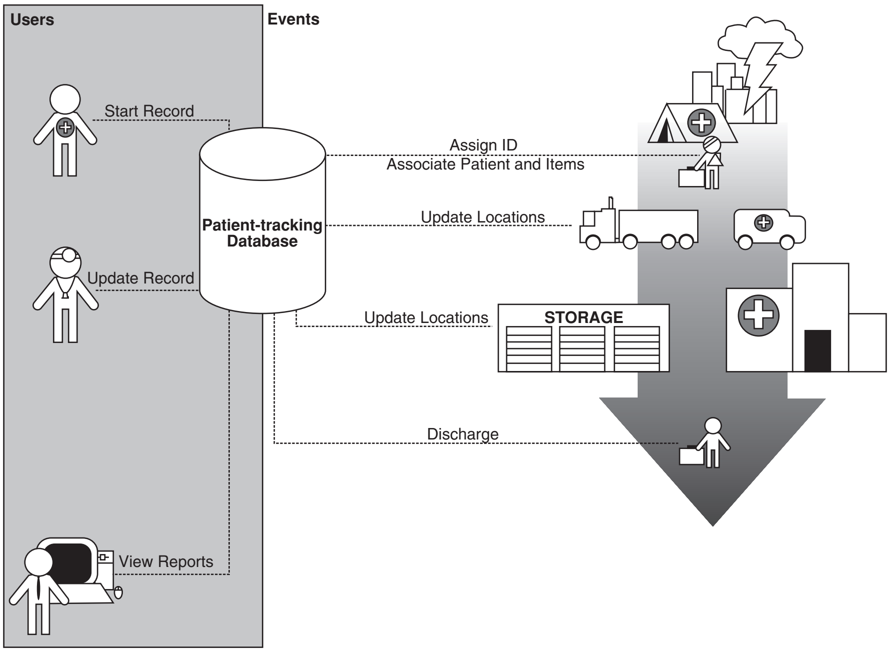

Figure 25.3. Collaborative Fusion's Community Response System's Patient Tracking Module architecture. This graphic details one potential patient information path through the patient-tracking system. The beginning point of the patient's journey may vary. A patient may present to the hospital independently and the ID would be assigned there or the patient may be transported from one hospital to another and have multiple record updates. Copyright 2007, Collaborative Fusion Inc., reprinted with permission.

of WiFi in urban areas is largely due to Internet cafes and private (and often secured) WiFi hubs. The signal range in such locations is 30–50 m under ideal indoor conditions. WiFi 802.11 b and g frequencies also face interference from microwave ovens, cordless telephones, and Bluetooth devices. Even as more cities become WiFi enabled, it will be necessary for most WiFi hubs to have backup power sources to be functional in a disaster that disrupts the supply of electricity.

The Application Itself

Once data are collected from the patient, the information must be communicated, stored, viewed, and probably modified. Most systems utilize standard relational databases coupled with conventional web interfaces. Thus, emergency operations staff only need access to the Internet to enter and retrieve patient-tracking data. Understanding the specific requirements of the network and how a proposed system might function are important, whether it is locally hosted in the jurisdiction or remotely hosted as part of an application service provider arrangement. Figure 25.3 provides a schematic of the architecture of Collaborative Fusion, Inc.'s Community Response System – Patient Tracking Module, which tracks both patients and materials. Figure 25.4 provides a schematic of Salamander Technology's MedTrax system.

Considerations include

- The database should be an industrial-strength database from an established vendor. It should be a database designed specifically to work with the volume and data complexity appropriate to the task, thus avoiding the common problem in emergency management systems of using a small database and an individualized simplistic application to provide functionality in excess of its capability. Vendors should address such issues as whether or not their future product releases will be compatible with earlier releases, management of potential software obsolescence, and availability of support.
- The user interface should be contemporary, incorporating industry standard metaphors and conventions (i.e., Microsoft Windows or other commonly used software). Individualized and small-scale systems seldom reflect in-depth usability testing, and often rely on mechanisms such as pop-up windows. Such mechanisms often trigger pop-up blockers and antispam ware. A system designed for mass casualty incidents and large-scale disasters will be used infrequently. Therefore, it should be as easy and intuitive to use as possible. "Intuitive" usability comes not from one developer believing a system is intuitive, but from adherence to contemporary approaches and frequent customer/user testing and feedback.
- The network providing data interchange between the various users in the field and in operations centers is typically the Internet, but a private network can also be employed. An Internet-dependent application is, however, only as robust and reliable as the network (and the public power grid) itself. A large earthquake, hurricane, or other event can disable the Internet in a given locale.
- User retrieval of data should be secure and should offer multiple tiers of access for different levels of data. Personnel entering data do not need exposure to all system information, whereas Emergency Operations Center staff require complete access.
- Because there are no established standards for monitoring patient location and movement, different jurisdictions are likely to adopt different patient-tracking systems. To ensure

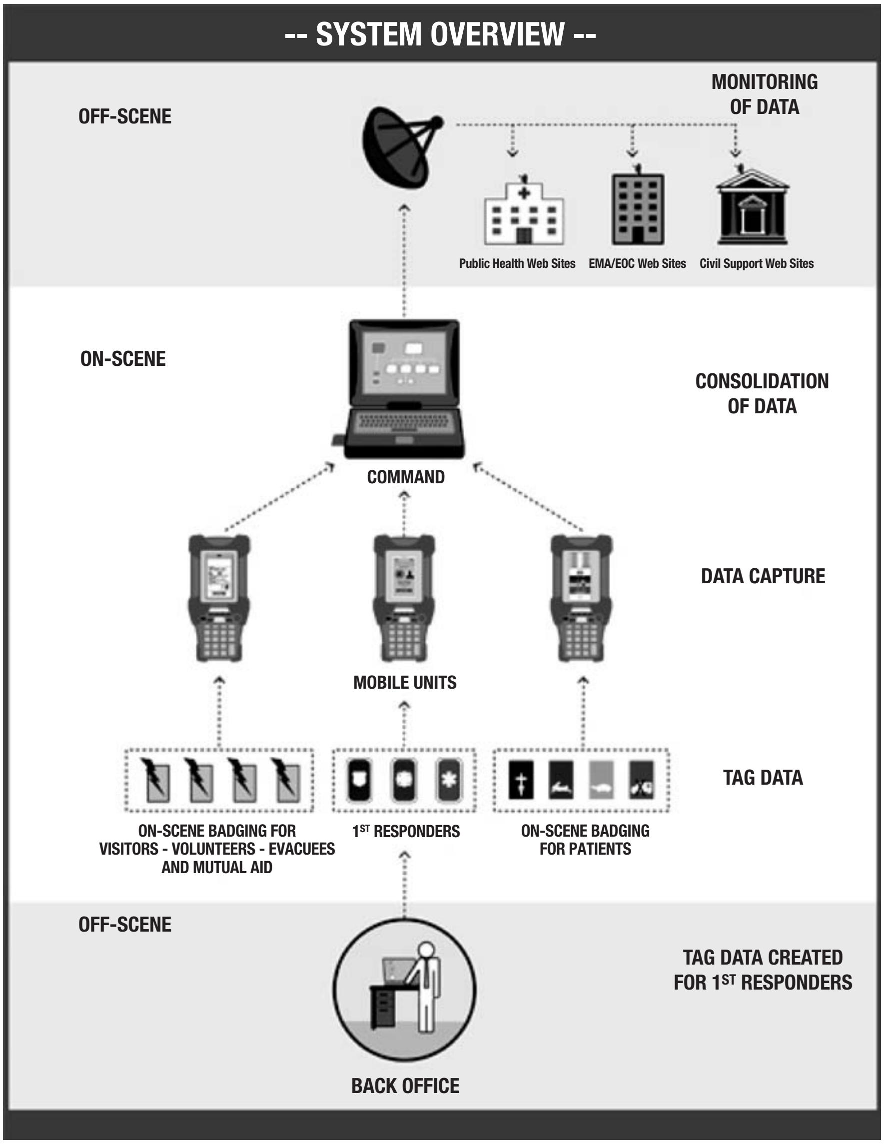

Figure 25.4. Data capture is performed via handheld units capable of scanning triage tags; these units then upload data to a local laptop, where data are consolidated, viewed, and sent to off-scene users (including hospitals and command centers). Reprinted with permission. See color plate.

interoperability, mutual aid, and movement of information through the regional level to the state (and possibly federal) government, a system should be capable of importing and exporting patient-tracking data. This can be managed with an interface. It is the responsibility of jurisdictions evaluating patient-tracking systems to understand both their needs and the vendors' capabilities. Interfaces may function in real time, or in delayed "batch mode." They may require considerable effort by personnel to manage the data formats or perform these functions in a fully automated way. Such specific characteristics require investigation and testing.

- Disaster recovery and application durability (including its servers) are of paramount importance for a patient-tracking system designed to function in a wide-area disaster that threatens power and other infrastructure. Disaster recovery is defined as the ability of an application to function continuously during, or recover from, such threats as power interruptions, damage to primary servers, damage to disk drives, or impairment of other system components. The hosting environment should be protected from fire, water, flooding, and unauthorized entry. This supporting infrastructure should also have access to a stand-by power system with at least enough fuel (or battery power) to last as long as the longest probable scenario for that location. At a minimum, this should be for a period of at least 72 hours. Ideally the application is hosted in such a way as to obviate downtime due to equipment failure; the typical approach is to use dual systems with near-instantaneous fail-over from one system to the other. Jurisdictions using an application service provider agreement should require hosting at two geographically disparate data centers, with at least one removed from the operational area.
- Security and privacy concerns are of paramount importance and extend well beyond legislative requirements such as the U.S. *Health Insurance Portability and Accountability Act.* Government agency credibility for the management of patient

and personal information has been challenged by historical federal incidents. Therefore, jurisdictions should treat information security and privacy as being equally important as the basic mission-critical function of patient tracking. This means evaluating any potential system's data management from the point of collection to the viewing by any authorized user. Essential questions that should be addressed include: 1) what data are being collected, and are patient identifiers (such as name, social security number or equivalent, or other patient-specific information) included? 2) Are data encrypted when transmitted over WiFi, cell phones, or over the Internet? 3) Are data encrypted when stored on a field laptop computer? 4) What kind of log-in and user authentication is required to access the system? 5) Is the hosting environment physically secure? 6) Is software that connects with public infrastructures (the Internet, WiFi, cellular phones) protected with intrusion countermeasures such as virus protection and is that protection updated routinely?

- Service provisions, whether part of an application service provider or part of a purchase agreement, should be evaluated in terms of support, maintenance, and upgrades.
- Any system used for patient tracking should be fully tested. Testing by the purchaser should include user acceptance testing. The purchasing jurisdiction should also require, and review the results of, failure mode analysis (what are the weak points in a given system?), stress testing (impact on system function of increasing demands, such as multiple users, high data traffic, and storage of large data volumes), and security and intrusion testing.

An evaluation tool that builds on the considerations previously outlined appears in the appendix to this chapter. System acquisition processes should examine not only capabilities (can a system perform a given function?), but should also explore how functions are performed. Even more importantly, the acquisition process should rely heavily on an outcomes approach, using both examinations and demonstrations of working systems at reference sites (ideally under terms and conditions dictated by the purchaser, not the vendor).

Systematization Efforts

There are at least three emerging mandates and standardization efforts within the United States that could affect patient tracking. Each involves a mix of technology issues (such as data definitions) and other factors such as funding imperatives from the federal government. The first one is a federally driven approach to hospital bed availability monitoring, which has logical connections to patient tracking. The second one is a data interchange format. The last one is a more comprehensive industry vision for healthcare information interchange. Although each is unique, all three have the potential to affect patient-tracking systems and so are important.

The first involves the U.S. Health Resources and Services Administration's (HRSA) promulgation of requirements for current and accurate bed availability. This HRSA mandate (backed by the imperative of compliance to maintain eligibility for federal funding) does not specifically require patient tracking, but there is a natural connection between patient tracking originating in the field and bed availability. In support of these requirements for bed availability systems, the U.S. Agency for Healthcare Research and Quality funded the HavBED project – the National Hospital Available Beds for Emergencies and Disasters. The HavBED data definitions constitute a de facto federal standard for bed availability data interchange. The HavBED project also considered patient tracking. The project team concluded:

> "The first question which must be answered is to determine at what point the identification and tracking processes begin. The ideal answer is for this activity to be initiated at the actual incident site. Unfortunately, past experiences clearly indicate that casualties do not necessarily remain at a disaster scene. If they are capable of ambulating, most victims will not await the arrival of public safety agencies, including EMS, but rather will seek alternative transport modalities to obtain medical care. In fact, prior incidents suggest as many as 80% of casualties will make their own way to the hospital. Therefore, any patient identification and tracking system must be flexible and be capable of permitting data entry about recognized victims at various points in the medical treatment point-of-entry chain. This includes such locations as the incident scene, receiving hospitals (both near and distant) and points in-between, as patients who attempt to get to a hospital, but are unable to do so, enter the EMS or healthcare delivery system at locations remote from the actual disaster scene.
>
> To date, all patient identification and tracking systems are associated with significant cost, both financial and in personnel, for data entry. Systems such as the Raytheon Patient Tracking System partially automate the initial data entry process and provide for FedEx-style patient (package) tracking using scannable barcoded armbands. This system has significant associated fixed costs and ultimately still requires personnel to acquire and enter personal identifying data for each patient. New York State includes a less robust patient identification and status system in HERDS (Health Emergency Response Data System) for purposes of being able to track what victim is being treated at a particular hospital. This functions more as a patient locator system and also requires expenditures for personnel for data entry.
>
> In the development of any patient-tracking system, decisions will also need to be made about the definition of a victim, the time frame in which they present for care and other similar issues. A consensus will need to be reached about who should be included and identified as a victim as well as how open-ended the time period will be for including victims in such a database.
>
> In addition, for any patient identification and tracking system to work effectively, it must either be extremely easy and intuitive to use or it must be used on a routine basis. If routinely used, on-going costs associated with such a system become an issue.
>
> In summary, a "patient-tracking" system is currently technologically feasible, however, the implementation, sustainability and manpower costs present significant fiscal challenges."[18]

Although beds alone do not equate with patient care capacity, staffed and equipped beds can be considered a component. Therefore, it is useful for emergency managers to monitor HRSA mandates for bed availability tracking systems as a possible connection to patient-tracking requirements and (eventually) systems.

The second effort to improve patient tracking is a straightforward data interchange format known as EDXL, shorthand for the Emergency Data Exchange Language. A schema-based standard for data interchange over the Internet, EDXL is a specialized version of Extensible Markup Language (XML) designed to promote interoperability between different jurisdictions and different vendors. The development of EDXL is an initiative of the United States Department of Homeland Security in conjunction with an industry-based consortium. Once the EDXL data definitions are accepted, interchange of patient data, jurisdiction-specific data (e.g., hospitals, transfer definitions), and incident command parameters can be easily accomplished via XML interfaces between different vendors.[19] This is important, because the easier it is for different patient-tracking system vendors to exchange information, the easier it is to implement local patient-tracking systems without being burdened by information sharing with neighboring jurisdictions. Government entities seeking patient-tracking systems might be more inclined to adopt one system, without waiting for state or federal standardization, knowing that data transfer is a relatively easily solved problem. The HavBED data schema is consistent with EDXL.[20]

Finally, it is worth briefly discussing Comcare's Integrated Patient Tracking Initiative. Comcare (Comcare.org) is a 100+ member national advocacy organization in the U.S. dedicated to advancing emergency communications. The Integrated Patient Tracking Initiative (IPTI) sponsored a national patient-tracking summit to develop definitions for required components and has plans to further define optimal patient-tracking systems. The Comcare effort also showcases local patient-tracking projects, provides a directory of vendors, and is a useful source of information regarding patient tracking.[21] However, the overall vision of smooth data interchange across disparate jurisdictions and vendors, all in compliance with requirements generated via Comcare's IPTI conferences, is unlikely to reach fruition in the near future. Nonetheless, the IPTI has the potential to improve the field of patient tracking and will continue to play a role.

RECOMMENDATIONS FOR FURTHER RESEARCH

The development of a patient-tracking system is a worthwhile endeavor. Once fully implemented, it will give officials a way to locate patients, reunite families, and track general data such as the number of patients treated, their dispositions, and the types of illnesses and injuries being treated. It provides the state, region, and local jurisdictions with another tool to manage effectively a disaster.

However, patient tracking is not as simple or streamlined as tracking packages by the United Parcel Service or similar companies. Although it appears analogous, the United Parcel Service sends packages to its own hubs, trains its own people, uses its own transportation vehicles, and has common equipment throughout the package handling process. In contrast, in many countries, patients are treated by a myriad of healthcare providers who operate independently of each other and are not bound by common data systems, training, or equipment.

There are a number of companies that are developing hardware and software for tracking patients. Bar-coding and RFID technology is popular but should not be considered a tracking system per se. These are simply tools that assign unique identifiers to patients that will help to connect various records. They do not indicate who the patients are.

For local jurisdictions that already have patient-tracking capability or are currently developing this capability, it is highly improbable that these entities would be willing to switch to entirely different systems for the sake of having a consistent approach throughout a state. Rather than requiring utilization of a specific hardware/software method for patient tracking, it is more important to ensure that systems used by local jurisdictions can gather certain data elements and that the data are entered into a common secure database that is developed and maintained by the state or equivalent entity and can be accessed by select individuals and organizations.

Also, in consideration of stakeholders that operate on a very small budget, it may not be necessary to invest in specialized equipment (e.g., scanners) for tracking patients. It is entirely feasible that a simple spreadsheet could be completed by healthcare providers and sent to a secure Internet portal.

There are sophisticated patient-tracking systems available that are capable of tracking patients and capturing the data elements suggested in this chapter. Even though it is technologically possible, there may be inherent challenges that may be difficult to overcome. For example

- Implementation and maintenance costs combined with ongoing costs for training and retraining
- Unfamiliarity of end users with devices that are not needed, or practical, to use on a daily basis
- Battery failure; inability to obtain fresh batteries quickly in a disaster
- Insufficient numbers of equipment devices
- Obsolescence of equipment purchased, but not used, needing periodic replacement
- Complex data entry (as opposed to completion of a triage tag) slowing down the rapid disposition of patients in the field setting
- Data entry devices that are too labor intensive for the field setting and probably difficult to use in a moving vehicle
- Reliance on cellular telephones, computers, and the Internet – all of which may be inoperable in the immediate aftermath of a disaster.
- Reliance on satellite communication systems that are scarce and not used with sufficient regularity to ensure user competence

Another issue is that most of the patient-tracking systems being developed are designed for multicasualty events where all patients are initially located in the same incident location. At single locations, it is conceivable that barcode readers, laptop computers, cellular phones, and satellite capabilities may be available at a command post. Whenever a disaster is widespread over many locations, it is not likely that the specialized equipment will be available to all first responders deploying to incidents in which a command post is not established. Consequently, it is more realistic to track only those patients who are transported via EMS to hospitals or field treatment sites as well as those patients who self-triage to these locations.

If it is accepted that each jurisdictional area should have the flexibility to select or maintain an existing system that best meets its respective needs then a statewide or regional patient-tracking system requires a secure Internet portal that can process a large amount of data from a variety of sources. Whether using high-tech or low-tech solutions for collecting patient-tracking data, it may be prudent to reduce the amount of information being collected. This recommendation is made for the following reasons

- The more data that is collected, the more labor-intensive is the data collection effort and the less compliant jurisdictions are likely to be. Following a disaster, EMS and hospitals are generally managing a higher volume of patients than at baseline. The goal should be to expedite patient care and disposition, not create a bottleneck. (Triage tags were designed to take the place of a comprehensive patient record and to collect a succinct body of information.)
- The more data fields required, the slower data will be transmitted.
- Patients' information should be contained in their medical care records, which should accompany them when they are transferred from one healthcare facility to another.
- A very limited amount of data is needed to track a given patient. A good example is the Safe and Well website implemented by the American Red Cross. In this case the only data elements that are needed are a person's name, current address and/or telephone number.

Even if the amount of data is reduced, the critical point establishing the success of a patient-tracking system is the selection of individuals to perform data entry. Serious consideration should be given to identifying and training volunteers to handle this important function and to developing automated systems that reduce or eliminate personnel needs.

Another issue that needs clarification is the duration emergency managers should track patients following a disaster. This is a difficult question to answer because the recovery phase of a disaster can be prolonged, lasting for years. This point is exemplified by Hurricane Katrina, where people were displaced for months following the storm.

All of these issues are tractable and should be the focus of in situ research efforts. Research should evaluate pilot systems during both routine and emergency use. In summary, the patient-tracking systems are widely variable from those that are simple and inexpensive (such as the manual completion of a triage tag and manual entry of a few data elements into an Internet portal) to a more expensive and sophisticated processes (such as use of computerized equipment that electronically sends real-time information to disaster managers and hospitals). The cost of implementation and maintenance of these systems (including personnel training) is directly correlated to their level of sophistication.

System dependability during a disaster may, in fact, be inversely proportional to the sophistication of the system being utilized. The greater the reliance on handheld computer devices, functional power supplies, telecommunications, and training, the greater is the chance for system failure. If more sophisticated systems are used, a back-up simpler system should be available. One promising sophisticated electronic system known as the Wireless Internet Information System for Medical Response in Disasters (WIISARD) is being funded in part by the National Institute of Health. This electronic network is designed for rapid implementation after a disaster and facilitates recording of medical data, aids in the monitoring and tracking of patients, and facilitates communication of field data to hospitals. Researchers at the Veterans Affairs Medical Center in San Diego concluded that a wireless electronic system improved documentation and tracking of triage status, changes in patient condition, treatments, destination, and transporting units compared with a traditional paper system.[22]

The tracking systems currently under development have not been tested under actual disaster conditions. Nevertheless, their ongoing development and refinement should be encouraged as it is likely to improve future disaster management. The more feedback manufacturers receive from end users, the better the resulting product is likely to be.

APPENDIX A: PATIENT TRACKING VENDOR EVALUATION TOOL

Jurisdictions, EMS managers, and others evaluating the acquisition of a patient-tracking system should engage in a formal evaluation process. The following questions comprise an evaluation tool that may be readily adapted to formal Request for Information or Request for Proposal formats. Vendor responses may be narrative or Yes/No/Not Apply. Vendors responding to requests for proposals typically answer "yes" to most questions. Therefore, vendors should be pressed for detailed explanations of how various tasks are accomplished, for in-person product demonstrations, and for references from current customers using the product under consideration. It is particularly important to ascertain whether vendors of patient-tracking systems can demonstrate a current working model with a given set of features. Many such vendors are system integrators only and may not have actually built a functioning entity.

1. Is your system designed for routine operational use (i.e., all the time, daily), for local mass casualty incidents, and/or for large-scale disasters?
2. Does your system provide on-site casualty entry?
3. Does your system allow initial medical assessment entry?
   a. How is this done (drop-down list vs. free text; entry on a portable device vs. laptop computer)?
4. Does your system allow real-time notification and communication between EMS, incident command, and hospitals?
5. Does your system have the ability to add walk-in patients from an incident at a variety of scene locations? https://disastersafe.redcross.org/
6. Does your system record patient age/sex?
7. Does your system have the capability of locating patients involved in an incident? Does your system allow the identification of associated evidence or property?
8. Does your system have the capability of recording critical vital signs? How many sets? Are entries time-stamped?
9. Does your system track ambulance status and end destinations? How?
10. Does your system keep a record of on-scene treatment? How? (Free text, pick list, and so forth) What treatment data are supported? (Please provide a copy of a full record.)
11. Does your system record treatment status? How? (What data elements? Are they customizable?)
12. Does your system allow critical information sharing between multiple response agencies across the EMS system? How?
13. Does your system have the ability to communicate casualty and resource information to command centers and hospitals? How?
14. Does your system allow analysis of patient disposition status and flow throughout an incident to the final disposition to

allow tracking of patients across agencies and jurisdictions (e.g., city, county, and state)? If so, how is data interchange accomplished, and at what cost?
15. Does your system provide compliance with HPP-critical benchmark requirements for patient tracking? How and to what extent?
16. Is your system capable of collecting and reporting information required by the U.S. Federal Emergency Management Agency?
17. What tagging or ID technology does your system use?
18. What field data collection tool(s) does your system use?
19. What patient data does the system collect?
20. Does your system handle unidentifiable patients?
    a. If so, how?
    b. How is accession numbering or tracking of multiple unidentified patients from multiple locations managed?
21. Does your system allow the entry of patient information at a variety of locations (e.g., hospital, field treatment site)?
22. How does your system track patient status? Specifically, what patient categories are used (e.g., ambulatory, deceased, injured), and how are these categories updated?
23. How does your system identify locations, destinations, and other geographic information? Free text or controlled list?
24. How does your system handle multiple updates from multiple locations to the same patient data?
25. How many incidents and patients can your system accommodate simultaneously without performance degradation?
26. How many users can use the system simultaneously without performance degradation?
27. Describe your system's search/query functionality.
28. Can your system function in the field? With what limitations?
29. Describe your system's architecture, with specific focus on: field data capture, where data are stored, how data are made available to command posts and others such as hospitals.
30. What restrictions govern data communication between field data capture and centralized system access? What technology links the field to the central database? Radio? Satellite? WiFi?
31. What telecom/data communication infrastructure is required to implement your system?
32. What measures does your system employ to protect patient data and privacy?
33. Describe your system's user access permission scheme and structure. How are user IDs and passwords assigned?
34. Does your system automatically identify the healthcare provider? The incident location? The patient location? How is this information entered or captured?
35. What measures does your system use to ensure data integrity, including back-up systems?
36. Please describe your system's compatibility with other entities and identify them. What data interchange approaches are used?
37. Describe your implementation/deployment approach.
38. Describe your approach to training.

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Part III

Clinical Management

Section A: CBRNE and HAZMAT

26

Explosive Events

John M. Wightman and Chetan U. Kharod

OVERVIEW

Explosive events occur in many settings. They can have a variety of etiologies, which can be accidental or intentional. Many blasts damage only property, but every explosion can be classified as a potential injury-creating event (PICE).[1] It is the human impact with which this chapter is mostly concerned. Injuries may occur to individuals or groups. Massive and multiple explosions may affect entire communities or larger regions, resulting in a disaster situation. According to Noji, "A disaster is defined as a natural or manmade event that results in an imbalance between the supply and demand for existing resources."[2]

Most explosive events are unlikely to result in major catastrophes, as defined by Lumley and Ryan, "where the social fabric of a society is disrupted and the medical infrastructure fails."[3] Some important exceptions exist, however. A single bombing of the only hospital in a region may cause temporary failure of that local healthcare system, until external resources can be mobilized. Multiple, intentional explosions specifically targeting critical services may impact a larger population to a greater degree. A nuclear detonation would likely disable much of a city's infrastructure. Volcanic eruptions have, and will again, create devastation on local, regional, national, and global levels.

Individual Impact

Blast injuries to persons encompass the full spectrum of polytrauma. Individual physical injuries range from minor abrasions to "total body disruption" associated with wide scattering of multiple body parts. These are detailed under sections on pathophysiology and clinical care. Short- and long-term effects on survivors and their families can be devastating.

Not all blast casualties will require hospitalization. Many minimally injured victims may be discharged from the emergency department (ED) if they have appropriate social support and adequate access to the healthcare system. At the other end of the spectrum, some casualties will require intensive initial resuscitation and stabilization, multiple surgical procedures, ongoing physiological support, and management of any complications that develop. Hospitalization at a regional referral center is frequently necessary to bring together the many services essential for management of complex, multidisciplinary issues seen in victims surviving severe blast injuries.

Too often, the focus of healthcare attention is only on resuscitation, stabilization, and definitive medical and surgical care. Victims requiring hospitalization may also need prolonged rehabilitation, physical therapy, and occupational therapy before returning, to some degree, to their preinjury lives. Even those blast-exposed individuals who may not even have entered the healthcare system through emergency medical services (EMS) or a hospital may need identification and follow-up services, particularly as regards to their mental health.

The psychological impact of any sudden traumatic event should not be overlooked. The importance of this underrecognized element of trauma management is beginning to receive attention in the lay press and the professional literature.[4–7] Additional information may found in Chapter 7.

Epidemiology

Very little has been written on the epidemiology of natural explosions. A computerized search of the medical literature regarding the Mount St. Helens volcanic blast of 1980 – the largest in the United States in the last century – revealed less than a dozen clinical articles covering medical and mental health consequences. Even as massive as this explosion was, only 57 people were reported dead or missing, likely due to a short but adequate warning time. Volcanic eruptions are discussed in more detail in Chapter 39.

The relative paucity of useful epidemiological information relative to blast injuries has been true of accidental and intentional explosions as well. One review of intentional bombings in the United States (U.S.) reported limited information, but could draw no clinical conclusions because it was compiled from a law enforcement database.[8] One complete report described all blast injuries in Finland over a 5-year period 1991–1995.[9] Fireworks were the cause in 29%, explosive materials in 25%, and rupture of pressurized containers in 13%. Soft tissue injuries and burns were the most common injuries, but traumatic amputations and crushing injuries also occurred. Two victims for every 100,000 persons in the general population were admitted to the hospital every year for an average of 11 days. An international list of major accidental explosions resulting in more than 100 fatalities occurring between 1906 and 1964 may be found in a review by Hamit.[10] Most reports, however, are less comprehensive and describe casualties from individual events.[11,12]

One of the most detailed studies of an accidental industrial explosion was published after a series of blasts occurred at a petroleum plant in Pasadena, Texas, in 1989. Twenty-two victims were found dead at the scene and 131 casualties were transported to six area hospitals.[12] Injuries to survivors were dominated by simple abrasions, contusions, and lacerations. The largest proportion of casualties was men 25–44 years old, likely because the initial explosion and subsequent fires mostly affected workers at the plant itself. Nonetheless, the three casualties not on the plant grounds were injured indirectly by blast effects up to 5 km away. Three-quarters of patients were treated and released from EDs. One admitted patient died, one was transferred to a rehabilitation facility, and all others were discharged home after 1–46 days as inpatients, although only three burn patients stayed longer than 3 days.

Accidental industrial blasts also occur in the manufacture of explosives.[13] The use of fireworks, especially by nonprofessionals, has resulted in many injuries in many countries every year.[14–18] In a U.S. study, boys 10–14 years old were found to be the population at highest risk, although 60% of all victims were older than 14 years.[16] Injuries affected the hands, face, and eyes in order of descending frequency. Seven percent required hospitalization.

With regard to intentional bombings, numerous reports of individual incidents have appeared in the medical literature.[19–43] Waterworth and Carr published two articles in 1975, which, when analyzed together, provided a picture of casualties from nearly simultaneous bombings inside two crowded public houses.[22,23] One hundred casualties were either dead at the scene (18%) or managed at The General Hospital in Birmingham, England (82%). The overall mortality rate was 20%. Of the 82 reaching the hospital alive, 2.4% died during resuscitation. There were no late deaths. Approximately three of every four casualties were discharged from the ED. Ten of the 19 admitted patients (53%), excluding one patient sent directly to a burn unit, suffered superficial flash burns to 10%–50% of their body surface areas.

One of the first large case-series of civilian bombing victims was published by Rutherford in 1972.[44] Hadden et al., extended this study at the same hospital.[45] They described the injuries sustained by 1,532 consecutive patients seen at a single hospital in Belfast having an ED "with the capacity to accommodate up to 100 patients simultaneously" and availability of "all major surgical specialties." Device sizes varied in equivalency from 1 to 90 kg of trinitrotoluene (TNT). Most of the 78 events generated 10 or fewer casualties reaching the hospital, but the range was 1–122 with approximately 10% of the incidents generating more than 20 patients at a time. The majority of victims managed in the hospital sustained abrasions, contusions, and lacerations without internal injury. Approximately five of every six casualties were discharged from the ED, leaving 250 total patients admitted. Nine (3.6%) of these died, with most deaths being due to blunt or penetrating head or torso trauma. Four (0.3%) of all 1,532 patients required an emergent laparotomy with one patient also undergoing a thoracotomy. Fifty (3.4%) patients were burned, 33 of whom were admitted but none of the injuries necessitated skin grafting. Twenty casualties had traumatic amputations and four of them died. Forty other open extremity fractures were reported in an unknown number of patients.

The next large case-series from Northern Ireland was published by Pyper and Graham in 1983.[46] They described the injuries sustained by 339 consecutive patients seen at a 200-bed hospital, which was located 48 km from Belfast and had just opened at the beginning of the study period. Device sizes were not reported. Consistent with previous articles, a large proportion of victims reaching the hospital sustained abrasions and lacerations without internal injury. Slightly more than half (58%) of the casualties were discharged from the ED, leaving 142 total patients admitted. Five (3.5%) of these died, with most deaths due to head injury. Eight (2.4%) of all 339 patients required an emergent laparotomy. Two others underwent delayed laparotomies, both of whom died. Six (1.8%) patients were burned, and two of these required skin grafting. Twelve casualties had traumatic amputations. Seventy-four other open extremity fractures were sustained by 35 patients.

In a report from Jerusalem the same year, Adler and coauthors also published a case-series from a single hospital.[47] They were the first to assign Abbreviated Injury Scale (AIS) scores and calculate an Injury Severity Score (ISS) for each of the 272 victims they managed from 24 terrorist bombings over a 4.5-year period. The majority received minor injuries: 237 (87%) had an ISS 1–6; eight (3%) had an ISS 7–12; and 27 (10%) had an ISS 13–75. The authors noted that many ED charts were incomplete, so these data could be biased by casualty volumes or other nonmedical factors. Of the 340 total patients received in the ED, 228 (67%) were discharged, 96 (28%) were admitted to the receiving facility, and 16 (5%) were transferred to a university medical center for specialty care. Only three hospitalized patients died. Eighteen abdominal operations were performed, but the urgency of these was not specified. Survivor duration of stays ranged up to 21 days.

Two separate events – each with two simultaneous intentional bombings – occurred in Istanbul on November 15 and 20, 2003.[48] Ballistic injury was sustained by 86 and 93 victims on each of the 2 days, respectively. Two individuals on each day suffered intracranial injuries. The authors noted that inadequately controlling the scene resulted in a significant maldistribution of casualties to area hospitals. Approximately one in every six victims was admitted to the hospital where they presented or were transferred to another facility.

Over the last few decades, prospective trauma registries have been established during and after extended conflicts, and the data they contain have been published. For encounters in Northern Ireland, the Hostile Action Casualty System was established to track injuries sustained by police and military personnel.[49] A report of 828 of these casualties was published in 1989.[50] The number of events was not reported, so rates could not be calculated. Nonetheless, some useful epidemiological information regarding types and severities of injury, particularly with regard to the effects of personal protective equipment ([PPE] i.e., body armor in these cases), could be ascertained.

Data from the Israel National Trauma Registry were used to publish the country's experience with suicide bombers during the years 2000–2004.[51] A total of 1,155 victims were studied, many injured by shrapnel intentionally placed around devices to cause extensive ballistic trauma. These casualties were compared with other trauma patients in the registry, although few details of the control group were provided in the article. Victims of suicide bombers were statistically more likely to require intubation, pleural decompression, resuscitative thoracotomy, and each of a variety of ancillary studies (e.g., plain radiography, ultrasound, computerized tomography, and arteriography) in the ED. As a result of a higher proportion of internal injuries requiring surgical intervention, they were also more likely than the control group to be sent directly to an operating theater.

Societal Impact

The events cited previously represent terrorist actions. They do not include blast injuries from land mines and more conventional warfare, which are certainly PICEs, but are beyond the scope of this chapter, as is the societal impact of war itself. It can be noted, however, that from the beginning of the Global War on Terrorism on October 7, 2001 through August 2, 2008, there were 161 deaths and 1,184 injuries from improvised explosive devices and conventional explosive munitions in Operation Enduring Freedom. In Operation Iraqi Freedom, casualties included 2,787 killed and 22,979 injuries due to explosive blasts. These numbers only report U.S. service members. They do not include military coalition partners, enemy combatants, and civilians. Measurement of the prior and ongoing impact to individual and collective societies is ongoing.

Unrelated to conventional warfare, intentional bombings remain common throughout the world. Over a 20-year period in the U.S. from 1983–2002, there were 21,237 explosive bombings, 6,185 incendiary bombings, 7,581 attempted bombings, and 1,107 bombs that exploded prematurely during manufacture or before reaching the intended targets.[8] The U.S. Department of Justice's extensive database does not allow for much additional clinical analysis, however.[52]

The societal impact of one or more sudden traumatic events is difficult to measure. Perhaps the best examinations of the clinical epidemiology of a large explosion have come from the April 19, 1995 bombing of the Murrah Federal Building in Oklahoma City.[32,53–69] This event created a paradigm shift in the conduct of disaster research.[70,71] It was estimated that more than 400,000 people in the metropolitan area were affected in one manner or another.[58] There were clearly adverse effects on the mental health of portions of the exposed population: injured survivors, families and acquaintances of those killed and injured, and people whose levels of fear and stress were heightened by the event.[56–58,61–68] Long-term epidemiological studies following the events of September 11, 2001 are just beginning to appear in the medical literature. The affects of explosive events on local healthcare systems have been more frequently reported and will be discussed later.

STATE OF THE ART

Research into the mechanisms of blast injuries and their clinical evaluation and management has proceeded steadily over the last century, with important accelerations in periods of wartime. Some information gained during World War II is just as relevant today, while more recent biochemical and imaging technologies with enhanced computing power and sophisticated mathematical modeling have allowed keener insights into pathophysiological mechanisms applicable to the world's most recent wars. Kluger described four areas of essential knowledge for medical personnel: blast physics; injury patterns; triage; and "treating multiple patients with multidimensional injuries."[72]

Physics

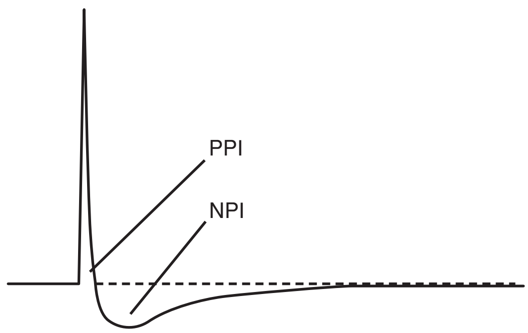
Understanding the physics of explosions enables anticipation of trauma in blast-exposed individuals, some of whom will have no immediate symptoms or external signs of injury. Basic comprehension of the mechanistic forces involved will aid healthcare workers in identifying the full spectrum of blast injuries, especially those that may initially be clinically occult.

Blast Waves

Natural explosions and some industrial accidents occur when gases confined under high pressure are suddenly released. Most intentional blasts are created by high-order or low-order explosives, both of which involve the rapid chemical conversion of a liquid or solid material into a gas of essentially equal numbers of molecules in an equal volume. Low-order explosives burn rapidly to generate gas, whereas high-order explosives detonate to create gas in nanoseconds. As a consequence, this newly formed gas with highly compacted molecules is under extreme pressure. The initial pressure generated by detonation of the high-order explosive, cyclotrimethylene trinitramine, the primary ingredient in Composition C4, is typically greater than 30 GPa (4×10^6 psi). The power of an explosive is customarily normalized to an equivalent weight of TNT, because it is mathematically related to its mass, but may be different for different substances.[73,74]

The molecules composing the newly formed high-pressure gas are forced away from each other at supersonic speeds. They push against and compress molecules in the surrounding atmosphere faster than baseline thermal motion can disperse them. This "stacking" generates a dense band of greatly compacted air or water, depending on the surrounding milieu. The energy of this band is propagated spherically away from the epicenter of the explosion as an impulse blast wave. Its leading edge, which is typically only a few millimeters thick, is called the blast front. Figure 26.1 shows the pressure–time relationships relative to a stationary point in space as an idealized blast wave passes.[75] The positive-phase impulse represents the initial spike of overpressure as the blast front speeds past the reference point. Because explosive gases continue to expand from their origin, a negative-phase impulse of relative vacuum follows the positive-phase impulse. As its energy dissipates, a blast wave eventually deteriorates into a high-magnitude acoustic wave.[76,77]

High-order explosive detonations cause such a rapid increase in pressure at their blast fronts (hence, force generation from high pressure to low pressure) that their blast waves are also referred to as shock waves. Low-order explosives generally do not release sufficient energy fast enough to demonstrate the shattering effects of shock waves.[77] Thermobaric and volumetric weapons, fuel-air explosives, and nuclear detonations create thicker blast waves, which tend to envelope objects after the initial shock effect of the blast front.[78,79]



PPI = positive-phase impulse; NPI = negative-phase impulse.

Figure 26.1. Estimated overpressure and underpressure as a mathematically idealized blast wave passes a fixed point in space with time on the x-axis and atmospheric pressure on the y-axis. Peak overpressure may be found at the apex of the pressure spike. This figure is in the public domain as a U.S. government work. It was reproduced from the *Ann Emerg Med.* 2001;37(6):664–678.[75]

Pressure differentials between the blast front and the surrounding atmosphere also create net movement of molecules that generate a blast wind. Detonation of a high-order explosive causing a peak static overpressure of 35 kPa, which is just strong enough to rupture half of exposed tympanic membranes (TM), may also generate a dynamic pressure sufficient to create wind speeds of 70 m/s.[76] Although they only exist briefly, blast winds can propel objects and people considerable distances. The wind created by a blast sufficient to cause internal injury in a significant number of casualties may exceed 400 m/s.[75]

Internal Force Propagation

When a blast front contacts an object, the band of high pressure exerts a force on the object existing at relatively low pressure. This is called blast loading.[76,80,81] This briefly applied but high-magnitude force creates an acceleration of the object's surface to a peak velocity and maximal displacement, until the elasticity of the surface overcomes its inertia. This rapid surface acceleration induces an internal stress wave propagated into the object roughly parallel to the direction of the incident wave. Solid objects, such as building surfaces, tend to shatter under this stress. More compliant surfaces, such as those of the human body, tend to compress under the force then rebound to their former shape once the blast wave passes. The magnitude of the stress wave in animal tissues is proportional to the peak surface velocity.[82] Figure 26.2 shows the relationships of acceleration, peak velocity, and internal pressure generation.[76] Compression also creates tangential shear waves proportional to the degree of displacement as surfaces are stretched inward.[83] When this rapid compression occurs at the chest wall, it develops too fast to allow internally increased air pressure to decompress through tracheal venting.[76,81,83,84]

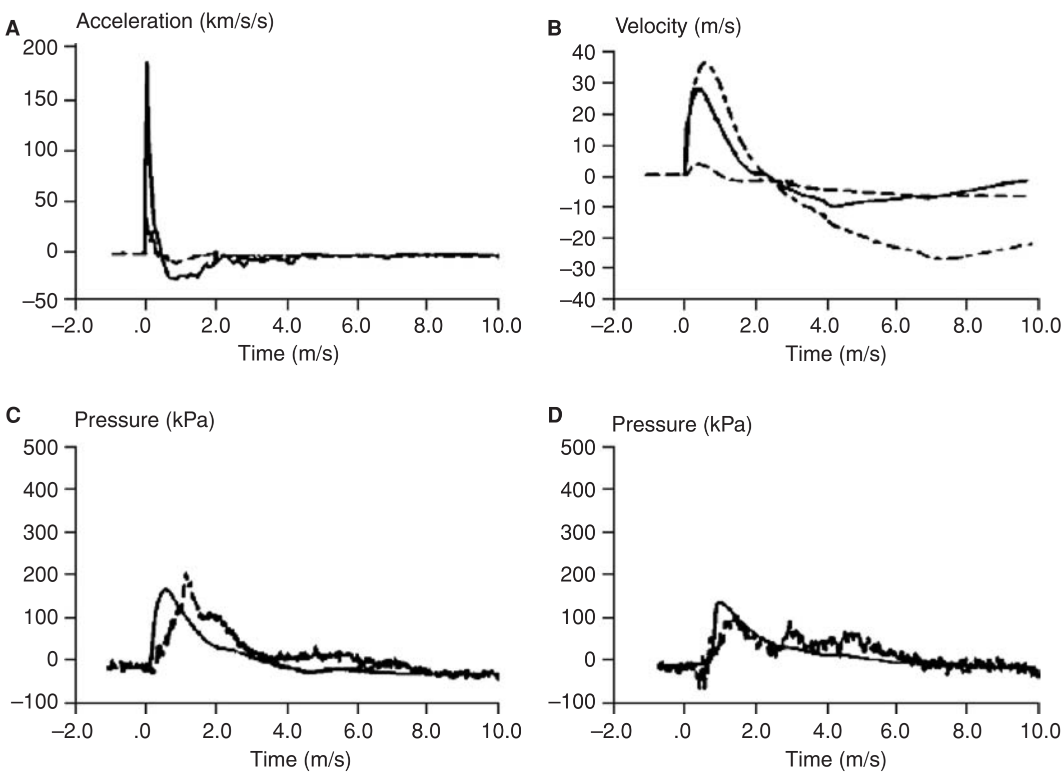


Figure 26.2. Mathematically predicted (solid lines) and experimentally measured (dashed lines) thoracic dynamics caused by blast loading after detonation of 2.2 kg of Composition C4 to the right side of a sheep: (A) acceleration of the right rib cage peaked near 200 km/s^2; (B) velocity of the right rib cage peaked near 40 m/s; (C) pleural pressure under the right rib cage peaked more than 210 kPa (30 psi); and (D) airway pressure in the right lung exceeded 100 kPa (14 psi). This figure is in the public domain as published by the Office of the Surgeon General of the United States Army, Falls Church, Virginia, USA. Reproduced from the *Textbook of Military Medicine.* 1991:266.[76]

Pathophysiology

Mechanisms of internal organ injury following blast exposure are multifactorial but stress and shear on biological tissues may result in irreversible work being applied. Irreversible work can be thought of as overwhelming the elasticity (i.e., ability of a substance to return to its original shape) of a given tissue, thus causing damage in some ways similar to blunt trauma. The best analogy can be found in the *Textbook of Military Medicine*.

> An aluminum beverage container that is pushed in only slightly will pop back to its original shape when the force is removed (and any work done by that force is recovered). The onset of damage occurs when the stress equals the tensile strength of the material. As the stress increases beyond the tensile strength, the work done by the excess external force will not be recovered.[76]

Although the precise internal force vectors applied and the exact tensile strengths of all biological tissues are not known, this concept can be used to support integrated finite-element modeling to predict injuries.[76,85,86]

On more of a macro scale, the concept of blast loading can be used to estimate the severity of injury. The Northern Ireland Hostile Action Casualty System was used to devise a table with five nonparametric groupings of charge weight against three groupings of intervening distances.[50] The calculated overpressures in pounds per square inch (1 psi = 6.895 kPa) were then clustered and tagged to descriptors of blast loading: less than 20 psi, minor; 20–50 psi, moderate; 50–80 psi, severe; and more than 80 psi, very severe. Of the 828 casualties registered in the years 1970–1984, there were approximately equivalent numbers in each of these four groups. No casualty in the first three groups died of "severe chest injury alone . . . with no serious external injury," whereas 17% of those with very severe blast loading fell into this category and presumably died of blast lung injury (BLI). Of the 42 patients who died in a hospital, 12 did so during the initial ED resuscitation and 14 during or shortly after an initial surgery. Half of the later deaths were due to severe head injury, and half were due to respiratory failure – whether from BLI, acute respiratory distress syndrome (ARDS), or a combination of both could not be established with certainty.

The primary effects of blast overpressure tend to more severely affect air-containing structures of the body. Differential velocities of stress waves traveling through water-density tissues and through air-density lumina create additional internal shear waves that can tear parenchyma at air–tissue interfaces.[75] This can also occur at any location where a density transition is present.[83]

Injury Classification

The trauma caused by explosive detonations has traditionally been categorized by mechanism. Primary blast injury (PBI) is caused by the effects of the blast wave transmitting forces into the body. Secondary blast injuries are ballistic injuries from fragments, shrapnel, and debris energized by the explosion or associated blast wind. Tertiary blast injuries occur when people are displaced by forces of the blast front and blast wind and are thrown through the air, tumble along the ground, and impact objects.[87] Other authors have added quaternary and quinary blast injuries, but these have not been standardized.[88–91] The taxonomy described by Stuhmiller is probably the most appropriate.[86] He depicted quaternary injuries as those resulting directly from "all explosion-mediated injuries not associated with pressure or wind effects," most notably thermal, toxic, and asphyxiant mechanisms. Collateral injuries – such as crush from building collapse, fall from a height, motor vehicle crash, and so forth – encompass all other outcomes.

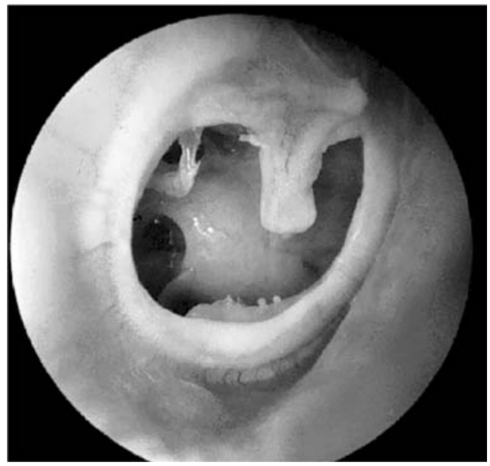


Figure 26.3. TM ruptured by blast impulse. Note nearly complete loss of tissue, which will likely require grafting. Most ruptures will heal spontaneously. Photograph courtesy of Dr. Bartolomé Scola, Head of ENT Service, University General Hospital Gregorio Marañón, Madrid, Spain. See color plate.

Obtaining a description of potential mechanisms of injury is important in the management of trauma victims, but these categorizations are more useful when devising equipment and tactics related to injury prevention. Those caring for these patients simply need to know that an explosion occurred, thus creating the possibility of PBI, and blastwind–mediated total body acceleration if not confined. Otherwise, with the exception of the unique entity of PBI, victims of explosions sustain thermal, penetrating, blunt, crush, toxic, and other injuries similar enough to nonblast mechanisms that medical personnel should be familiar with the pathophysiological results.[75,92] Healthcare personnel just need to understand the myriad possibilities for injury occurring during a single split-second event.

Blast Auditory Injury (BAI) and Ocular Injury

It has been estimated that 7–55 kPa (1–8 psi) is required to rupture the human TM (Figure 26.3), whereas peak overpressures from extremely loud acoustic waves are usually less than 0.3 kPa (0.04 psi).[73,94] Small shock waves able to rupture some unprotected TMs in open air have approximately the same impulse magnitude as those barely capable of shattering automobile safety glass, snapping utility poles, and cracking brick walls.[95] The pars tensa is the region most frequently injured.[96] Although much less common, fractures of individual ossicles and dislocations of their joints also occur.[94,96–98] Disruption of the conductive chain, but not TM perforation alone, may have a protective effect on impulse damage to the inner ear.[94,96]

When inner ear injury does occur, it manifests as a stunning of receptor organs without long-term sequelae in most patients.[94,97] Temporary hearing loss and tinnitus are common, the severity of which typically decreases at farther distances from

Table 26.1: Conditions Resulting from Disruption of Tissue Interfaces in Air-Containing Structures of the Torso

Chest	*Abdomen*
Escape of air	Escape of air
into lung parenchyma results in traumatic pseudocyst	into bowel parenchyma results in pneumointestinalis
into pleural space results in pneumothorax	into peritoneal space results in pneumoperitoneum
into vasculature results in systemic air embolism	into vasculature results in portal air embolism
Escape of blood	Escape of blood
into lung parenchyma results in pulmonary contusion	into bowel parenchyma results in bowel-wall hematoma
into pleural space results in hemothorax	into peritoneal space results in hemoperitoneum
into airways results in hemoptysis	into bowel lumen results in GI hemorrhage

GI = gastrointestinal

This information is in the public domain as published by the Center for Total Access, Fort Gordon, Georgia, USA. Adapted from the Special Operations Forces Medical Handbook. 2001:7–23.[104]

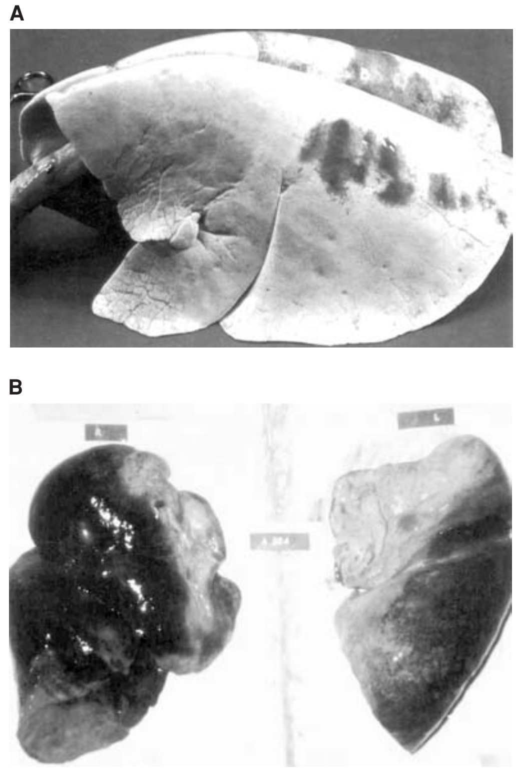


Figure 26.4. Spectrum of BLIs showing: (**A**) survivable localized areas of contusion following a relatively small blast impulse in a sheep model; and (**B**) fatal diffuse internal contusions and external lacerations from a battle casualty. These photographs are in the public domain as published by the Office of the Surgeon General of the United States Army, Falls Church, Virginia, USA. Reproduced from the *Textbook of Military Medicine.* 1991:276 and 228, respectively.[76] See color plate.

the explosion.[99–101] Severe structural damage to the organ of Corti and permanent hearing loss may occur, however.[97,98]

Foreign material and penetrating eye injuries are common after explosions.[60] Ocular PBI has not yet been conclusively demonstrated, but was the suspected cause of a hyphema in one report.[102] The management of penetrating and nonpenetrating eye injuries is beyond the scope of this chapter, but ED management following suicide bombings has been studied.[103]

Healthcare providers should ask questions focused on visual and auditory symptoms.[104] "Do you have pain or problems with your eyes or ears?" Any decreased vision should be assumed to be a penetrating foreign body or hyphema until proven otherwise. Ringing, roaring, or decreased hearing is common, but determination of the long-term effect on hearing will require detailed audiometric testing with serial follow-up evaluations. "What does your pain feel like?" Eye pain is typically severe, and blepharospasm may make thorough examination difficult. Ear pain caused by a ruptured TM is often sharp initially but wanes over time.

Blast Lung Injury (BLI)

A variety of injuries may occur in the lungs due to tissue tearing. Blood can leak into the parenchyma, into the pleural space, or into the airways. Air can leak into the tissues, into the pleural cavity, or into the circulatory system. Table 26.1 summarizes the conditions resulting from disruption of air–tissue interfaces in the chest.

The prototypical BLI is hemorrhage into the pulmonary tissues and small airways. This can range from subpleural petechiae to contusions of various shapes and sizes (Figure 26.4).[99,105] The degree of damage is proportional to the peak chest wall velocity.[106] Pulmonary lacerations can result in alveolar-venous fistulae and traumatic emphysema, if contained within the lung parenchyma, and hemopneumothoraces and bronchopleural fistulae, if involving the visceral pleura.

Alveolar–venous communications can allow air to enter the pulmonary venous circuit, travel to the left heart, and be ejected as systemic air emboli. Organ infarction and death can occur within minutes.[107] Air embolism can also occur following blunt or penetrating trauma.[108] Bronchopleural fistulae can lead to unilateral or bilateral tension pneumothoraces.[109] Both of these conditions can be rapidly and significantly exacerbated by positive-pressure ventilation (PPV).[75,108] It has been suggested that the commencement of PPV has led to early deaths in initial survivors.[110]

Medical personnel should ask targeted questions of casualties who can speak.[104] "Are you short of breath?" Dyspnea may indicate tension pneumothorax, hemopneumothorax, pulmonary contusion, or shock from hypoxia, hemorrhage, or systemic air embolism. "Do you have any chest discomfort?" Penetrating or blunt trauma, pneumothorax, and myocardial ischemia due to coronary air embolism can all cause chest pain. "What does your pain feel like?" Pain associated with pneumothorax will usually be sharp and focal, lateral or central, typically aggravated by breathing until the lung is completely collapsed. Pain of pulmonary contusion is often described as dull and diffuse. Discomfort may wax and wane with respirations. Bronchospasm or difficulty expanding the chest may be described as tightness. Chest pain that seems consistent with an acute coronary syndrome may

Table 26.2: Severity Categories for Blast Lung Injury (BLI) Reported by Pizov et al., Which May Help Predict the Necessity for Use of Positive-Pressure Ventilation (PPV) and Positive End-Expiratory Pressure (PEEP)[109]

	BLI Categorization		
	Mild	*Moderate*	*Severe*
Infiltrates on plain chest radiography	Unilateral	Bilateral but asymmetrical	Bilateral and diffuse
p_aO_2/F_iO_2 ratio	> 26.7 kPa (200 torr)	8.0–26.7 kPa (60–200 torr)	< 8.0 kPa (60 torr)
Bronchopleural fistulae	Absent		Present
PPV requirement	Unlikely for a respiratory problem	Highly likely but conventional methods usually effective	Universal and unconventional methods often necessary
PEEP requirement	<5 cm H_2O if PPV required	5–10 cm H_2O usually necessary	>10 cm H_2O if volume-controlled PPV still used

be due to air embolism of one or more coronary arteries. "How much effort is required to breathe?" Dyspnea at rest indicates shock due to external or internal hemorrhage or hypoxia due to airway obstruction, pneumothorax, or severe pulmonary contusion. The less exertion that leads to dyspnea, the more likely is BLI or pulmonary damage by another non-PBI mechanism.

Examination findings consistent with BLI include tachypnea; difficulty completing sentences in one breath; dry cough, with or without wheezing; hemoptysis of varying degrees; diminished breath sounds indicative of pulmonary contusion, pneumothorax, or hemothorax; inspiratory rales or dullness to percussion caused by interstitial edema, parenchymal hemorrhage, or hemothorax; and poor chest wall expansion caused by decreased lung compliance.[111,112] Rapid, shallow respirations are characteristic of BLI casualties.[113]

BLI is uncommon from terrorist bombings in open air civilian settings.[114] Most victims close enough to high-order detonations to sustain BLI are killed by other blast mechanisms.[50] In distinction, explosions in confined spaces, especially those protected from significant secondary ballistic objects, create casualty populations with much higher proportions of survivors manifesting BLI.[28,115]

Pooling data from two 1996 terrorist bombings inside enclosed buses in Jerusalem, Pizov and colleagues published a report on their observations regarding BLI severity.[109] They were able to classify injuries into mild, moderate, and severe based on plain chest radiography, arterial blood gas analysis, and the presence of bronchopleural fistulae. Contusion densities on chest radiographs ranged from localized unilateral to massive bilateral, whereas the p_aO_2/F_iO_2 ratio (PFR) was utilized as a marker of lung injury impairing oxygen diffusion.

Wightman and Gladish combined this classification with information from other studies to create the correlates found in Table 26.2.[75] Minor BLI, defined as one lung focally injured and a p_aO_2 maintained above 5.6 kPa on an ambient F_iO_2 of 0.21, may require supplemental oxygen administration, but generally will not require PPV for respiratory compromise. Victims may require PPV for other reasons such as decreased level of consciousness or the need for a surgical procedure requiring a general anesthetic. Moderate BLI, defined as most of one lung or both lungs involved asymmetrically and an inability to maintain a p_aO_2 of 13.3 kPa with a F_iO_2 of 0.5, normally requires some period of volume-controlled ventilation using reasonable levels of positive end-expiratory pressure (PEEP) or pressure support. Severe BLI, defined as the inability to achieve a p_aO_2 of 8.0 kPa with a F_iO_2 of 1.0, often requires pressure-controlled ventilation, inverse inspiratory/expiratory ratios, and permissive hypercapnia.

For out-of-hospital responders, Wightman used relationships in the oxygen–hemoglobin dissociation curve to estimate pulse oximetry (S_pO_2) measurements corresponding to the previous PFR categorizations. These recommendations assumed no major left or right curve shifts, no significant elevations in altitude, and no hemoglobin or mitochondrial toxin.[104] Minor BLI would be defined as any S_pO_2 reading at or above 75% hemoglobin saturation on ambient air with an F_iO_2 of 0.21. Moderate BLI would be any reading at or above 90% on 100% supplemental oxygen. Severe BLI would be any reading less than 90% on the same.

Blast Intestinal Injury (BII)

Table 26.1 summarizes the conditions resulting from disruption of air–tissue interfaces in the abdomen. When stress-induced pressure differentials cause tissue tearing of air-containing structures in the gastrointestinal (GI) tract, these organs can bleed into mesentery, the bowel wall, or into the lumen (Figure 26.5). They can rupture, releasing air and GI contents into intrathoracic, intraperitoneal, or extraperitoneal spaces.[98,105] The colon is the most common organ affected, likely because of its larger gas content.[116,117] Tension pneumoperitoneum has been reported.[118] PBI-induced esophageal rupture is extremely rare.

Targeted questions to ask casualties are similar to those for blunt abdominal trauma.[104] "Do you have abdominal or testicular pain, nausea, urge to defecate, or blood in your stools?" BII may cause visceral, parietal, or referred pain. "What does your pain feel like?" Stretched bowel wall will feel like a persistent gas bubble with possibly sharp and crampy waves as it is affected by peristalsis. Once the bowel ruptures, pain often decreases until peritonitis begins. The pain of peritonitis is commonly diffuse and severe and may be associated with a fever. The abdominal, flank, back, genital, perineal, and rectal examinations are the same as for any other polytrauma patient, although the probability of bowel rupture is comparatively higher. Moreover,

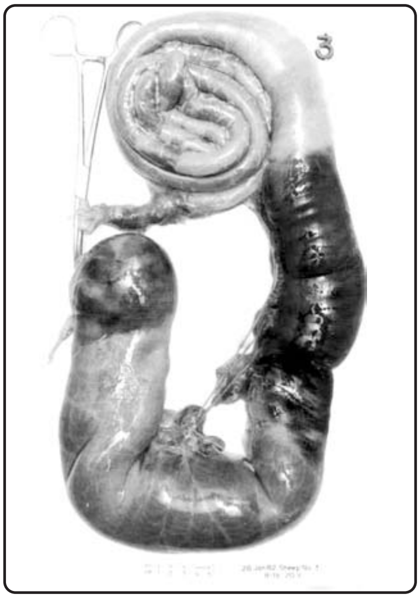


Figure 26.5. BII from a sheep model. Note segmental parenchymal hemorrhage and intraluminal blood visible through other areas of relatively intact bowel wall. This figure is in the public domain as published by the Office of the Surgeon General of the United States Army, Falls Church, Virginia, USA. Reproduced from the *Textbook of Military Medicine*. 1991:288.[76] See color plate.

problems can evolve over time as intestinal perforation can be delayed by several days following bowel wall injury without immediate rupture.[119–121]

Traumatic Brain Injury (TBI)

Blast-induced traumatic brain injury (TBI), when neither definitively blunt nor penetrating in nature, occurs in casualties, and ranges from severe to mild. The pathophysiology of damage is not well understood and often not apparent when using conventional imaging techniques. Putative mechanisms of primary TBI are likely a combination of gross acceleration, vascular surge, and electromagnetic pulse. Local biochemical and systemic metabolic derangements contribute.[86,122] A long list of humoral and inflammatory mediators suspected of causing ultrastructural injury is generated by these pathophysiological mechanisms.

Blast-pressure forces applied to one side of the head microseconds before the other side can result in gross acceleration until the blast front traverses the skull, when the head could be accelerated in the reverse direction. Simulations have shown that explosive blasts can cause accelerations exceeding the maximum survivable magnitude of 300 G (G = the force of gravity).[86] Based on a sport injury model, 50 G may be the threshold for mild TBI.[123] Coup and contre-coup trauma may be caused by localized regions of high pressure and relatively low pressure, which distort tissues to cause damage during head jerks.[124,125] Axonal tension can affect neural activity.[126]

Compression of the torso, which is relatively more compliant than the skull, can force blood into the cranium, producing a vascular surge that increases both pressure and volume resulting in dysfunction.[86] Neuronal changes also occur in those cells responsible for hearing and vision.[127,128] Systemic derangements sustained in many serious traumatic events (e.g., hypoxia, hypotension) further compromise brain function and may lead to irreversible tissue damage.

Superheated gases created by high-order explosives that are under pressure at the blast front can charge atmospheric particles to generate an electromagnetic pulse.[129] The resultant energy flux may adversely affect neural tissue.

In a 10-year study of accidental explosions seen at the Maryland Institute for Emergency Medical Services Systems, more than one third of patients with a normal Glasgow Coma Scale score had some element of TBI missed on the initial evaluation.[130] Questions can be used for rapid screening for potential neurological injury.[104] "Do you have headache, vertigo, unsteadiness, or nausea?" This may help identify patients at risk for mild TBI and lead to initiation of casualty protection and medical management as early as possible. When time allows, the best screening tool currently available is the Military Acute Concussion Evaluation (MACE).[131]

Neurological deficits found on examination of blast victims may range from subtle dysfunction to complete unresponsiveness. Causes of altered mental status or seizures include conventional blunt or penetrating head injury; stroke from cerebral air embolism; hypoxemia from lung injury; or shock from tension pneumothorax, hemorrhage, or air embolism–induced myocardial infarction or spinal cord dysfunction. Intracranial lesions resulting in focal deficits will most likely be due to cerebral or extraaxial hemorrhage. Visualization of air in retinal vessels, mottling of nondependent areas of skin, or demarcated tongue blanching are insensitive but specific indicators of systemic air embolism.[132]

Other Primary Blast Injuries

A syndrome of bradycardia and hypotension without blood loss has been described in blast-injured soldiers.[133] Blast loads directed only toward the chest in animal models cause a unique, vagal nerve–mediated form of cardiogenic shock without compensatory vasoconstriction.[134] This phenomenon occurs within seconds of exposure, and partially resolves over 1–2 hours. Pressure-sensitive pulmonary C-fiber receptors may be the initiating afferent limb of this reflex.[135]

Blast waves that gain access to the upper respiratory tract can cause pharyngeal, laryngeal, and tracheal petechiae and ecchymoses. These findings may be consistent with sufficient blast loading to also cause BLI.[136] Blast waves, however, do not cause BLI via an air pulse down the respiratory tract.[133] BLI is caused by forces applied to the chest wall.

Blast loading can also damage solid organs through displacement of body surfaces, shear wave stretch, and acceleration at organ attachments. The heart and intraabdominal solid organs may sustain petechiae, contusions, lacerations, or rupture.[98] Stress waves are not apparently as important, likely because of these organs' relatively homogeneous densities.[137] Mesenteric, retroperitoneal, and scrotal hemorrhages have also been reported.[98,105]

The combination of stress wave–induced shattering of bone and subsequent blast wind can tear off all or portions of the extremities and the head. Isolated torsos were all that were found of many victims exposed to the detonation of 1 metric ton of TNT-equivalent explosives behind the U.S. Embassy in Nairobi, on August 7, 1998 (author's personal observation). Decapitation is universally fatal, as are many proximal extremity traumatic amputations, but survival has been reported for the latter.[50,138–141]

Local Medical Responders

The destruction of structures and associated debris resulting from explosive blasts will hamper how well first responders can perform their initial actions. The threats of accidental or intentional secondary blasts; evolving hazards such as fire, smoke, toxic substances, and building collapse; and potential follow-up attacks with ballistic weapons can restrict local responders' efforts to reach victims. Even when victims are located, single or combined threats can affect the speed and accuracy of clinical assessment prior to movement of patients out of these hazardous environments.

No matter how dangerous the rapid movement of blast victims may seem, the risks of lingering in an area of recent explosive activity to stabilize victims more adequately may be greater than any risk associated with early rescue or transportation. Organizations assigned to first response should certainly anticipate the unique challenges of rapid evaluation, triage, initial treatment, and evacuation of individual or multiple blast victims.

Stein and Hirschberg have described four out-of-hospital management phases based on their experiences with terrorist bombings in Israel.[142] The "chaotic phase" is characterized by ambulatory victims self-evacuating or being transported from the scene by well-meaning bystanders. No professional responders have arrived, and no Incident Commander has assumed control of the situation. The "reorganization phase" begins with the arrival of law enforcement, fire/rescue, and EMS assets. Triage is performed and resources are allocated for the most seriously injured casualties. The "site-clearing phase" involves evacuation of known patients and thorough searches for missed victims. In urban settings in Israel, scenes are typically cleared in less than 3 hours. The "late phase" encompasses the time required for all victims suffering from blast-related injuries to present for care. Minimally injured casualties and those with medical or psychological complaints usually seek care within 1–2 days of the event.

Einav and coauthors have suggested three phases: rapid on-scene triage with a minimum of medical interventions; urgent evacuation of critically injured casualties to the nearest hospital for resuscitation and stabilization; and transportation of all other casualties to more distant and presumably less-burdened facilities, so as not to overwhelm those closest to the scene.[143] A fourth phase might be the redistribution of casualties from less capable hospitals to regional trauma or medical centers.

The Israeli experience in out-of-hospital responses to terrorist attacks has been detailed by Singer et al.[144] The first medical team that arrives does not provide care. Its primary function is scene assessment and communication to the Incident Command. Key elements include 1) type of event, 2) estimated casualty numbers, 3) location(s) of casualties, 4) safe approach and evacuation routes, and 5) estimated time of first casualty arrival at the closest hospital. As the next medical teams arrive, they evaluate and manage casualties as they find them. Larger responses would allow additional medical teams to be assigned to different geographical regions.

Human access, care, and evacuation (HACE) is a term coined by Mark Gebhart and James Gruenberg of the National Center for Medical Readiness (personal communication). The concept describes the situations faced by emergency responders in performing their out-of-hospital duties after a call for help has been initiated and will serve as an outline for the next discussion.

Human Access

The potentially unstable environment associated with explosive blasts may limit search and rescue efforts. There is a dearth of best-practice recommendations for out-of-hospital responders; however, a few observations can be stated.

Significant rescue and response efforts always demand coordination among public safety agencies (e.g., emergency management, fire/rescue, law enforcement, and public health). As such, the effort should be directed via application of the Incident Command System. Utility companies should be closely engaged to allow rapid response to situations that put rescuers at risk, such as ruptured pipelines or damaged power lines. Bomb squads or military explosive ordnance disposal teams may be required, if unexploded devices are discovered.

Explosions can cause collapse of buildings and other structures. Access to trapped victims falls under the discipline of urban search and rescue (US&R).[145] Delayed access may result in natural progression of pathophysiological processes, with more complications from blast manifesting prior to rescue or before medical personnel can make initial contact with the victim. Conditions unfamiliar to EMS providers may exist. Some examples include confined-space hypoxia, hypercarbia, or restriction of ventilation; dust, smoke, or toxic inhalations; prolonged, and possibly irreversible, hemorrhagic shock; compartment and crush syndromes; dehydration; and even advanced wound infections and sepsis. Delays in evacuation can similarly result in abnormally prolonged medical responder–patient contact time prior to extrication and evacuation for stabilization or definitive care at a hospital or alternate care site.

Collapse of smaller structures may result in larger proportions of victims surviving to hospital admission.[36] With the collapse of larger structures, the outcome is less favorable, as was observed in those victims trapped inside the Murrah Federal Building in Oklahoma City. In that event, the relative risk of dying was more than 16 times greater in the collapsed portion than it was in other areas of the structure.[32] The only fatality that did not occur as a direct result of the explosion was a rescuer who was struck in the head by a falling object.

Therefore, potential benefits and risks must always be carefully assessed before any decisions on access and rescue are made. Safety is a prime function of the Incident Command System. Evolving sensor technologies may facilitate locating victims, and even assessing their physiological statuses, so decisions regarding responder risks can be better considered.

Field Triage

Although triage is usually discussed in the context of a disaster or mass casualty scenario, where inadequate resources exist to meet medical needs, triage occurs daily in medical settings around the world. It can be applied to any decision related to allocation of resources. In the field, it applies to all aspects of HACE.

Triage for Targeting relates to locating and accessing victims of an explosive blast. This may be made difficult by threats discussed previously, debris or hazardous materials dispersed by the energy of the explosion and the blast wind, and the lack of provider technical expertise to enter collapsed structures or buildings on fire. Reconnaissance by aircraft may be helpful in assessing the area affected, but there is currently little in the way of best practices or technological solutions to support the process of victim location beyond rescuers conducting thorough on-the-ground searches. Assigning personnel assets to structures with the highest probability of containing salvageable victims should be coordinated through the Incident Command System. External assistance in the form of specialized search-and-rescue teams and equipment may be necessary.

Triage for Treatment in the out-of-hospital setting involves sorting patients based on required medical interventions. This presumes that the patient requiring the most immediate life-saving interventions is the one who will be triaged to the highest priority category. There are a number of triage systems available for use in mass casualty settings (see Chapter 12). Simple Triage and Rapid Treatment (START) and Secondary Assessment of Victim Endpoint (SAVE) encompass one triage scheme commonly used in the United States.[146] JumpSTART is a system proposed for pediatric use.[147] The Paediatric Triage Tape has gained some acceptance in Europe and South Africa.[148,149]

Internationally, there are other triage methodologies commonly in use, such as Triage Sieve and Sort in the United Kingdom and an algorithm created by CareFlight in Australia.[150–152] One group attempted to apply these two systems retrospectively, as well as the START methodology, to the 2005 London terrorist bombings to assess performance.[153] Although all three seemed to be equivalent, conclusions were severely hampered by missing data and small numbers of critically injured patients.

Move, Assess, Sort, and Send is a more recently published approach.[154,155] Move Assess, Sort, and Send (MASS) requires victims to hear and understand rescuer commands. This may limit its utility for children, those who do not understand the language spoken, and those with hearing loss after a blast. The Sacco Triage Method has been advocated by some authors as an improvement to the START/SAVE method, because it takes into account resource constraints and uses expert consensus to model expected deterioration rates in casualties awaiting treatment.[156,157] It is not currently in widespread use, likely because it is proprietary and requires a labor-intensive numerically scoring calculation for each of three parameters using a 0–4 scale and totaling the results. This sum is then used to categorize victims into groups with the following numerical ranges for organizing scene resource allocation: 0–4, 5–8, and 9–12. At the time of this writing, neither of these systems has been used in an actual disaster, so data supporting their efficacy are limited.

A recently published article has called for a national U.S. standard for disaster triage. A multidisciplinary consensus committee supported by the U.S. Centers for Disease Control and Prevention (CDC) reviewed previously published triage methods and suggested an approach it believes combines the best aspects of several of these systems. It was given the acronym SALT for Sort, Assess, perform Life-saving interventions, and Treatment/Transportation.[158] No additional commentary or studies have been published on this new proposal to date.

Whichever methodology is applied, two facts are critical: the responders must be intimately familiar with the chosen technique, and they must dynamically reassess patients and reassign categories to optimize victim benefit and allocation of resources. Casualty receivers must also be aware of the system or systems used in their communities, so they are prepared for the types of casualties that will require care in each triage category.

Most field triage systems divide casualties into some combination of five categories (listed in order of priority): immediate, delayed, minimal, expectant, and dead.[159] The Magen David Adom (MDA) Israeli National EMS system uses three categories: urgent, nonurgent, and dead.[42] The MDA has the advantage of being a nationwide network with centralized organization in a relatively small geographical area, but response systems in other communities could adopt a similar approach.

Immediate or urgent casualties are those for whom immediate life-saving intervention is required. The resource(s) needed to save the life of any given casualty in this category are as variable as the conditions that cause the life-threatening conditions. When immediately available, and not anticipated to be needed elsewhere, most communities and cultures have an expectation that the necessary resources will be committed. If, however, these resources are not available in the time frame needed, cannot be obligated to a single patient, or must be redistributed to many patients (e.g., large supplies of fluid or blood or the time a medical provider can spend with a single patient); casualties in the immediate category might be reclassified into the expectant category (see later).

Other victims would be nonurgent in the Israeli system. Delayed casualties are categorized as such based on the triage officer's brief assessment of who does not need immediate life-saving interventions, but who still has not had potentially life-threatening problems excluded. Minimal casualties are those believed to have conditions not requiring intervention during the mass casualty situation to prevent undue mortality, morbidity, or suffering.

Although the expectant category derives from medically austere military settings with typically longer evacuation times, it may be necessary to use this designation in civilian settings when needs outstrip resources. Many EMS educators teach an approach to expectant casualties as if they are "expected" to die, or are otherwise labeled as "unsalvageable." A better approach would be to "expect" reevaluation of these casualties, and possibly undertake more aggressive management once sufficient resources become available.

In a disaster situation where needs exceed resources, resuscitation should not be attempted on victims who are found or received dead. Specific examples of injuries that might warrant assignment to each of the other four categories are detailed in many textbooks and publications. Baker summarized those with military application.[160]

Undertriage refers to categorizing patients into a lower acuity category than their conditions warrant and risks excessive morbidity and mortality from delays in care.[159] On the other hand, overtriage categorizes patients into higher acuity categories than necessary and commits resources that might be needed elsewhere. Such activity is postulated to lead to a linear relationship between the overtriage rate and mortality in the overall population of critical casaulties.[159,161,162] No evidence is available demonstrating this assertion, however. All publications to date on the subject describe only associations. It is equally valid to postulate that the strain of working at mass casualty events with higher mortality rates results in more overtriage. Because no studies currently exist demonstrating a cause and effect relationship, either interpretation is equally valid. Nonetheless, during resource-constrained responses, incorrect triage decisions may have far-reaching consequences on the community affected by the disaster.[163]

Triage for Transportation is less understood outside of the military. It should be self-evident that patients incapable of moving themselves to treatment facilities will ultimately require evacuation. Most of the world's military organizations use triage to sort patients into categories for allocation of scarce transportation resources. In the U.S. Army and Marine Corps, for example, "urgent" patients are those requiring a higher level of treatment within the next 2 hours. "Priority" patients are those who require additional treatment within 4 hours. "Routine" patients require movement within 24 hours, so this would rarely apply to a civilian disaster setting in the developed world. Nonetheless, significant constraints on the availability of evacuation assets, long distances, and lack of suitable destinations may force consideration of this category. Civilian agencies also have the option of changing the expected time frame (e.g., 6 or 12 hours, instead of 24 hours).

The Israeli MDA uses only "urgent" and "nonurgent" categories to triage for treatment and transportation. In a paper that defined mass casualty incidents as those of "large enough scale to recruit most of the rescue teams . . . within a defined region, regardless of the actual number of casualties," Einav and colleagues examined evacuations from urban and rural scenes of terrorist bombings over a 2-year period.[143] Approximately one in every five victims was deemed to be urgent. Of note, a few incidents were not related to explosions, and those that did result from blasts encompassed both open-air and closed-space detonations. Even in "large urban" areas, less than half of these critical casualties were evacuated to trauma centers, although most of the remainder were transported to other medical centers, rather than smaller hospitals. The majority of patients arrived at the closest facility, whether self-evacuated or transported by ambulance.

Ideally, critically injured casualties should be managed at trauma centers, when available.[38] Children should be transported to hospitals with pediatric capabilities and expertise.[164] Less critical casualties should be dispersed to less burdened facilities farther away from the incident.[144] Use of helicopters, which represent high-value, low-density assets in any disaster response, must be carefully considered.[165] Effective transportation systems for critical casualties require significant community and regional preparedness before an event, but evacuation processes are made even more complex by ongoing threats following initial explosions.[166] Difficult on-the-spot decisions must be made in determining the best mode of transportation (e.g., ambulance or nonmedical vehicle of convenience, ground or air) and best destination for casualties, who did not self-evacuate, based on triage category and specific injury types.

Out-of-Hospital Care

Once patients are adequately accessed in a relatively safe environment, the individual out-of-hospital care each victim receives should not be affected by the specifics of postblast settings. This is true as long as due consideration is given to the potential for exceeding available time, personnel, equipment, and supply resources. Civilian first responders should be aware of the tactical combat casualty care (TCCC or TC3) recommendations made in the military version of the Prehospital Trauma Life Support manual or other references that approach out-of-hospital care in postblast scenarios.[167–169] These guidelines discuss appropriate care in high-threat, time-constrained, and resource-limited situations.

Mass casualty out-of-hospital care may require EMS providers to use techniques with which they are less familiar. Examples include use of methods other than direct pressure to control hemorrhage (because this action consumes medically trained personnel resources that may be more effective elsewhere). Exsanguinating extremity hemorrhage may necessitate control with a proximal tourniquet, either by inflating a blood-pressure cuff or applying a prefabricated or field-expedient device.[170] The use of tourniquets in recent wartime applications has shown that correctly placed extremity tourniquets may be the leading lifesaving device used by soldiers in combat.[171–173] They may also have applications in disaster medicine, but utilization should meet specific criteria in the civilian setting.[174] Not all clinicians agree with their applicability in a civilian healthcare system.[175–177] The speed and efficacy of various devices have been studied in detail.[178] Clot-enhancing agents such as microporous polysaccharide microsphere, mineral zeolite, or poly-N-acetylglucosamine (chitosan) may be useful adjuncts, or applied primarily for truncal or proximal extremity wounds where tourniquets cannot be used.[179]

Although rarely reported in the literature, massive hemoptysis from severe BLI may compromise a victim's airway. If simply allowing patients to attain their own best positions for oxygenation and ventilation is ineffective, rescuers must act by attempting to selectively intubate the least injured lung.[75] In 99% of cases, a standard endotracheal tube passed orally to its full depth will cause the tip and balloon to sit in the right mainstem bronchus. After cuff inflation and a few ventilations, unilateral isolation should be assessed. If more blood passes around the tube than through the tube, then the right lung is protected from left-sided hemorrhage. If more blood passes through the tube, the right lung is likely the origin, and the left lung must be selectively intubated. This can be accomplished blindly using one of three maneuvers (Figure 26.6).[180]

Rescuers should permit victims to breathe spontaneously whenever possible.[75] Increased airway pressure or decreased venous pressure exacerbates the risk of air entering the pulmonary venous circuit.[181] The head should be kept at the level of the heart.[132] When other injuries allow, casualties with unilateral blunt or penetrating chest trauma can be positioned on the side of injury to increase venous pressures.[108] Victims with BLI might benefit from left semilateral decubitus or prone positioning, but no studies have demonstrated efficacy.[75] The left semilateral position (i.e., halfway between left-lateral and prone positions) will place the coronary artery ostia in their lowest positions to decrease the likelihood of air entering these vessels.[132] Prone positioning will place the left atrium at its highest point to potentially prevent air from passing through the mitral valve into the left ventricle and being ejected into the systemic circulation.[75]

Tension pneumothorax is common in BLI patients and may be bilateral.[109] Rescuers must be taught to rapidly recognize the presentation of this condition and act quickly to prevent continued hemodynamic compromise. The three potential indications for emergent needle thoracentesis in the field are 1) unilaterally decreased breath sounds and any clinical evidence of shock, 2) unilateral penetrating chest trauma and progressive (or already severe) respiratory distress, or 3) bilaterally decreased breath sounds in a moribund patient who is still attempting to breathe.

Intravenous access is indicated in most trauma patients; however, fluid administration may not be required in all situations, especially those in which resources are relatively scarce. If external bleeding is controlled, and ongoing internal hemorrhage is not suspected, fluids are unnecessary in casualties who are not hemodynamically compromised, in shock, or unstable. Hypovolemic deterioration would not be expected without continued bleeding. Patients without ongoing hemorrhage, but clinically determined to be in shock, should be resuscitated with isotonic crystalloid

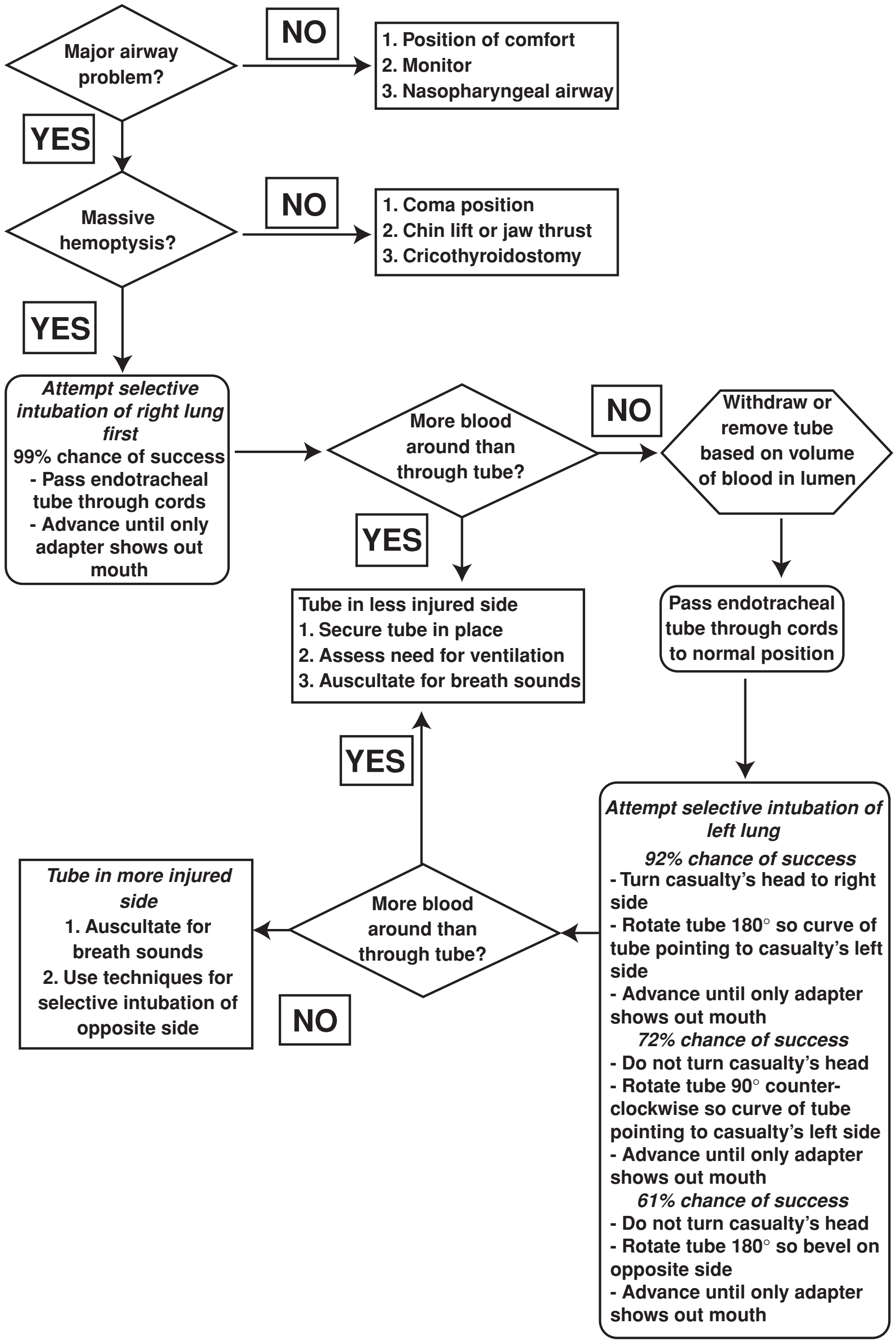


Figure 26.6. Algorithm for blind selective mainstem intubation. This information is in the public domain as published by the Center for Total Access, Ft. Gordon, Georgia, USA. Adapted from the *Special Operations Forces Medical Handbook*. 2001:7–25.[104]

fluids to the point of shock reversal. Healthcare providers can administer fluids in 5-mL/kg boluses, thus theoretically minimizing the impact on potentially damaged lungs. Vital signs should improve, but attaining normal values is not necessary. If external or internal bleeding cannot be expeditiously controlled, there is no point in administering crystalloid fluids. It is unlikely to be beneficial and may, in fact, be harmful.[182]

When responding to explosive events, civilian out-of-hospital medical personnel may inadvertently place themselves at risk for accidental or intentional injury. Under the military TCCC guidelines, the appropriateness of casualty assessment and field treatment are based on the relative threat(s) to the medics. In military terminology, these are divided into "Care Under Fire" and "Tactical Field Care" situations.[168,169] There is a third situation for evacuation from the battlefield, which will not be discussed in this chapter.

Scene security is of paramount importance during any response to prevent the responders from becoming casualties themselves. When the responders could be actively threatened by approaching the victim, it may not be appropriate to attempt rescue. Casualties who can move under their own power should be told to either move to cover or remain still, so as not to attract attention and become a target again. If a responder proceeds to a casualty and is caught in a hazardous situation, most medical interventions would be inappropriate when both individuals remained threatened. On the battlefield, care under fire is usually confined to control of rapidly exsanguinating external hemorrhage. Airway problems are rare, basic remedial maneuvers require a constant position, and adjunctive interventions can be time consuming. If the responder moves to a position of cover, the casualty should be transported by field-expedient lifts, carries, or other available methods.

Tactical field care applies when medics are not experiencing an active threat, but close enough to danger to remain at risk. Table 26.3 lists civilian adaptations of the guidelines for battlefield interventions in these situations.[167] Some items from the original recommendations were removed because civilian rescuers do not normally have access to a variety of medications carried by military operators and medics, and evacuation times to reach a treatment facility from a nontactical civilian setting are rarely as long.

Evacuation

Local and regional protocols as well as existing disaster plans should be the primary determinants of the modes of transportation and patient destinations; however, the postblast environment may warrant additional considerations. Experience has shown that many, if not most, disaster victims self-evacuate before the arrival of rescuers. This was true following the Tokyo sarin incident of March 20, 1995.[183] It has also been noted in the aftermath of several accidental and intentional explosions.[38,48,55] On the other hand, in 2004, following the almost-simultaneous detonations of high-order explosives in four commuter trains in Madrid, “the vast majority of survivors” were evacuated by ambulance.[39] Walking times to area hospitals were not provided.

The intent of scene control and incident command with regard to evacuation is to determine the best destination for casualties, based on moment-to-moment clinical parameters matched to ever-changing capabilities and capacities of receiving facilities. In a 2-year study of evacuations from terrorism-related mass casualty incidents, one Israeli study found that most casualties were transported to the closest ED, despite centralized control of their EMS system.[143]

Unsecured scenes after an attack or the threat of accidental or intentional secondary explosions may preclude or seriously delay the use of civilian evacuation assets. Nonmedical vehicles of opportunity in the area of the explosion are sometimes used to transport victims to a safer nearby casualty collection point or all the way to a hospital. Waterborne evacuation is not often considered, but, in certain locations, it may be an option during regional disaster planning and response. Factors that can prevent airborne evacuation of patients include scene safety considerations, natural explosions (e.g., volcanic eruptions), or even poor weather conditions unrelated to the disastrous event. Aeromedical evacuation will also require pilots and medical personnel to consider the effects of altitude on conditions such as hypoxemia, air embolus, pneumocephalus, ocular air after penetrating trauma, pulmonary pseudocyst, pneumothorax, pneumoperitoneum, and bowel injury.[184] All of these can be worsened by decreased partial pressures of oxygen and reduced atmospheric pressures, the latter of which enables existing trapped air to expand.

Receiving medical facilities may be affected primarily by the event or their capacity secondarily degraded by inaccessibility, utility failures, or staff absenteeism. They may also be overwhelmed by unusual patient volumes and severities in a disaster’s aftermath. This may be especially true for any specialty referral centers.

Specialized Responses

Some explosive events may necessitate additional considerations for local responders. Specialized teams with subject matter expertise and problem-specific training exist in many countries to assist local authorities and respond when requested. Incident managers must be aware of these external assets so they can request, coordinate, and oversee deployment of these resources within their jurisdictions.

Urban Search and Rescue

Many victims injured in collapsed structures will be rescued by well-meaning bystanders.[145] Nonetheless, it remains very important for the lay public, public safety professionals, and out-of-hospital medical personnel to understand the significant dangers involved in attempting to rescue victims trapped in collapsed structures. One of the first principles taught to first responders is scene safety. Untrained approaches to victim extrication run the risk of additional harm to existing casualties and turning would-be rescuers into additional casualties, thereby increasing the demand for rescue resources, while simultaneously decreasing the supply.

Professional US&R teams exist in many countries;[145] however, they are usually not plentiful and are often controlled by governmental organizations higher than the community level. For instance, U.S. federal US&R teams are unlikely to be available to assist local rescuers in the first 3–4 days after an event, unless positioned in the region in advance of an anticipated event. On the other hand, many fire/rescue personnel around the world have been cross-trained in some of these specialized rescue techniques. Individuals may even serve on federal US&R teams in a reserve capacity. Some local fire departments or regional coalitions of departments have pooled resources to create their own formal US&R capabilities, which can be dispatched by local authorities.

Dirty Bombs

Dirty bombs are any explosive device that intentionally releases a secondary agent (e.g., chemical, biological, or radiological). Most people associate this term with radiological dispersion devices (RDDs) discussed in Chapter 30, but blast energy can be used to disseminate many hazardous or infectious materials. Management of chemical and biological casualties is discussed in Chapters 28 and 29.

RDDs, if constructed properly and used effectively, have the potential to pose a significant risk to an exposed population. Most plausible terrorism scenarios involve acquiring open-source isotopes.[185] These can either be disseminated with an explosion or delivered in manners similar to biological and chemical agents (e.g., contamination of food, distributed through ventilation systems, and so forth). Internal contamination via inhalation or ingestion poses the greatest threat to health. Radioactive sources simply carried near or placed in the vicinity of people are called radiological exposure devices. These emanate ionizing radiation but generally do not cause radiological contamination.

Detection of an occult isotope release or covert attack is beyond the scope of this chapter; however, once identified, treatment of radiological casualties is possible (Chapter 30).

Table 26.3: General Guidelines for Civilian Application of Tactical Combat Casualty Care in Threatening Situations

- Casualties with an altered mental status should be disarmed immediately
- Airway management
  - Unconscious casualty without airway obstruction
    - Chin-lift or jaw-thrust maneuver
    - Nasopharyngeal airway
    - Place casualty in recovery position
  - Casualty with airway obstruction or impending airway obstruction
    - Chin-lift or jaw-thrust maneuver
    - Nasopharyngeal airway
    - Allow conscious casualty to assume any position that best protects the airway, to include sitting up; or place unconscious casualty in recovery position
  - If previous measures are unsuccessful, surgical cricothyroidotomy – induce local anesthesia with lidocaine, if conscious
- Breathing
  - Consider tension pneumothorax and decompress with needle thoracostomy, if casualty has torso trauma and respiratory distress
  - Sucking chest wounds should be treated by applying a three-sided dressing during expiration and monitoring for development of tension pneumothorax
- Bleeding
  - Assess for unrecognized hemorrhage
  - Control all sources of bleeding
  - Use tourniquets for extremity hemorrhage, if necessary
- Vascular access
  - Start an 18-gauge intravenous (IV) line or saline lock, if indicated (see text)
  - If resuscitation is required and IV access is not obtainable, use the intraosseous route
- Fluid resuscitation
  - Assess for hemorrhagic shock: altered mental status in the absence of head injury and weak or absent peripheral pulses are the best field indicators of shock
    - If not in shock
      - No IV fluids necessary
      - Oral fluids permissible, if conscious and evacuation delayed
    - If in shock
      - Hextend 500-mL IV bolus
      - If still in shock, repeat Hextend 500-mL IV bolus once after 30 minutes (no more than 1,000 mL Hextend)
  - If a casualty with TBI is unconscious and has no peripheral pulse, resuscitate to restore the radial pulse
  - Continued efforts to resuscitate must be weighed against logistical and the risk of incurring further casualties
- Prevention of hypothermia
  - Minimize casualty's exposure to the elements
  - Keep protective gear on or with the casualty, if feasible
  - Replace wet clothing with dry, if possible
  - Warm the casualty and prevent additional heat loss
    - If available: apply Ready-Heat blanket to torso; wrap in Blizzard Rescue Blanket; and put Thermo-Lite Hypothermia Prevention System Cap on the casualty's head under helmet
    - If not available: use dry blankets, poncho liners, sleeping bags, body bags, or anything that will retain heat and keep the casualty dry
  - Apply additional interventions as needed/ available
- Monitoring
  - Pulse oximetry should be available as an adjunct to clinical monitoring – though readings may be misleading in the settings of shock or marked hypothermia
  - Inspect and dress known wounds
  - Check for additional wounds
  - Analgesia as necessary
- Splint fractures and dislocations
  - Check distal neurovascular status before splinting
  - Check distal neurovascular status after splinting
- Antibiotics, if available and evacuation is delayed
- Communicate with the patient if possible
  - Reassure
  - Encourage
  - Explain care
- Cardiopulmonary resuscitation
  - Resuscitation on the battlefield for victims of explosion injury or penetrating trauma who have no pulse, no ventilations, and no other signs of life will not be successful and should not be attempted
- Documentation
  - Clinical assessments, treatments rendered, and changes in casualty's status
  - Forward this information with the casualty to the next level of care

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Additionally, the U.S. Department of Health and Human Services has posted comprehensive information on the medical management of radiation-exposed patients (http://www.remm.nlm.gov/). More information in the public domain can be obtained from the U.S. Armed Forces Radiobiology Research Institute's *Medical Management of Radiological Casualties* handbook (free download available at http://www.afrri.usuhs.mil/outreach/pdf/2edmmrchandbook.pdf). For expert assistance, the U.S. Department of Energy maintains a worldwide 24/7 consultation capability in its Radiation Emergency Assistance Center/Training Site (REAC/TS) (contact information is available at http://orise.orau.gov/reacts/). The U.S. Department of Defense supports a similar mission with its Medical Radiobiology Advisory Team (MRAT) (contact information is available at http://www.afrri.usuhs.mil/outreach/emergency_response.html).

Nuclear Detonations

Accidental or intentional nuclear detonation is a particularly devastating disaster because it creates a combination of thermal, blast, and radiological injuries to a massive number of casualties in addition to major infrastructure destruction over a wide area. Blast wave overpressures from nuclear detonations may be orders of magnitude greater in amplitude than conventional high-order explosives and several meters thick with positive-phase impulses lasting seconds instead of milliseconds. These are expected to crush objects and people.[186] Combined with an intense blast wind, disintegration or total body disruption usually occurs. Casualties of nuclear PBI are usually not salvageable, even if found intact. Secondary and tertiary blast injuries are actually more important mechanisms of casualty generation following nuclear detonations, because a greater percentage will initially survive than those affected by PBI. Prolonged blast overpressures can also result from fuel-air explosives, but these are unlikely to be acquired or delivered by nonmilitary groups. Nonetheless, some industrial accident scenarios may mimic their effects, with blast wave characteristics between those of nuclear devices and conventional high-order explosives.

As many as 80% of casualties directly injured by a nuclear detonation might have thermal trauma of various degrees either alone or in combination with blast or radiation injury.[78] Mass burn care is by itself a daunting consideration for medical planners and responders.[187,188] Irrespective of concomitant radiation injury, no validated triage guidelines exist for such an event.[189] The medical and surgical management of serious burn injury requires significant resources, even for a few individual victims (see Chapters 3 and 27).

Radiological injury manifests from either the prompt symptoms of radiation exposure accompanying the detonation or the delayed symptoms from fallout of radioactive contamination. Nuclear detonations can be considered as collective radiological exposure devices/RDDs with similar but much more powerful and widespread effects. A standard fission device distributes its energy as approximately 5% initial radiation, 35% thermal, 50% blast, and 10% fallout radiation.[78] Dispersed radioactive materials may emit α- or β-particles, neutrons, or γ- or x-rays. The large number of casualties with combined injury patterns will profoundly affect triage decisions and the allocation of medical resources.

Following a nuclear detonation, the potential initial radiation dose decreases exponentially with distance from the device when exposure from subsequent fallout is excluded. Some physical barriers may be protective, depending on the type of radiation and the materials and thickness of the shielding. Initial radiation doses less than 0.35 Gy will generally not cause early symptoms. Greater exposures will result in symptoms of the acute radiation syndrome (ARS) with time of onset inversely proportional to dose (see Chapter 30).

Delayed onset of nausea until 6–12 hours after a known event implies a relatively minor dose under 0.75 Gy. Higher doses may eventually cause the hematopoietic syndrome weeks later, but these doses can still be considered relatively minor if nausea is the only clinical manifestation. Vomiting or any systemic symptoms imply a dose exceeding 1.25 Gy, which has the potential to cause death in some exposed individuals. Diarrhea in the first 1–2 weeks implies the onset of the GI syndrome and receipt of a moderate dose over 3 Gy, which will kill at least 50% of the exposed population unless significant intensive care unit (ICU) resources can be allocated. Onset of the GI syndrome within the first day, when the time of exposure is known, indicates a more lethal level usually greater than 7 Gy. Neurological symptoms at any time signify severe radiation injury.[190]

Table 26.4 depicts one suggestion for alterations in standard triage practices when radiation injury may be a coexistent problem.[191] Severely exposed victims will all die, even with the most sophisticated medical care available. Therefore, all of these individuals should be considered expectant in the context of a mass casualty situation. Palliative and pastoral care should be provided whenever possible. When resources are not limited, minimal additional care might be appropriate and culturally expected.

Victims with early onset of the GI syndrome should be considered expectant in a mass casualty situation, unless their conventional injuries are minimal. By definition of the term "minimal," no excessive morbidity or mortality would be expected to result from their nonradiation injuries, even if no professional care were rendered to them. Their radiation injury could then possibly be addressed later, if more resources become available.

Casualties with more severe conventional trauma and early radiation injury symptoms will have significant difficulty healing and be at much higher risk for infection than similarly injured casualties without radiation effects.[191–193] When resources are scarce, their triage categories may require adjustment until they can be reassessed when more support might be available. Rapid onset of moderate ARS symptoms indicates a potentially lethal radiation dose, so immediate and delayed casualties should be considered expectant.

Prompt but minor radiation symptoms have the same effects on reparative and immunological responses, but usually indicate a sublethal radiation dose. Therefore, immediate and delayed conventional injuries could both be considered minimal, while casualties in the same categories without ARS symptoms are managed first. Once sufficient resources become available, subsequent triage decisions could incorporate information regarding prognosis based on biological dosimetry (see Chapter 30).

"Probable" radiation exposure without rapid clinical manifestations is more problematic. Triage of minimal and expectant conventional injuries should remain unchanged in this circumstance. Due to the effects mentioned previously, however, immediate and delayed conventional injuries might be considered delayed until biodosimetric information can be assessed. If radiation exposure is unlikely, no alterations to conventional triage categories are necessary, unless ARS manifests at a later

Table 26.4: Priorities in Combined-Injury Mass Casualty Triage when Radiation Injury is Possible

Triage Category Based on Conventional Trauma Assuming No Coexistent Radiation Injury	*Change to Triage Category Based on Possibility of Coexistent Radiation Injury*				
			Exposure Confirmed by Prompt Clinical Manifestations		
	Unlikely Exposure	*Probable Exposure*	*Minor Symptoms*	*Moderate Symptoms*	*Severe Symptoms*
Immediate	Immediate	Delayed	Minimal	Expectant	Expectant
Delayed	Delayed	Delayed	Minimal	Expectant	Expectant
Minimal	Minimal	Minimal	Minimal	Minimal	Expectant
Expectant	Expectant	Expectant	Expectant	Expectant	Expectant

The information in this table is in the public domain as published by the Office of the Surgeon General of the United States Army, Falls Church, Virginia, USA. It was adapted – and slightly modified for civilian applications – from the *Textbook of Military Medicine*. 1989:45.[191]

time. Casualties with less likely but possible exposure must be followed closely for months to monitor for bone marrow suppression.

Local Medical Receivers

The most significant problems for receiving hospitals will be related to degraded capacity when victim needs exceed available resources. Staffing shortfalls and infrastructure failure must also be considered when facilities are directly affected by the event. Although Israel has had some success in redirecting patients seeking care for problems unrelated to the disaster, the majority of patients in most countries will still present with a variety of baseline conditions. The ability of hospitals to provide rapid and accurate screening of patients for such problems and refer them to other sources of care may enhance disaster operations at the receiving facility.

Primary Triage

The ED is usually a hospital's primary site for receiving patients requesting unscheduled care. Thus, it is often designated as the place where primary triage occurs following an off-site mass casualty event. As on any day, all presenting patients must be effectively screened for emergency conditions, including those due to the blast or explosion. Therefore, the ED staff or other designated team performing triage must be acutely aware of specific blast-related history and physical examination findings. This will facilitate early identification of less obvious clinical entities that may otherwise be missed. Some targeted questions to ask are suggested in the pathophysiology section of this chapter.

Part of primary triage's function might be to relieve bottlenecks in the ED by dispersing casualties not requiring ED management directly to other services within the hospital. For example, some immediate casualties, who may have had temporizing interventions in the field or at the primary triage location, could be sent directly to operating theaters or ICUs. Delayed casualties may be diverted to large receiving areas or sent directly to general medical wards for assessment by physicians and nurses stationed there. Although these healthcare providers may be less experienced with severe trauma, they should still have the training to evaluate blast-injured casualties for specific life-threatening problems that may develop over time. One study reported that patients admitted directly from triage were sent to the following locations: 28% to an operating theater, 10% to an ICU, and 58% to a hospital ward.[51] Another technique, which has been used during mass casualty situations in Israel, is to triage victims with nonimmediate/nonurgent injuries away from the ED to other locations. Minor casualties could be seen at hospital or community clinics.

One of the major bottlenecks in mass casualty management of trauma victims is the need for radiological services. One process used in Israel is to send all casualties with nonimmediate soft tissue wounds to general medical wards for history-taking and physical examinations. If potentially serious delayed injuries are discovered, blood typing and possibly arterial blood gas analysis are generally the only laboratory studies necessary. Portable plain chest radiography could be performed on the wards, if equipment and technicians are not needed more urgently in the ED, ICU, and operating theater.

After all immediate patients are cleared from the ED, delayed patients can be brought back to the ED for expert reevaluation and any additional ancillary studies. Plain chest radiographs are important for most of these patients. Noncontrast computed tomography (CT) scanning has been utilized to screen all body areas of concern for blast, blunt, and penetrating trauma. Both are used to identify and localize foreign bodies created by debris, shrapnel, and bone fragments from a suicide bomber or other victim.[194] Surgical decision making and ED dispositions can then be based on clinical examination and imaging results.

Emergency Care

Injuries from explosions include penetrating, thermal, and blunt mechanisms. Clinicians experienced in trauma management should be familiar with all of these. As such, only those considerations unique to blast injuries will be discussed in this chapter.

Massive hemoptysis will often require selective mainstem-bronchial intubation to protect the least injured lung from blood emanating from the opposite lung. This may be accomplished blindly as described for out-of-hospital care (Figure 26.6).[180] It may also be sequestered by use of a double-lumen endotracheal tube or a Univent tube.[195] In a situation in which significant resource constraints do not exist, resuscitative thoracotomy and isolation of the injured lung may be an option of last resort to save the victim's life, if it can be determined from which bronchus the majority of the hemorrhage is emanating.

BLI is relatively rare in survivors of large detonations occurring in an outdoor location.[27,32,37] In open-air explosions, those close enough to the blast to develop significant BLI are usually dead at the scene.[50,80] One notable exception was the terrorist bombing behind the U.S. Embassy in Nairobi, where BLI was a significant finding in victims. This was largely due to the truck detonating in a space surrounded by three multistory buildings that reflected the blast wave multiple times.[196] BLI is more commonly seen by medical providers when explosions occur in confined spaces.

Katz and colleagues were the first to publish the connection between confined spaces and increased incidence of BLI and BII in initial survivors.[28] They reported on 55 casualties transported to two major medical centers in Jerusalem following detonation of a 6-kg device placed under a seat inside a commuter bus. Overpressures at various locations inside the bus were estimated at 385–527 kPa for 2–3 ms before the constraining windows and metal shell were blown away. Close to half of the casualties were evaluated and discharged from the ED. All 29 admitted patients had PBI of the ears, lungs, or bowel. For victims less severely injured but still admitted, there was a 29% (five of 21) incidence of BLI and a 10% (two of 21) incidence of "nonperforating bowel injury" (presumably BII). In casualties with more severe injuries, 75% (six of eight) had BLI and 25% (two of eight) had BII.

Pizov and colleagues pooled data from two similar explosions in commuter buses to report on their experiences with managing BLI.[109] Forty-seven victims were found dead at the scenes and one more died on ED arrival. Of the 17 survivors, 15 (88%) had BLI. Nine (60%) had pneumothoraces, which were bilateral in seven. Five had clinically significant bronchopleural fistulae.

Patients with tension pneumothorax require needle thoracentesis followed by tube thoracostomy. Unilaterally decreased breath sounds and evidence of clinical shock should prompt immediate pleural decompression. Air escape without clinical improvement should raise suspicion for bronchopleural fistula, which may require more chest tubes, independent lung ventilation, or interventional surgery. In mass casualty scenarios, chest tubes before radiography have been recommended for any serious thoracic injuries.[142] If bilateral tension pneumothoraces have been ruled out in patients with blunt traumatic cardiac arrest, resuscitative thoracotomy should not be performed, because these casualties most often have unrecoverable BLI.[142]

Spontaneous, negative-pressure ventilation is preferred over PPV whenever possible.[75,196] In a study of BLI patients admitted to the ICU at one Israeli medical center, 61% were intubated in the field or on arrival to the ED and 14% were intubated within 2 hours for progressive respiratory distress. The other 25% did not require mechanical ventilation.[198] Noninvasive PPV has been used successfully to avoid endotracheal intubation in some patients.[199] When invasive PPV becomes necessary, the initial use of PEEP up to 10 cm H_2O is acceptable early in management.[109] The need for more PEEP to maintain oxygenation should prompt a reassessment of ventilator mode.

Systemic arterial air embolism should be considered anytime a communication between the airways and the pulmonary venous circuit is suspected (e.g., hemoptysis).[181] Yee et al., observed hemoptysis in approximately one of every six air embolism patients in a series of blunt and penetrating trauma.[108] Infarction syndromes simultaneously affecting multiple organs may be noted on clinical examination.[75,181] Left semilateral decubitus or prone positioning have theoretical but not proven benefits.[75] Otherwise unexplained cardiac arrest might also suggest

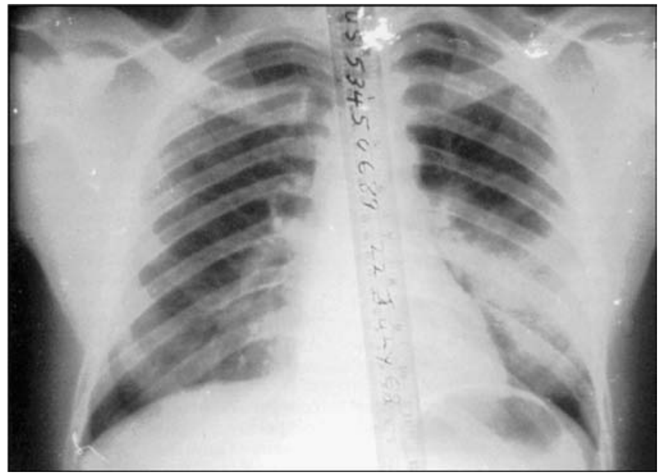

Figure 26.7. Plain chest radiographs of blast-injured casualties showing: mild unilateral left-sided contusion. See color plate.

systemic air embolism. When managing individual cases (i.e., not in a resource-constrained setting) and the side of injury can be determined, resuscitative thoracotomy with hilar twist may be life saving.[200]

Optimal fluid management in patients with BLI is controversial, just as it is for pulmonary contusions due to blunt chest trauma.[201] Colloids have been recommended over crystalloids for BLI, but outcome data are lacking.[110] Following blunt trauma, neither the amount nor type of fluid seems to make a significant difference.[202,203] Similar issues exist for blast and blunt TBI.[75,204]

Arterial blood gas analysis may be used to stratify patients into mild, moderate, and severe lung injury, regardless of whether they are due to blunt contusion, BLI, or ARDS (Table 26.2).[75,109] The presenting PFR is predictive of outcome in blunt pulmonary contusion.[202,203] Most other laboratory tests are unlikely to be of assistance in early identification or management of PBI.[117,136,205] During mass casualty situations, individual facilities must determine the appropriate application of their own laboratory protocols for blunt, penetrating, and thermal trauma.

A plain chest radiograph is mandatory in victims with any traumatic torso-related complaint. This may also be used to confirm endotracheal, thoracostomy, and gastric tube placements. The cardiac silhouette may be enlarged as a result of right heart overload from increased pulmonary vascular resistance due to significant BLI.[19] Although almost any radiographic finding might have a conventional traumatic cause, manifestations of BLI include interstitial or alveolar fluid, hemothorax, pneumothorax, or pulmonary pseudocyst.[19,206] Infiltrates consistent with pulmonary contusions are the most common parenchymal findings (Figure 26.7). Pulmonary injury severity can also be assessed radiographically (Table 26.2).[109]

Thoracic CT scanning may also be used to quantify interstitial and alveolar fluid and relate findings to ventilatory requirements of mild and severe categories similar to those reported by Pizov et al.[109] In one report of patients with nonblast trauma, all those with more than 28% airspace filling required ventilatory assistance; none with 0% to 18% filling did.[207] Transthoracic and transesophageal echocardiography have been used to image air bubbles transiting cardiac chambers.[180]

BII is generally uncommon, but perforation may be delayed up to 2 weeks after the event.[208] Evaluation of individual patients should be similar to each institution's protocols for blunt abdominal trauma, except clinicians should be aware that the pretest probability of bowel rupture will be higher, especially following closed-space explosions.[75] Based on literature from World War II and Israeli naval battles, BII is more common in victims exposed to underwater blasts.[116,209] Fragments do not travel very far in water, but blast waves are propagated much greater distances than they are in air. Individuals treading water or buoyed upright by a flotation device have no TM exposure, only partial thoracic exposure, and full abdominal exposure to underwater blast fronts. Hence, the abdomen receives proportionally greater blast loading.[76,113]

Focused assessment using sonography for trauma (FAST) scanning has been suggested as a rapid screening tool for intraperitoneal hemorrhage, whether or not combined with START triage methodology and screening images.[75,142,210,211] Free intraperitoneal fluid, however, is not a common finding in intestinal perforation from any cause. CT scanning, especially without GI contrast material, is also not particularly sensitive in detecting bowel rupture. During mass casualty situations, some authorities have recommended that CT examination be reserved for diagnosing intracranial mass lesions during the initial phase of management – the period while casualties are still arriving.[142]

All blast-exposed individuals must be screened for TBI. The MACE is one useful tool, but no specific assessment methodology for brain dysfunction has proved superior in all settings. Even patients believed not to have TBI should be provided detailed instructions regarding the postconcussion syndrome and posttraumatic stress disorder, which may be more closely related to each other than previously suspected.

While BAI is not life threatening, it should be sought at some point during casualty evaluation. During mass casualty incidents, auditory and ocular injuries were the most frequently missed in one Israeli report.[142] The ears should be examined by direct otoscopy. TM perforation, disruption of the ossicular chain, and gross contamination should be noted. Rupture and blood together could be indicative of TBI. In the absence of multiple casualties, an otolaryngologist should be called to the ED or the patient should be seen within 1 day, if there is significant debris in the ear or the torn edges of the TM require realignment.[212] Transient, intermittent, or permanent blast-induced vestibulopathy and dysequilibrium can occur.[59]

TM rupture may be a marker for TBI.[213] It should certainly indicate exposure to blast overpressure, thus prompting mental status and neurological examinations. On the other hand, contrary to previous expert opinions, the presence of TM rupture in patients without manifestations of BLI in the first hour after injury does not appear to be a surrogate marker of sufficient blast overpressure to produce delayed-onset BLI.[214] The finding of oropharyngeal petechiae might, however.[81,111] Absence of TM rupture makes BLI less likely but does not completely eliminate the possibility.[75]

Anesthesia and Surgery

Older journal articles have suggested that patients with BLI have poorer outcomes when operative procedures were required within a day after injury.[19,133,209] This was presumed to result from PPV and inhalational anesthetic causing unrecognized pneumothoraces and bronchopleural fistulae to create tension pneumothoraces, or forcing air into the pulmonary vasculature to create systemic air emboli.[209] Some experienced authors have recommended prophylactic chest tubes for any BLI patient undergoing surgery.[111,112,197,215] Local, regional, and spinal anesthetics were touted as preferred methods whenever possible.[19,111,133,209] These complications seem less likely with modern monitoring equipment and might be mitigated further by an understanding of the risks and benefits of PPV.[75,197] Thousands of surgeries have been performed on blast-injured casualties while they received general anesthetic agents during recent conflicts without known complications directly attributable to PPV.

Stein and Hirschberg have suggested dividing hospital-based surgical care into initial and definitive phases.[142] The "initial phase" is the interval when casualties continue to arrive and the final number of patients is still unknown. They recommended that only the minimum acceptable level of care should be practiced during this period. Casualties categorized as immediate/urgent should be screened in the ED by personnel familiar with trauma management. Hemodynamically unstable patients should be emergently taken to an operating theater, if one is available. Facility-wide blood use should be controlled by a senior surgeon. The "definitive phase" allows a more conventional approach to surgical management, once the total patient load is known and the operational status of current and surge resources has been assessed. Nonexsanguinating torso injuries should take precedence over fracture management, wound cleansing, debridement, and other minor procedures.

The surgical treatment of trauma can be significantly complicated by radiation exposure.[193,216,217] All major surgical interventions must be performed within the first 2 days, or be delayed months until late in the "convalescent phase" of ARS. Therefore, damage control, irrigation, and debridement of significant conventional wounds are normally conducted in this time window. A "second look" procedure may be indicated, if performed within the following day or so. Any attempt at fracture healing or wound closure beyond this period, however, is likely to result in nonunion and dehiscence, respectively.

Intensive Care

High ISSs characterize victims of terrorist bombings, who often need critical care.[208] In a study from Israel published in 2006, 26.6% of casualties from suicide bombers required ICU management compared with 6.7% of other trauma patients.[51] In the detailed study by Pizov et al., examination of 15 BLI patients in ICUs found that only one could be managed without PPV, and eight (53%) required pressure-controlled ventilation or high-frequency jet ventilation.[109] A more recent study from a different institution by Avidan et al., reported that seven of 28 (25%) BLI patients were managed without intubation.[198] Permissive hypercapnia has been recommended to keep transalveolar pressures less than 35–40 cm H_2O, while still facilitating adequate oxygenation.[109,218] Nitric oxide inhalation has also been used.[109,198] Extracorporeal membrane oxygenation has been suggested.[214]

Arterial air embolism is a rare but serious complication of BLI. It was suspected in only two cases of BLI patients admitted to Israeli ICUs over a 10-year period.[198] One developed an acute electrocardiographic injury pattern and suffered cardiac arrest. The other developed a left hemiparesis without CT or magnetic resonance imaging abnormalities. Both cases resolved with medical management. Details of treatment were absent, however, particularly with regard to hyperbaric oxygen therapy, which is the definitive treatment for air embolism after temporarily placing the patient on 100% oxygen to wash out dissolved nitrogen. Transferring patients out of the ED or ICU to a hyperbaric chamber, or secondary transportation to another facility that offers this resource, can be a logistically difficult undertaking with a critical casualty.

Mass casualty situations may severely challenge ICUs with patients being sent directly from the ED, and postoperative patients requiring intensive care. According to a recent report by the American College of Chest Physicians' Task Force for Mass Critical Care:

> Most countries have insufficient critical care staff, medical equipment, and ICU space to provide timely, usual critical care to a surge of critically ill and injured victims . . . many people with clinical conditions that are survivable under usual health-care system conditions might have to forgo life-sustaining interventions. Failure to provide critical care will likely result in high mortality rates.[219]

In situations of overwhelming casualty numbers, scarce resources must be justly allocated to provide only "essential care" for the greatest number of critical patients, rather than attempting to stretch existing or surge resources to deliver customary or "usual" treatment to all ICU patients.

It has been suggested that all hospitals with ICU capabilities be prepared to manage three times their normal capacities for a minimum of 10 days to be as prepared as reasonably possible for any of several disaster events.[220] The Sequential Organ Failure Assessment (SOFA) score may be a useful tool to estimate prognosis in ICU patients. It can assist triage decisions when allocating critical care resources after initial surge capacity has been maximized and patients have been secondarily redistributed between regional hospitals, but prior to the arrival of significant external assets.[221]

Additional Triage

Secondary, tertiary, and subsequent triage decisions occur at any point after primary triage. The first decision is where to send patients after initial evaluation and management in the ED or other location. Additional triage decisions could also involve transfer to regional centers. In nondisaster settings, specific criteria have been studied to determine the need for interfacility transportation to a trauma center.[222] Many countries have established regional referral centers to provide specialty services, which may not be offered at all hospitals (e.g., burn care, hyperbarics, neurosurgery, traumatology). Established transfer patterns may require revision under surge or crisis conditions at both sending and receiving facilities. When resource availability is exceeded, overwhelmed local hospitals will need to perform triage of patients to facilities designated by an Emergency Operations Center (EOC) overseeing total community or regional resources. Depending on the capacity of those included in "normal" referral patterns, transfer out of the affected area may be necessary. In the United States, this can be coordinated through the National Disaster Medical System (Chapter 9).

Contingency plans must be developed for community hospitals to manage patients provisionally until normal referral and transportation conditions can be reestablished. Disaster-induced surge operations and altered evacuation patterns will require healthcare professionals to adjust procedures. Referral centers should be prepared to increase capacity and to provide extended consultative services by telecommunications or Internet to facilities with less capability or inability to transfer patients.

Figure 26.8. Multiple penetrating wounds of the lower extremities from ballistic projectiles following a suicide bombing. Photograph reprinted with permission of Lippincott Williams & Wilkins from Almogy G, Belzberg H, Mintz Y et al., Suicide bombing attacks: update and modifications to the protocol. *Ann Surg.* 2004;239(3):295–303.[35]

Disposition

Many patients with open wounds do not require hospital admission. Tetanus immunization status must be assessed, and updated if necessary; prophylactic antibiotic administration is often provided; and interventions for body-substance exposures from a suicide bomber or other victims are considered. Blood, bone, and other biological tissues can contact or penetrate casualties – and these substances may be contaminated with infectious agents.[223–225] The U.S. CDC has recommended stratifying casualties into three risk groups: 1) penetrating injuries or exposures to "nonintact" skin; 2) mucous membrane exposures; and 3) superficial exposure to intact skin.[226] Within each of these risk categories, guidelines are discussed for hepatitis B and C viruses, human immunodeficiency virus, and *Clostridium tetani.* Despite published consensus recommendations from an authoritative source, the true risk is unknown, because no case of person-to-person disease transmission by this mechanism has been documented.

All open wounds are irrigated, yet few are debrided due to personnel constraints in mass casualty situations.[227] Figure 26.8 shows the multiple penetrating wounds typical of secondary blast injury following bomb detonation. If, for example, only 10 casualties had 10 wounds each, then 100 wounds would require debridement. More casualties or more wounds per casualty would exponentially increase the workload. This could require allocation of surgical resources that might be better used in the operating theater for intracavitary injuries and open fractures, managing postoperative patients in ICUs and on wards, or arranging patient transfers to other facilities.

Discharge planning at ED and hospital levels will require creative coordination in the setting of disasters. Patients displaced by events may find it difficult to return home. Several issues must be considered when discharging such patients: 1) security; 2) physical structure of the patient's home or extended care facility; 3) status of utilities and food services in that area; 4) accessibility to emergency services (e.g., no telecommunications, EMS overwhelmed) and outpatient healthcare (e.g., portable oxygen, pharmaceuticals, in-home nursing care); and 5) ability to return for in-hospital treatments of chronic conditions (e.g., chemotherapy, dialysis).

Although it might be possible for patients to remain in the hospital, this could further limit the admission and treatment capacity of the facility. Patient transfer to less-crowded facilities is another option, but one that would require systematic employment of validated protocols guiding "rapid discharge." In this context, rapid discharge is predicated on a triage methodology for assessing which admitted patients can be discharged safely from a medical facility to ensure adequate space to treat an incoming surge of casualties.

Only patients without chest complaints who have normal chest radiographs and arterial oxygenation (by p_aO_2 or S_pO_2) should be considered for ED discharge.[75] Missed pulmonary contusions will likely develop relatively slowly, enabling patients to return to the ED provided they have rapid access to an EMS system or good social support and transportation access. Any patient with an abdominal complaint or objective finding should have a surgical consultation and be observed in the hospital. Such patients should not be discharged until BII has been excluded or sufficient time has passed to significantly reduce the possibility of late bowel perforation.[75]

Patients with only TM rupture may be discharged home with instructions to protect their ear canals from foreign material, including water. Antibiotics are not indicated unless there is established infection with myringitis or otitis following a delayed presentation. Most perforations will heal spontaneously, especially those involving less than 80% of the TM surface.[82,84]

Follow-up

Most blast-exposed and blast-injured casualties require some form of follow-up evaluation for medical concerns, forensic investigations, and the collection of research data. If managed appropriately, BLI mortality and lasting morbidity is not the norm. Follow-up pulmonary examinations of 11 BLI patients admitted to ICUs, who had an average hospital duration of stay of more than 1 month, found that none had respiratory complaints, and most had normal chest radiographs and pulmonary function tests 1 year later.[228] In a retrospective study examining short- and long-term outcomes of ICU patients following terrorist bombings, only 24% of survivors contacted had some degree of respiratory sequelae 6 months–21 years after injury.[196] Care of discharged patients with BII should follow standard surgical practices.[75] Patients with TM rupture must be followed for cholesteatoma formation.[229]

Healthcare Systems

During mass casualty situations, medical care may need modification, so that the most good can be done for the most people. Optimal care cannot be provided to all when resources are constrained. The concepts of "essential care" or "minimum acceptable care" may require consideration. While initiatives are underway[230] at the time of this writing, there are no standardized definitions for what constitutes these situation-specific levels of care.[152] In some circumstances, identifying those who will benefit most from "optimal care" may be possible, in which case such individuals would receive high priority for scarce resources.[231] Acceptability will likely vary for how each event impacts a given community's culture of expectations.

Permanent Facilities

Hospitals can be directly and adversely affected by explosive blasts, regardless of the cause. Direct explosive damage to healthcare facilities may limit the capacity of casualty receivers to manage those patients who either find their own transportation or are transported by others to surrounding EDs. The most critical problems for operations of healthcare systems are

- Fire
- Structural integrity
- Staff, patient, and visitor injuries
- Personnel's ability to access the facility or specific work areas
- Access to or replenishment of supplies and equipment
- Functioning utilities and internal and external communications
- Adequacy of supervisory and managerial support
- Transportation of patients into (or out of, if evacuating patients) and within the facility

Power loss may disrupt lighting, medical equipment, and safety systems. Disruption of water supplies may affect the adequacy of clean drinking water, and water for personal hygiene and infection control. Sewage outflow may also be affected. Widely scattered debris or direct damage to roads may make it difficult for personnel to report for work. Those already on duty at a facility may need to work extended shifts, or additional days, without relief. Supplies may not be replenished and malfunctioning medical equipment may not be repaired.

On November 2, 1991 in Belfast, Northern Ireland, bombers targeted the military wing of an orthopedic specialty hospital.[31] A device of unknown size was placed in a basement fire exit tunnel near a location where personnel would be watching a major sporting event while off-duty. Two floors above collapsed into the basement room injuring nine people. Two victims died outright; three seriously injured individuals sustained fragment injuries, burns, and smoke inhalation; and four casualties with minor injuries were able to self-extricate.

Only a resident physician, junior surgeon, and anesthesiologist were on duty at the time because no emergency department existed in this particular facility and the detonation occurred during off hours. The resident became the Incident Commander until the local fire department arrived. PPE was not available. Although two wards in the wing were evacuated to other areas of the facility, there were no casualties elsewhere. In this example of an intentional attack against a hospital, sufficient external resources were available to manage the situation.

A device the size of the one used in Nairobi or Oklahoma City employed against a city's multistory hospital would likely result in hundreds or thousands of casualties. Many victims, some already inpatients with a wide variety of resource needs, would require evacuation to other area hospitals because the targeted building would likely sustain significant damage and be partially or totally unusable. Hospitals do not typically practice complete evacuations, although the events surrounding the 1994 Northridge earthquake and 2005 Hurricanes Katrina and Rita in the U.S. showed that catastrophic circumstances can make such a drastic and extremely difficult action necessary.[232–234]

Surge Capacity

Surge capacity is a concept that can be intuitively grasped yet remain difficult to define in specific terms. A broad-scope approach to defining a community's surge capacity must include the following areas: out-of-hospital care (e.g., fire/rescue and EMS), in-hospital care, community and extended care (e.g., free-standing same-day surgery centers, medical clinics, and nursing homes), and medical (e.g., pharmacies, out-patient imaging centers) and nonmedical (e.g., electricity, telecommunications, water and sewer) assets supporting healthcare delivery.[234] Addressing surge capacity must include each of the aforementioned component areas if a community intends to accurately assess its true overall capacity and to improve its surge response. The U.S. and Israeli military experiences suggest that those providing leadership must understand the art and science of surge capacity to respond successfully in the setting of real-world contingencies (Chapter 3). Such issues include risk communication, comprehensive training, creative use of resources, command and control, communications, and effective use of technology.[235]

Temporary Facilities

A variety of temporary facilities might be established by governmental and nongovernmental organizations to mitigate the human impact of an overwhelmed healthcare system. In the context of a community's emergency operations plan, the likelihood of complete infrastructure disruption by a single nonnuclear explosive event is low. The media could use public service announcements to direct persons in need of medical, surgical, psychological, and other services to locations designated by a functioning EOC. Shelter considerations are discussed in Chapter 37.

In disaster situations requiring additional healthcare capacity, consideration should also be given to using resources developed for other purposes. An excellent example of this dual-use approach in the United States would be the Modular Emergency Medical System created primarily for a response to biological terrorism. If prepared and integrated into a community's disaster plans prior to an event, the concept provides a framework for expanding community healthcare capacity as required. One or more high-volume reception and triage facilities can be established directly within affected areas by using the Neighborhood Emergency Help Center concept. This strategy provides initial community healthcare that is more accessible when victims do not have ready access to transportation, roads are impassible or unsecured, EDs are overwhelmed, or there are no post-event functioning healthcare institutions.[237] When hospitals are full, the Acute Care Center concept establishes one or more off-site inpatient facilities. These entities are staffed and equipped to manage large volumes of patients with less serious problems, thus allowing hospitals to concentrate on more seriously ill and injured victims.[238]

Rapid Needs Assessments

The rapid determination of infrastructure dysfunction and initial resource needs is critical to avoiding an ineffective response, and beginning the process of recovery from an explosive event. One or more rapid assessments are necessary to determine the level of response required.[239] Aerial surveys of the affected area are probably the best initial method of determining the scope of the problem. If a large region is affected, the U.S. CDC recommends modified cluster sampling as the epidemiological data collection method of choice.[240,241] The technique essentially involves identifying 30 randomly selected clusters of land in the affected area, and then interviewing residents of these areas by using assessment teams. Data are then collected and analyzed to estimate rates, which are then extrapolated to total population numbers based on pre-event census information.

On-the-ground needs assessments can also identify victims with injuries and illnesses, whether event related or not. Illnesses may be new or exacerbations of chronic conditions, either from inability to access customary care or exposure to dust, smoke, or other dispersed materials. Healthcare access, in the forms of EMS availability or capabilities of individuals and families to travel to medical facilities, can also be surveyed.

External Response

Major disasters disrupt and overwhelm local response capacity to a degree that outside assistance may be required to help mitigate the human impact of the event. Higher levels of government may control regional resources. Responses are coordinated through an EOC capable of coordinating all necessary resources.

In the United States, federal healthcare assistance to a region may come in the form of a Disaster Medical Assistance Team (DMAT). This is a community-based asset of the National Disaster Medical System that has intermittently been under the operational control of the Federal Emergency Management Agency (within the Department of Homeland Security) and the Assistant Secretary for Preparedness and Response (within the Department of Health and Human Services). DMATs are composed of 50 or more physicians, physician assistants, nurses, pharmacists, respiratory therapists, paramedics, emergency medical technicians, and a variety of healthcare, logistical, and administrative personnel. Team members provide medical care during a disaster or other local, regional, or state event. They function as rapid-response elements, which are self-sufficient for 72 hours, and supplement local medical care by treating up to 250 patients per day in a fixed or temporary site. Roles and responsibilities of DMATs may include triage, provision of acceptable care in medically austere settings, and preparation for evacuation to more appropriate healthcare facilities. DMAT personnel may also be deployed to more distant facilities to assist in receiving large numbers of patients from affected areas. Chapter 9 provides additional information.

Public Information

The ultimate goal of any public educational effort is to prevent problems before they occur (Chapter 22). In the United States, the CDC has called for standardization of public health messages issued for a variety of events.[242] One purpose of this initiative will be "to receive, manage and disseminate alerts, protocols, procedures and other information for public health workers, primary care providers, and public health partners in emergency response."[243] Medically related information disseminated to the public and to healthcare personnel should be based on evidence where it exists. Messages should focus on immediate and delayed signs and symptoms of injuries incurred following an explosive blast. Representatives of local, regional, or state public health departments and hospital coalitions can facilitate crisis communications via the media, as well as real-time needs assessments via ongoing monitoring of the situation. Public health assets can further support the medical community in these scenarios by developing surveillance instruments to enhance early identification of TBI and the need for "psychological first aid."[244]

RECOMMENDATIONS FOR FURTHER RESEARCH

As with many research questions in public health, it is difficult to measure the results of interventions designed to prevent an outcome. Particularly in the field of disaster medicine, comparisons can usually only be made to similar events that were analyzed in the past. Any research beyond that of observation is hampered by the fact that explosive events are extremely heterogeneous. Exposure time, place, and population are difficult to predict, and the number of exposed individuals is usually relatively small without a valid cohort or control group. For these and other reasons, true meta-analyses have not been possible, although some authors have examined multiple individual incidents to determine whether any knowledge can be identified.[245–248] There are no prospective, double-blinded, randomized, controlled, clinical trials of blast-injury management in humans.

Natural explosions are rare, but their power ranges from sudden steam releases that shower debris in the immediate area to volcanic eruptions that explode with forces exceeding those of military-grade nuclear weapons. Accidental explosions related to human activity range from destruction of single houses following ignition of concentrated natural gas to massive industrial explosions, which might also include dispersion of hazardous materials. Bombings and other intentional blasts also vary significantly, ranging from devices rupturing small compressed-gas cylinders to detonations of truckloads of high-order explosives.

The U.S. Bureau of Alcohol, Tobacco, Firearms, and Explosives administers the U.S. Bomb Data Center.[249] In the 3 years from 2004 to 2006, the most recent period for which data have been compiled, there were 210 accidental explosions killing 39 people and injuring 293. During the same interval, 2,020 intentional bombings occurred, but the injury rate was lower because many of these were directed against property only. For these events, 11 people died and 108 were injured. This U.S. Department of Justice entity does not, however, collect medically relevant data from which to draw more than broad epidemiological conclusions.[52] Data obtained from casualty triage, evaluation, management, and disposition cannot be collected or compared.

Most disaster research should be multidisciplinary and collaborative, with defined data collection instruments created before events occur.[33,49,50,70,71,250]

- Uniform data sets must be created, vetted, and validated for explosive events
- universally collected during training exercises and real-world responses
- and shared between agencies and the medical community for analysis and future applications
- Specific areas of interest would include risk mitigation
- system preparedness
- out-of-hospital access, triage, medical care, and evacuation
- hospital primary triage, resource allocation, and patient redistribution
- medical, surgical, and psychological evaluation and management
- and medical and nonmedical infrastructure recovery

Best practices for these have been promulgated by a myriad of governmental and nongovernmental organizations. These agencies have codified the knowledge to be gained and applied to the next event; however, little high-quality outcomes research on the response process has been published in open sources.

Response System Preparedness

Security, public safety, protection of critical infrastructure, and preservation of medical capacity must be immediate considerations following an explosive event. Therefore, they must also be dominant topics for readiness research. Many organizations have received large amounts of funding for preparedness, mitigation, response, and recovery activities. Decisions on how to spend those funds, however, are often formed from anecdotal reports and personal opinion, not on evidence-based research. Even the concept of all-hazard preparedness (presumably a more efficient method for planning, equipping, and training for a variety of predictable and unpredictable scenarios) has not been rigorously demonstrated to be the best approach for responses to heterogeneous PICEs. The same could be said about the U.S. National Response Framework and the National Incident Management System (NIMS).

On the other hand, explosive events are a common problem, with which response organizations must contend, whether or not there are evidence-based recommendations for best practices. Standardization, currently through the NIMS structure in the U.S., seems like a good first step toward quality research into all phases of the disaster cycle, assuming that useful data are being collected and appropriately analyzed. Some after-action reports are useful, but they do not constitute research.

One report took a paradigm for approach to disaster response, promulgated by the American Medical Association, and applied it to several recent bombings to determine common findings.[150,151,251] Population-based measures of effectiveness must be created for domestic emergency management in all countries, just as they have been for humanitarian responses to disasters and complex emergencies in the developing world.[252] Healthcare system surge capacity is another area that deserves increased attention, although it has been a focus for many professional groups in the last several years.

Hazard Determination

Determining the likelihood of natural or accidental explosions, or detecting the first or additional intentionally planted explosive devices, is a key function of operational risk management. Excessive concern for responder safety could delay care for casualties with immediate needs, but overwhelming desire to help victims could lead to responder injury making the overall problem worse. Significant research is being conducted by the U.S. Department of Defense and related agencies to detect improvised explosive devices in military scenarios. Knowledge translation and technology transfer should aid the public safety sector as new tactics, techniques, and procedures are developed.

Depending on the type of explosive event, any one of many active or passive sensing methodologies could be layered to assist in risk determination. Acoustic and seismic; chemical; and electromagnetic, infrared, and visual technologies all exist – but research into their best application, employment tactics, and analysis for decision making is needed. Determining the best platforms for these sensors is another question that must be answered. Animals have been used very effectively to detect chemical signatures in the air, and several electronic devices have been designed for similar purposes. Visual and x-ray techniques, either directly by humans or remotely through ground-based robots, are already used by bomb squads and explosive ordnance disposal teams throughout the world. Manned and unmanned aerial systems – from military aircraft to remotely controlled microvehicles – are on the cutting edge of hazard detection.

Personal Protective Equipment

Secondary devices, the possibility of additional explosions, release or threat of hazardous materials release, potential structural collapse or water-vessel sinking, and many other scenarios require protection of responders if they are to implement HACE. PPE for healthcare providers and decontamination of hazardous materials in these situations are addressed in Chapters 13 and 14, respectively. With regard to blast injury, ballistic protection is the most important consideration.

Bomb fragments released after detonation have the potential to cause injury at the greatest distance from the blast site and penetrating trauma is the mechanism that kills or injures the majority of victims in the absence of structural collapse.[50,75,253,254] Intervening barriers protect against secondary blast injury but not PBI.[75,81] Helmets and body armor are crucial in preventing penetrating injury to critical organs, but the latter can increase coupling of the blast wave to the body surface and may magnify its translation into internal stress waves.[82,255–257] Some research and reviews on improved armor designs have been published in the medical literature but more work would be beneficial.[258–260] Research into hearing protection that remains functional in the out-of-hospital environment is also needed.

Clinical Care

Many more questions than evidence-based answers exist in the research agenda for blast injuries. Triage, for instance, requires substantial additional scientific investigation.[261] Even the ability to effectively conduct triage in situations with significant ongoing threats has been questioned.[262] Several authors have retrospectively applied mass casualty triage systems to patients in existing databases in an attempt to answer some of these questions.[149,153,157,158,263] No significant prospective research has been published, however.

From the field, what is the best destination for casualties in each of the four most common triage categories? Should those with minimal injuries be primarily directed or sent to hospitals out of the affected region? In rural settings, should victims be taken to a closer hospital for stabilization or evacuated over longer distances to a regional trauma center?

In the field or in the hospital, how much medical evaluation is required for a blast-exposed individual without significant external injury? Does categorization into mild, moderate, and severe BLI based on imaging and PFR assist in subsequent clinical decision making? Do interventions based on any categorization method have a significant impact on outcome? Designing research investigations to answer these questions is difficult given the complex environments involving different overpressures, body positions relative to the blast front, intervening barriers and armor, and quaternary effects on fixed structures and moving vehicles. Specific injury types and their severities occur over a wide range of blast overpressures.

Do seemingly minor head injuries have long-term consequences and therefore require early detection? No specific risk factors for BLI sequelae have been found other than those related to ARDS. The brain may be different, however. Further research on TBI is needed, but the degrees to which ultrastructural and functional changes contribute to the problem are still largely unknown. If inflammatory and neurohumoral mechanisms are pathophysiologically important, can they be modulated to improve outcomes?

Does specific early management of nonlife-threatening injuries change long-term outcome? In military theaters of operation, there is a significant effort being made to identify blast-exposed persons at risk for TBI. Unlike most civilian populations, military populations are expected to be at risk for blast trauma. Therefore, pre- and postexposure MACE scores can be obtained and compared after any event.

How do primary blast injuries obscure the management of other trauma during and after initial resuscitation? Massive hemoptysis can certainly complicate airway management. Tension pneumothoraces can often be bilateral and involve bronchopleural fistulae. Systemic air embolism is difficult to diagnose and treat during initial trauma resuscitation.

Should "standard" resuscitation measures be adjusted for blast-exposed casualties? Is it beneficial to place a blast victim in a different body position (rather than supine)? Can left lateral, left semilateral decubitus, or prone position improve oxygenation or decrease the risk of systemic air embolism? Does delay of intubation and PPV until absolutely necessary improve or worsen outcomes? Higher airway pressure may be required to oxygenate, but excessive airway pressure may increase risk of pneumothorax and systemic air embolism. Shock must be avoided or reversed and inadequate fluid resuscitation may perpetuate lower pulmonary venous pressures, thus increasing the risk of systemic air embolism. Is there any difference between standard 20-mL/kg crystalloid fluid boluses compared with smaller, more frequent aliquots of fluid with regard to improving perfusion without causing secondary lung or brain injury? Is there a best fluid type?

Potential complications related to standard operative and critical care also deserve additional research. What are the risks of tension pneumothorax and tension pneumoperitoneum? Are prophylactic chest tubes necessary and safe for PPV, inhalational anesthetic, or air transport as advocated by some experienced authorities? Can ventilator-associated complications be prevented by assessing specific risk factors or taking prophylactic measures? Could early independent lung ventilation decrease complications and improve outcome?

Longitudinal Studies

Blast-injured casualties should be followed long term for the emergence of medical and neuropsychiatric sequelae. In addition, researchers should examine the impact of blast exposure on the lives of victims in general as well as their families and society as a whole. Most of the recent longitudinal studies on primary and secondary blast injuries have evaluated eye and ear trauma.[59,60,264–273] Two studies have suggested that late sequelae from BLI are unusual.[196,228] No longitudinal studies of BII could be found in the literature.

Although many longitudinal mental health studies have examined survivors from the 1995 Oklahoma City bombing, research into the neuropsychiatric ramifications of sudden and unexpected trauma following explosions has just begun receiving significant attention and funding. In 2008, the U.S. Department of Defense announced a 300 million dollar effort to fund research in the epidemiology, clinical care, and long-term effects of TBI and posttraumatic stress disorder. The U.S. Congress has also appropriated nearly as much to study battlefield injuries. Both of these efforts should substantially increase the world's ability to care for blast victims.

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27

Burn Patient Management

John McManus and Ruben Gomez

OVERVIEW

Geopolitical events in the last several years have sparked the interests of governments and medical organizations in disasters, terrorism, disaster planning, and evaluation and treatment of patients resulting from disaster or terrorist acts. Arson has not typically been included in the terrorist's agenda.[1] Terrorists usually aim their attacks at human beings directly, whereas fires usually destroy property primarily and injure people only in passing. Hence, injuries from burn disasters are not typically different from injuries from burn nondisasters, except that the number of burn patients is larger in the former than in the latter. Some of the newer explosive devices used in terrorist attacks have led to casualties with severe combined penetrating, blunt, and burn trauma.

This chapter builds on principles of disaster management to highlight the key features of a regional burn disaster plan. Typical injuries that are best treated in the burn center facility will be highlighted. Burn rehabilitation, although an integral part of burn care, is beyond the scope of this chapter.

STATE OF THE ART DISASTER PLANNING

A review of burn disasters in the United States over the past 100 years[2] shows that these events are local disasters, and the most common scenario is a large group of people caught in some type of structure that catches fire and is either land based or sea based. The number of burn victims has steadily decreased over the years so that typical numbers of burn victims requiring hospitalization in the late 1990s seldom exceeded 20–50 patients. The majority of patients in a burn disaster die at the scene or in transport, but there are a very large number of victims with minor burns requiring minimal medical care. These casualties usually self-present early to on-scene care facilities or to local emergency departments often overwhelming the medical resources or the outpatient system. When casualties present to the treatment center in small numbers over a longer time, this can be termed an insidious disaster, whereas when the patients arrive at the same time in one large group, the situation can be termed a sudden disaster. A combination of both patterns can occur.[3] A burn disaster of national or international magnitude would likely only result from a thermonuclear detonation of the magnitude of Nagasaki or Hiroshima, Japan during WWII. The critical issue, however, is not the exact number of casualties, but whether the needs of the patients exceed the resources of the healthcare entity at the time they are required. If the facility, materiel, or personnel are hindered or destroyed, there may be insufficient surge capacity to manage the casualties. Another important concept proposed by the American Burn Association is that of a surge capacity state,[4] occurring when the number of casualties reaches 50% more than the maximum number of patients that the healthcare facility can manage under standard operating conditions. When capacity is reached and no further capacity can be created, patients should be transported to an alternate hospital or center with burn patient care capacity as designated in the facility's disaster plan.

The number of burn centers in Europe and North America has slightly declined over the last several years. In addition, the patient care capacity of some burn centers has declined.[5] Hence, in many cases, a single burn center would not have sufficient resources to manage the number of patients generated by a burn disaster. A regional system is needed to coordinate transfer and treatment of burn disaster victims. Hence, in times of disaster, cooperation among burn centers in a region must be effected for all victims to receive appropriate treatment. One example of regional coordination for burn care is the U.S. Southern Region Burn Disaster Plan.[6] This plan is designed to provide a communications network among burn centers in the southern region of the United States and to facilitate and coordinate the movement of patients among burn centers during a regional burn disaster. The system establishes a central command center that is staffed by experienced burn center providers during times of disaster. The burn center director of the nearest burn center to the disaster triages the burn victims and establishes direct communication with the central command center. Via this channel of communication, the front line burn center requests treatment and transport aid from the central command as needed. The central command, in turn, has an established grid of all the

Table 27.1: Triage Decision Table for Burn Victims Based on Anticipated Outcomes Compared with Resource Allocation

	Burn Size (%TBSA)									
Age in years	*0–10*	*11–20*	*21–30*	*31–40*	*41–50*	*51–60*	*61–70*	*71–80*	*81–90*	*91+*
< 2	Very high	Very high	Very high	High	Medium	Medium	Medium	Low	Low	Low
≥ 2 and < 5	Outpatient	Very high	Very high	High	High	High	Medium	Medium	Low	Low
≥ 5 and < 20	Outpatient	Very high	Very high	High	High	High	Medium	Medium	Medium	Low
≥ 20 and < 30	Outpatient	Very high	Very high	High	High	Medium	Medium	Medium	Low	Low
≥ 30 and < 40	Outpatient	Very high	Very high	High	Medium	Medium	Medium	Medium	Low	Low
≥ 40 and < 50	Outpatient	Very high	Very high	Medium	Medium	Medium	Medium	II Low	Low	Low
≥ 50 and < 60	Outpatient	Very high	Very high	Medium	Medium	Medium	Low	Low	Low	Low
≥ 60 and < 70	Very high	Very high	Medium	Medium	Low	Low	Low	(Low/ Expectant	Low/ Expectant	Low/ Expectant
> 70	Very high	Medium	Medium	Low	Low	Low/ Expectant	Expectant	Expectant	Expectant	Expectant

1) Outpatient: survival and good outcome expected without requiring initial admission; 2) Very high: survival and good outcome expected (survival > 90%) with limited/short-term initial admission and resource allocation (straightforward resuscitation, duration of stay 14–21 days, 1–2 surgical procedures); 3) High: survival and good outcome expected (survival > 90%) with aggressive care and comprehensive resource allocation, including aggressive fluid resuscitation, admission 14–21 days, multiple surgeries, prolonged rehabilitation; 4) Medium: survival 50%–90% and/or aggressive care and comprehensive resource allocation required, including aggressive resuscitation, initial admission 14–21 days, multiple surgeries, prolonged rehabilitation; 5) Low: survival < 50% even with long-term, aggressive treatment and resource allocation; and 6) Expectant: predicted survival > 10% or less even with unlimited, aggressive treatment.

burn centers in the region, the distances between the centers, and awareness of medical personnel and resources. If the burn center director who primarily receives the disaster patients (i.e., the closest center) determines that the number or acuity of the burn patients presenting is overwhelming the center's capacity, the director notifies the central command. The central command coordinates transfer of excess patients to other appropriate facilities. This system also allows for mutual aid with burn centers outside the region. By agreement among the burn centers participating in the system, the receiving burn center provides transportation assets and patient care funding. In addition to moving patients out, burn care specialists can also be transferred in to the front line burn center to assist in patient management and treatment.

PRELIMINARY TREATMENT

As with any mass casualty situation, casualty triage is an initial action with a burn disaster. One well-described method consists of combining the Simple Triage and Rapid Treatment (START) system[7] with the Age/Total Body Surface Area (TBSA) Survival Grid from the American Burn Association.[4] The survival grid segregates patients into different categories based on age and TBSA burned. The categories represent different benefit to resource ratios: a high ratio predicting a greater than 90% chance of survival, a medium ratio predicting a greater than 50% chance of survival, a low ratio predicting a less than 50% chance of survival, and an expectant category predicting a less than 10% chance of survival. This analysis assumes relatively infinite resources and the availability of state-of-the-art burn care; hence, survival rates would be expected to be lower in a scarce resource environment. Table 27.1 outlines the LD50 percentage TBSA versus the age of the patient based on an age/TBSA survival grid. The LD50 percentage TBSA is the percentage burn size that is predicted to result in death in 50% of patients in a given age group. Nonthermal injuries are usually considered to be more critical than thermal injuries. During an event with a large number of casualties that exceeds resources, however, patients with extensive TBSA burns and underlying factors that portend a poor prognosis (for example, an 80-year-old patient with an 80% TBSA full thickness burn) would likely be placed in the expectant category, even if the nonthermal injuries were of a trivial nature. Nonthermal injuries should first be assessed by standard triage methods such as START before addressing thermal injuries. Regardless of the triage system used, three problems unique to the burn patient should be concomitantly addressed with the nonthermal injuries in the early treatment phase. First, any suspicion of inhalation injury with airway compromise mandates immediate endotracheal intubation before airway edema makes intubation or the establishment of a surgical airway impossible. Next, the patient with deep circumferential burns of the extremities or the chest with compromise of the distal circulation or respiratory function, respectively, requires escharotomies. Finally, providers should initiate fluid resuscitation for shock from burns of 15%–20% TBSA or greater early in the patient care course.[8] Numerous formulas and recipes exist for determining fluid needs. Most involve administration of a balanced salt solution at an initial rate based on TBSA and the patient's weight. The fluid rate is titrated based on the patient's clinical response and hourly urine output. After field triage, burn injury patients would be transferred in order of priority to the next higher level of care. On arrival, reassessment of the patient includes the following.

- Address the airway immediately. If the patient was intubated in the field, ensure tube position with carbon dioxide detector and auscultation. Ensure tube security with cotton umbilical ribbon. DO NOT USE ADHESIVE TAPE on the

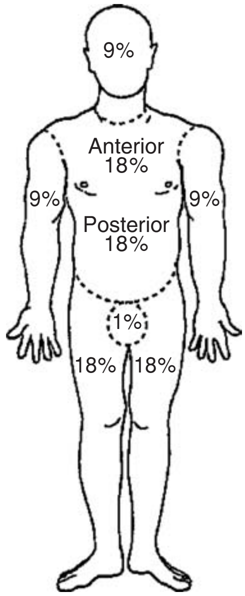


Figure 27.1. The "Rule of Nines" used to estimate the percentage of total body surface area burned (%TBSA).

endotracheal tube or any other important device or tube in the burn patient. The patient will become very edematous, the skin will fall off and the endotracheal tube will fall out if secured only with tape. If this happens, the patient will usually die from airway obstruction because it is extremely difficult to establish a surgical airway in a patient with a very swollen face and neck. If the patient is not intubated, closely observe for signs of airway obstruction and intubate the patient immediately if these signs appear.

- Remove clothes and jewelry. These items may have melted onto the skin. If this is the case, the burn team may need to excise these items along with the burned skin. Jewelry may have to be cut off with wire cutters or other similar devices.
- Insert two large bore peripheral or central femoral intravenous lines if these have not already been placed in the field. Rapidly infuse intravenous fluids.
- Insert a naso- or orogastric tube because patients with large burns (usually 20% TBSA or larger) will have an associated ileus.
- Insert a Foley catheter to monitor the hourly urine output.
- Estimate the percentage of total body surface that has partial thickness and full thickness burns and either estimate the patient's weight or weigh the patient. Use these numbers to calculate an initial fluid resuscitation rate. Figure 27.1 illustrates the "Rule of Nines."
- For adults, the total volume to be infused in the first 24 hours postburn is calculated as follows: 2 mL × %TBSA × weight in kilograms. One-half of the total volume is administered using lactated Ringers in the first 8 hours postinjury and the second half over the next 16 hours postinjury. For children (or patients weighing less than 30 kg), use 3 mL instead of 2 mL in the formula. In addition, in children, administer a maintenance rate of 5% dextrose one-half normal saline at 4 mL/kg/hour for the first 10 kg, 2 mL/kg/hour for the second 10 kg, and 1 mL/kg/hour for every kilogram thereafter.
- During the second 24-hour period, start albumin in normal saline at a total volume of 0.5 mL/%TBSA/kg to be administered over 24 hours. Replace the lactated Ringers infusion with 5% dextrose in water at one-half the last lactated Ringers hourly rate.
- Discontinue the albumin infusion at the end of the second 24-hour period. Continue 5% dextrose in water and adjust the rate based on the serum sodium level if available and estimates of evaporative losses of 1 mL/%TBSA/kg/day. Follow the same guidelines for children.
- The rate should be increased or decreased in increments of 20%–30% of the previous hour's rate with the goal to maintain a urinary output of 30–50 mL/hour in the adult, and approximately 1 mL/kg/hour in the child or in a patient weighing less than 30 kg.
- In all cases, glycosuria should be sought because this can lead to a spuriously high urine output in the face of inadequate fluid administration rates. Similarly, osmotic diuretics and certain other agents, such as ethylene glycol, may cause a high urine output in the face of inadequate fluid administration.
- Wrap the patient in dry clean linens. Do not put ointments or ice on burns. Do not give the patient prophylactic antibiotics.[9] Give small amounts of intravenous opioids as needed.
- If the patient has circumferential burns of either the extremities or the chest, these two areas should be monitored closely for the need for escharotomy and for the development of compartment syndrome. Burn eschar on the chest may interfere with ventilation and if this is the case, chest escharotomy should be performed without delay. For the extremities, eschar will act as constricting bands first occluding the venous return, then the arterial inflow. If available, Doppler signals should be followed hourly. Diminution of the signal or a change in its character is an indication for escharotomy (Figure 27.2). Escharotomy is performed with a scalpel or with electrocautery. If performed properly, there will be minimal bleeding because the incision remains just below

Figure 27.2. Location of escharotomy incisions for eschars on the extremities and chest. Note that the incisions cross the joints.

Table 27.2: Skin Characteristics of Partial versus Full Thickness Burns

Partial Thickness Burn	*Full Thickness Burn*
Sensate	Insensate
Blanches with pressure	Does not blanch with pressure
Moist, pliable, and blisters	Dry, leathery, sometimes with visible thrombosed vessels

the burn within the subcutaneous tissues. If much bleeding is encountered, the incision is too deep. Patients receiving massive amounts of fluid may also develop compartment syndrome. This results from an increase in the tissue pressure within an inexpansible compartment of the body. The compartment may be within the skull, the chest, the abdomen, or the extremities. If compartment syndrome is suspected in the extremities, compartment pressures should be measured unless escharotomy has been performed and compartments are decompressed. The pressures are measured with an 18-gauge needle connected to an arterial pressure transducer. The absolute intramuscular pressure is measured in each compartment. A difference between diastolic blood pressure and intramuscular pressure of less than 10–20 mm Hg in any one compartment is suggestive of compartment syndrome. In addition, the muscles in the compartment being measured should be squeezed. A sluggish rise in the pressure tracing with this maneuver is nearly pathognomonic of compartment hypertension. In all cases, to prevent tissue death and the systemic crush syndrome, the key treatment principle if compartment syndrome develops is to decompress the involved compartments immediately. The patient should undergo appropriate fasciotomies, when possible in the operating room by an experienced team.[10]

- Update patient's tetanus immunization.
- Perform adequate fluid resuscitation. Formulas for fluid requirements are based on the partial and full thickness burn size. Differentiating between partial and full thickness burns may prove difficult. An assessment of skin characteristics assists in the differentiation (Table 27.2).
- If high rates of fluid are required for resuscitation (more than 1 L/h), check bladder pressures hourly. The patient may have to be temporarily paralyzed to obtain an accurate reading. A reading of greater than 20 mm Hg in the context of a low urine output, or high ventilation pressure heralds the abdominal compartment syndrome with the need for an abdominal decompression.
- If the urine output is inadequate despite large rates of fluid infusion and a normal bladder pressure, acute renal failure should be suspected. In addition, the patient should be reassessed for other injuries. If renal failure or undetected internal hemorrhage fail to explain the low urine output, other resuscitation endpoints, such as lactate, base excess, bicarbonate, or central venous pressure measurements, may be useful.

After initial stabilization, if capacity exists, evacuate the patient to the next higher level of care, a burn center, or an equivalent. Person-to-person communication with the receiving center including written documentation is crucial for patient continuity of care. A sample documentation form is provided from the U.S. Army Institute of Surgical Research Burn Center (Figure 27.3).

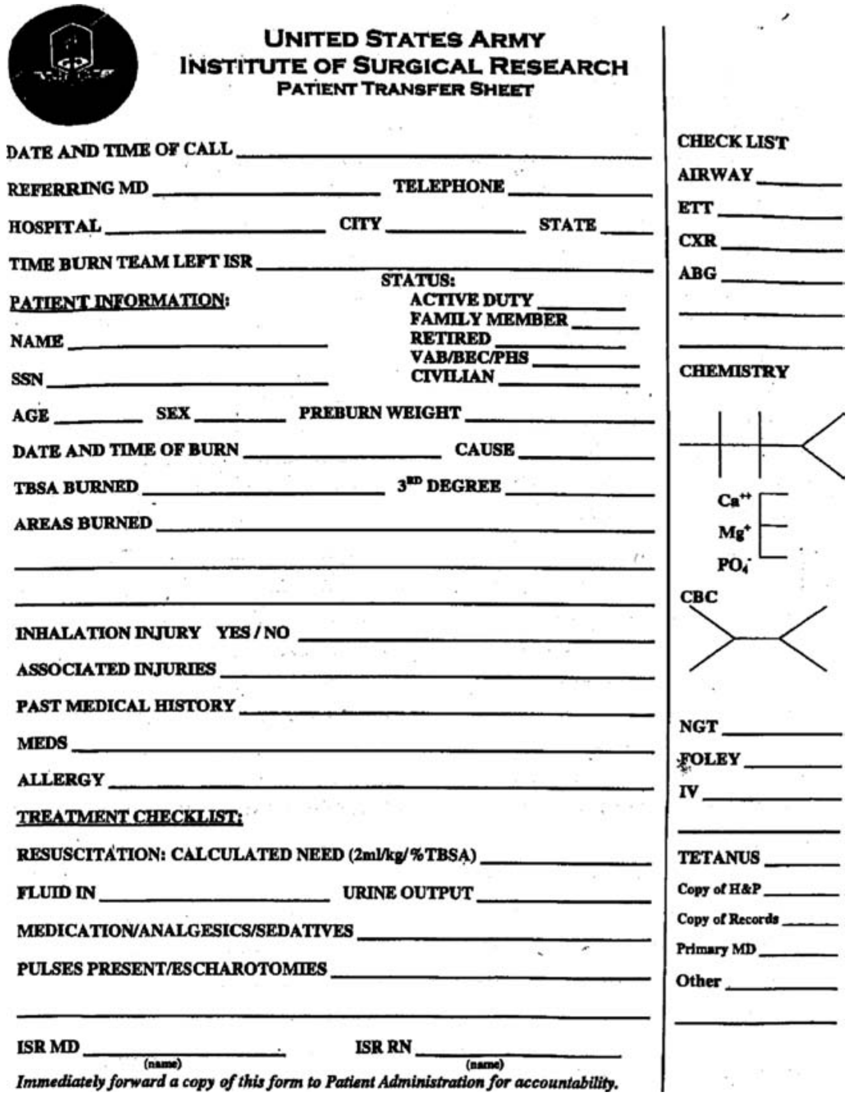
EVACUATION TO A BURN CENTER

The next higher level of care should have personnel experienced with burn surgery and postoperative burn care. There should also be blood-banking and microbiological testing capabilities. Rehabilitation should be available at burn centers, but during a disaster, these services may need to be performed at another location. If this is the case, the patient may be transferred elsewhere for rehabilitation after recovery from the acute burn care injuries. Transportation methods must be carefully considered. The Institute of Surgical Research Burn Center has developed transportation guidelines that include contraindications and relative contraindications for air evacuation.

- Ground transportation should be used if it is available and deemed equally as rapid and safe as air transportation.
- Air transportation should not be used if the patient's condition at the time of transfer suggests the patient is unlikely to survive the transport.
- If inadequate or insufficient staff are available for air transport, then this mode should not be used.
- Relative contraindications to air transport include the following patient conditions:
  - active bleeding
  - sepsis
  - poor respiratory function as manifested by minute ventilation of greater than 25 L/minute, a pO_2 of less than 100% on an F_iO_2 of 0.6 or greater [a p_aO_2/fraction of inspired oxygen (F_iO_2) (P to F ratio) of less than 166]
  - an uncontrolled dysrhythmia
  - chest or abdominal surgery within the last 24 hours
  - presence of intracranial or intraocular air
  - other conditions likely to worsen during air transport (e.g., pneumothorax, compartment syndromes)

At the burn center, the work begun at the initial patient care site continues with greater emphasis on three injury types unique to burns: inhalation injury,[11] chemical injury,[12] and electrical injury.[10]

Inhalation injury usually occurs when the patient is trapped inside a burning structure. Inhalation injury should also be suspected when the patient is at the extremes of life or he has sustained very extensive burn injury. Physical findings suggestive of inhalation injury include disorientation, obtundation, stridor, dyspnea, grunting respirations, and voice changes. Inhalation injury results from a chemical burn extending from the bronchial lining down to the level of the alveoli. The chemical injury is caused by products of incomplete combustion carried on smoke particles. Small smoke particles carry the chemicals deeper into the lungs compared with large smoke particles. True thermal injury to the airways is rare, occurring most commonly with direct exposure to flame or superheated steam. Flash flames may injure the supraglottic respiratory tract leading to upper airway occlusion but seldom with injury to the infraglottic respiratory tree unless there is concomitant smoke inhalation. In addition to the supraglottic or infraglottic inhalation injury, inhalation of carbon monoxide is common in patients found in burning



UNITED STATES ARMY
INSTITUTE OF SURGICAL RESEARCH
PATIENT TRANSFER SHEET

DATE AND TIME OF CALL ____
REFERRING MD ____ TELEPHONE ____
HOSPITAL ____ CITY ____ STATE ____
TIME BURN TEAM LEFT ISR ____
PATIENT INFORMATION:
NAME ____
SSN ____
STATUS:
ACTIVE DUTY ____
FAMILY MEMBER ____
RETIRED ____
VAB/BEC/PHS ____
CIVILIAN ____
AGE ____ SEX ____ PREBURN WEIGHT ____
DATE AND TIME OF BURN ____ CAUSE ____
TBSA BURNED ____ 3RD DEGREE ____
AREAS BURNED ____
INHALATION INJURY YES / NO ____
ASSOCIATED INJURIES ____
PAST MEDICAL HISTORY ____
MEDS ____
ALLERGY ____
TREATMENT CHECKLIST:
RESUSCITATION: CALCULATED NEED (2ml/kg/%TBSA) ____
FLUID IN ____ URINE OUTPUT ____
MEDICATION/ANALGESICS/SEDATIVES ____
PULSES PRESENT/ESCHAROTOMIES ____
ISR MD ____ (name) ISR RN ____ (name)
Immediately forward a copy of this form to Patient Administration for accountability.

CHECK LIST
AIRWAY ____
ETT ____
CXR ____
ABG ____
CHEMISTRY
Ca^{++}
Mg^{+}
PO_4^{-}
CBC
NGT ____
FOLEY ____
IV ____
TETANUS ____
Copy of H&P ____
Copy of Records ____
Primary MD ____
Other ____

Figure 27.3. Transfer form used at the U.S. Army Institute of Surgical Research Burn Center.

structures. Carbon monoxide levels of 15%–40% usually produce central nervous system symptoms. Levels greater than 40% usually produce coma.

The chemical reaction in inhalation injury produces increased lung vascular permeability and may lead to noncardiogenic pulmonary edema. Damage to type II alveolar cells leads to reduced surfactant levels and stiff lungs. The injury causes epithelial cell damage with desquamation of small airways with airway casts, bronchorrhea, and wheezing. The first phase of injury at 0–36 hours is characterized by acute asphyxia, carbon monoxide poisoning, bronchospasm, upper airway obstruction, and severe parenchymal damage. The second phase during 6–72 hours postburn is dominated by pulmonary edema. Bronchopneumonia is common during the third phase occurring 3–10 days postburn (Table 27.3). As previously outlined, early intubation is essential in these cases because supraglottic and infraglottic edema may make delayed intubation impossible. In addition, the patient should be placed on 100% oxygen until carbon monoxide levels are less than 10%. Other treatment for inhalation injury is supportive and consists of nebulized bronchodilators and nebulized heparin to reduce cast formation. Bronchoscopy is necessary to confirm the diagnosis of inhalation injury. Tracheostomy should be considered if endotracheal intubation is predicted to last more than 2 weeks. Prophylactic steroids and antibiotics are not indicated because they have not been shown to improve outcomes in inhalation injury.[9,13]

Another type of injury that should be managed at a burn center or equivalent institution is the electrical injury. A mass

Table 27.3: Pulmonary Clinical Characteristics at Different Time Points After Inhalation Injury

Time since Inhalation Injury	*Pulmonary Clinical Characteristics*
0–36 Hours	Acute asphyxia, carbon monoxide poisoning, bronchospasm, upper airway obstruction, severe parenchymal damage
36–72 Hours	Pulmonary edema
3–10 Days	Bronchopneumonia

casualty event involving electrical injury would be extremely rare; however, a possible scenario is that a group of people could be simultaneously struck by lightening. The situation could lead to one or two patients with combined thermal and electrical injuries within a group of causalities with only thermal injury. Injury to tissues from electricity occurs because the electrical current is converted to heat. The amount of heat generated is directly proportional to the amperage, the resistance, and the time of exposure. Bone exhibits a high resistance, so that structures nearest bone tend to incur more thermal damage than do structures away from bone. An electrical injury may appear superficial and small in size, but may extend to an extremely large area beneath the skin. Deep muscles may be necrotic while more superficial muscles may look intact. Overall assessment and management of electrical injury is similar to that of other injuries with a few exceptions.

- The size of the surface burn is not predictive of the extent or size of a deeper burn.
- Compartment syndrome can develop from necrotic subfascial muscle. A high index of suspicion must be maintained for compartment syndrome.
- Fractures and dislocations may occur as a result of spasms and contractures produced by the electrical current.
- Occult internal injuries in the chest or abdomen must be suspected.
- Bizarre neurological symptoms may develop. Perform a detailed neurological examination on initial patient assessment and periodically thereafter.
- Muscle injury may lead to pigments in the urine. Maintain a urine output of 75–100 mL/hour. This is a higher urine output than for thermal injuries in adults. Add sodium bicarbonate to intravenous fluids to facilitate clearing pigments from the urine. Attain a urine pH above 6.
- If the patient presents with cardiac arrest or dysrhythmia, assess for a primary cardiac event and initiate continuous cardiac monitoring for 24–48 hours.
- Muscle necrosis may require multiple debridement procedures.

In contrast to electrical injuries, mass casualties are much more likely to present with chemical injuries. Many industrial and transportation accidents involve large quantities of harmful chemicals. Secondary contamination of medical providers from chemicals or vapors is of concern. The first priority in these disasters is to protect the healthcare provider by using appropriate levels of protective clothing. Once this is done, the same principles already established for other injuries apply for burns involving chemical injuries. Chemicals may be associated with irritating and noxious fumes and vapors that when inhaled lead to an inhalation injury to the lung. The airway and breathing must be protected with early intubation and then all other injuries are evaluated and addressed. Principles specific to chemical injury can be found in Chapter 28.

CONCLUSIONS

This chapter sets forth important concepts in disaster planning for burn victims. A comprehensive plan should include a method of communication between a central command and the healthcare team at the front line and a robust triage and field treatment system. Combination injuries such as concomitant thermal and nonthermal burns must be detected and treated. Considerations specific to thermal injury patients that require expeditious interventions include: circumferential eschars of the extremities and chest, and hypothermia.

Transportation criteria determine when air transport is appropriate to move patients from initial treatment areas to definitive burn care facilities. After arrival at the burn facility, three major types of injury (inhalation injury, chemical injury, and electrical injury) that are commonly found among burn victims require assessment and treatment. A discussion of specific surgical procedures for burns and rehabilitation and physical therapy of the burn victim are beyond the scope of this chapter.

RECOMMENDATIONS FOR FURTHER RESEARCH

Although an "all-hazard approach" is often advocated for disaster preparedness and response, many emergency response plans fail to consider burn casualties. Future comprehensive emergency management plans must account for burn patients. Due to the high incidence of burn-related casualties in U.S. combat operations, investigators are collecting data that will guide future referral and treatment guidelines. As described earlier in this chapter, guidelines provided by the American Burn Association recommend initiating crystalloid fluid resuscitation for burn patients at a rate of infusion derived by multiplying 2–4 mL/kg/%TBSA burned administered over the first 24 hours postburn, providing one-half of estimated fluid over the first 8 hours. Difficulty in remembering the appropriate formulas and how to apply them has led to a high rate of noncompliance with these guidelines at various levels, especially in the prehospital setting or other locations where burn patients are treated infrequently. Future recommendations on appropriate fluid choice and rate of administration are currently being studied. Finally, additional study is urgently needed to guide triage and treatment decisions that would optimize outcomes for multiple burn patients when healthcare capacity is exceeded.

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28

Clinical Aspects of Large-Scale Chemical Events

John S. Urbanetti and Jonathan Newmark

INTRODUCTION

Since the dawn of civilization, chemical materials have been a part of human life. Today nearly 100,000 different commercial chemicals are known. Several thousand new chemicals are developed yearly. Of these new chemicals, nearly a thousand reach the commercial market. Annual worldwide chemical production is estimated at 400 million tons. Of this production, most is bulk stored and bulk transported. Hence there is a risk of large-scale release with resulting environmental and health effects. Human toxicity from chemical exposure has been well recorded since the beginning of the industrial age. Recognition and investigation of those effects have allowed the development of therapeutic interventions. Toxic effects of chemicals may result from exposures to small amounts such as present in foods or medications, or larger amounts resulting from accidental or intentional releases from storage or transportation facilities. The human toxic effects of smaller chemical exposure events have generally been well managed because there are rarely more than one or two patients requiring care at a time. Large-scale exposures vastly complicate the medical response to a toxic chemical event, principally because of overwhelming logistical difficulties. This chapter explores various clinical aspects of large-scale exposures to chemical agents. Several examples of both intentional (e.g., warfare or terrorist) and accidental events will be presented. Accompanying commentary will support the following central principles.

PRINCIPLES OF CHEMICAL EVENTS

1) The degree and speed of symptom onset results primarily from the amount of chemical incorporated ("dose response") and secondarily, from the speed of chemical incorporation.
2) Much of the clinical information about toxic (warfare) chemical effects has been collected from studies of young, healthy military men. Extrapolation of those data to other subsets of the population (old, female, and persons with complicating medical illness, or concomitant use of medications) can be very difficult.
3) Medical investigation of human chemical effects is hindered by:
   a) The extraordinary and rapidly increasing number of chemicals that seemingly warrant study;
   b) Concurrent use of multiple chemicals, which creates interactions that further complicate medical investigations;
   c) Research in nonhuman systems that may correlate poorly with human systems.
4) Medical investigation of clinical toxicity, particularly when occurring during a large-scale chemical event, must include study of both immediate and near-term effects, as well as associated illness and longer-term effects. Careful analysis of these events is critical to validation of current medical practice and development of novel approaches. This type of investigation is generally successful in commercial drug studies. The precision and attention to detail practiced in drug investigations should be applied equally to medical studies of toxic effects in a chemical event.
5) Immediate and near-term lethal sequelae of chemical events, even those intentionally orchestrated, rarely occur in more than 3%–5% of exposed individuals.
6) Large-scale chemical events trigger public anxiety and fear to a degree that is strikingly disproportionate to the number of deaths. The media appears to be a primary contributor to this public anxiety, largely as a result of its presentation format. The medical community must assist the media with both its presentation of content and methods.
7) Lethal sequelae of chemical events, in the immediate or near term, are primarily respiratory in nature. Thus, disaster preparedness for chemical events should emphasize respiratory illness as a principal focus.
8) Technology for rapid identification and intervention in chemical event–related respiratory illness is well developed and advancing rapidly on many research fronts. Therefore, the prospect of successful intervention in chemical event–related severe respiratory illness is high, particularly if early assistance is provided.
9) Traditionally, the medical community has focused primarily on immediate response to a chemical event. It must now

begin to focus on the broader aspects of an event. During the time period termed "recovery," the medical community has two unique responsibilities:

a) Critical assessment of the long-term clinical aspects of the event should include both medical and psychological sequelae. Careful long-term evaluations of all the victims from an exposure should be undertaken in a fashion similar to the September 11, 2001 U.S. terrorist attacks follow-up programs underway in New York City. Carefully documented clinical and laboratory victim data should be collected in a medically accessible database for future review and use. This long-term clinical/medical review should be undertaken independent of legal, political, or commercial interests in the event;
b) Critical assessment must be made of the medical aspects of mitigation, preparedness, and response in the event. This assessment must be compiled and produced as a referenced document, available for immediate and later review. This is a disaster preparedness review with a medical focus. It should also be produced independent of legal, political or commercial interest in the event.

10) The aforementioned two types of review should begin as soon as possible after a chemical release.
11) The clinical review mentioned should be undertaken by a national organization equipped to undertake epidemiological, medical, and psychiatric evaluations of all involved individuals from the beginning of the event through long-term assessment. There is no national organization that currently performs this type of function within the United States.

    The disaster preparedness review should be undertaken by a team of trained medical observers who would respond to an event with full access to medical and first responder facilities. The U.S. Department of Homeland Security, Federal Emergency Management Agency's (FEMA's) Chemical Stockpile Emergency Preparedness Program (CSEPP) (detailed later) has demonstrated, for the past 15 years, an exceptional ability to perform this function for large-scale chemical exercises throughout the United States. Shifting this CSEPP expertise from exercise observation alone to involvement in a real chemical event would be an immensely practical use of a well-established organization.
12) Many of the long-term medical evaluations that have been attempted in large-scale chemical events have been hindered by limitations placed on both medical data collection and reporting. Political and commercial interests often appear to interfere with and even degrade the quality of medical assessment of an event. Legal interests often appear to restrain an openness of medical evaluation and discussion. As a result of legal involvement, medical evaluators have become hesitant to perform critical assessments and their ability to discuss or publish their observations has been compromised.
13) The medical community has been complicit in accepting scant and poorly undertaken investigations of medical disaster preparedness (mitigation, preparedness, response, and recovery) in large-scale chemical events. As has been so well demonstrated by the U.S. National Traffic Safety Board and certain other federal organizations, critical investigation, independent of political, commercial, and legal influences is possible. This type of critical event investigation, performed with a specific medical focus, should become a routine aspect of any large-scale event.

The following text includes a historical presentation of chemical use and events, progressing to examples of large-scale events with commentary on disaster preparedness issues. Finally, suggestions for future medical system planning will be presented.

STATE OF THE ART

Chemical History

Since at least 1000 BC, chemicals in some form have been used as weapons. Initially those chemicals were found as natural materials that could be used to produce a particular desired effect when extracted from geological deposits. For example, in approximately 670 AD, the Byzantine Greeks in Constantinople developed a combination of materials that when ignited became an effective weapon. Greek Fire was a combination of uncertain composition that probably contained naphtha, sulfur, saltpeter, and pitch. When used against enemy ships, this "wet, dark, sticky fire" would float on water, stick to ships and even continue to burn under water. It was almost impossible to extinguish and hence was particularly effective against enemy wooden ships. Greek Fire not only produced substantial physical damage, but also, perhaps much more importantly, spread extraordinary fear among the enemy. That fear was the result of

1) Failure to anticipate the use of the material as a weapon (mitigation)
2) Failure to develop adequate weapon protection (preparedness)
3) Inability to control the immediate effects of the weapon (response)
4) Inability to learn the method of manufacture of Greek fire and develop plans for its future use (recovery)

Substantial effort was expended in attempting to educate sailors about the methods of use and effects of Greek Fire. Fear that this was a weapon "of the devil" was mollified. Training in methods of flame control helped ease anxiety as well. These early forms of "disaster preparedness" helped overcome the advantage of fear that Greek Fire carried.

By the 18th century, the discovery of unique chemicals such as cyanide and chlorine was quickly followed by recognition of their harmful effects. Shortly thereafter, various military groups around the world proposed use of these materials, specifically for their toxic properties. During WW I, large-scale production and use of chemical agents as toxic weapons became common.

French riot control agents were perhaps the first chemical weaponry of WW I. Riot control agents were relatively ineffective, however, because highly motivated soldiers could easily tolerate their irritant effects. On April 22, 1915, after extensive preliminary preparation and some false starts, the Germans released approximately 150 tons of chlorine from approximately 6,000 cylinders over a 7-km front line. Large clouds of a yellow-green, intensely irritating gas spread in the direction of the opposing French. Chlorine gas is heavier than air. As a result, the clouds settled into the very trenches that the soldiers thought would protect them. Choking and gasping, those soldiers ran from a fearful unknown substance, perhaps inhaling greater quantities simply as a result of their physical activity. The effects of that first attack, by some accounts, included 2,000 deaths and up to 20,000 wounded.[1] The Allies quickly identified the chemical agent used and shortly retaliated in kind. Within months, chlorine (and later phosgene) was produced, weaponized, and used in large quantities by both the Axis and the Allies. These agents are primarily toxic by inhalation. Accordingly, the development of increasingly effective gas masks diminished the "value" of these agents. Of course, gas masks were useful only if the soldiers had adequate education and training and were highly motivated. Use of the gas mask for any period of time was exceptionally uncomfortable. As a result, the soldiers often used them only when their noses provided an alarm. Chlorine, with its intensely irritating aroma, prompted immediate mask use and thus could be avoided. Phosgene, a later weapon development, had a more pleasant smell (likened to newly mown hay). As a result, inhalation of toxic amounts of phosgene easily occurred prior to donning of the mask. A delayed physiological effect, with (frequently lethal) pulmonary edema, occurred in 4–12 hours. Victims, appearing and feeling normal during the first few hours after exposure, would often continue full military activities. Later, it was learned that exercise during the "latent period" prior to development of pulmonary edema resulted in more rapid onset of more intense disease. This delayed onset of a sometimes-lethal respiratory failure was commonly seen in an individual who initially appeared and felt well. Extreme fear and anxiety resulted among the troops who never knew where or when they would become affected. Intensive efforts to provide the soldiers with a better understanding of chemical weapons and the circumstances/likelihood of their use were combined with improved mask protection. There was a resulting decrease in medical aid station visits for both real and imagined gas exposures.

Because improved Allied education, training, and equipment led to a decrease of effectiveness of the German chemical attacks, the Germans introduced a novel chemical material. On December 17, 1917, sulfur mustard, active either as a liquid (below 14°C) or as a vapor, was first released. Sulfur mustard damaged any topical/epithelial surface of contact. Unprotected eyes, skin, and respiratory tract suffered inflammatory damage to a degree related to the "dose" to which the individual was exposed. Sulfur mustard had a unique aroma, often characterized as similar to garlic or horseradish; however, severe exposure, particularly to the liquid, could occur with a minimal warning aroma. The primary molecular effect of the chemical agent, alkylation of nucleic acids, occurred within the first few minutes of contact. An intense, irritating, inflammatory biological response to that contact would typically occur after a latent period of some hours to days depending on the exposure dose. As a direct result, soldiers would often develop clinical symptoms distant in time and place from their original exposure. There was no available technology to permit identification of sulfur mustard–contaminated areas. As a result, soldiers were unable to identify contaminated places or even people. Fear of cross-contamination seriously compromised their daily activities. Blindness, painful skin blisters, and respiratory symptoms including cough, wheezing, and substantial shortness of breath occurred in soldiers without obvious sulfur mustard contact. An overwhelming sense of fear of chemicals resulted. Soldiers would avoid any areas that had unusual smells suspecting that mustard might be present. Certainly this fear was one of the most important effects of the use of chemical weapons.

Sulfur mustard rapidly became an important adjunct to WW I weaponry. By the end of the war more than one-half of all shells fired were filled with a chemical agent, often sulfur mustard. Approximately 25% of all WW I casualties were chemically related. The ease of chemical weapon manufacture attracted the attention of many countries after WW I. This resulted in substantial research, manufacture, weaponization, and stockpiling of chemical agents, particularly including mustard, in anticipation of possible future needs.

Since the discovery of mustard in 1850 by Guthrie, the intense inflammatory effects of mustard have been recognized. There has been substantial research regarding its cellular and systemic toxicity; however no specific antidote has been identified to date. Each instance of its use subsequent to WW I has been associated with production of large numbers of debilitated and disabled individuals. Medical statistical assessment of these injuries during WW I has documented the frequency, distribution, and duration of illness of each of the bodily systems involved. Of perhaps greatest interest is the documentation of a 3%–5% death rate, largely respiratory. An important comparison is the WW I Allies' 25% death rate from conventional weapons. This, statistically and perhaps surprisingly low death rate, appears consistently throughout records of subsequent large-scale chemical events, whether accidental or terrorist related.[2]

Despite the (relatively) low death rate that has historically occurred from chemical events, both military and public perception is that chemical events, whether accidental or intentional, are to be greatly feared. The degree of fear surrounding chemical events appears to be disproportionate to the degree of actual illness and death. Similar degrees of seemingly excessive public fear are evident in nearly every report of a chemical event. Fear of a chemical event, in fact, seems to create much more public distress than the actual morbidity and mortality created by the release itself. For this reason disaster preparedness professionals have expressed concern about possible terrorist use of easily available toxic industrial chemicals (TICs).[1] In theory, the difficulty of acquiring or manufacturing a military-style agent could be bypassed and an equally large-scale public effect could be achieved by making use of commercially available chemicals. In the public mind, chemicals are "all cut from the same cloth" and hence reports of any release are likely to provoke substantial public reaction: fear and terror. It appears that even the threat of TIC use may be enough to trigger intense public anxiety and terror (see Improvised Explosive Devices).

The majority of deaths that occur after a large-scale chemical release occur within the first few hours following the event. Salvage of severely ill individuals within this time window is obviously highly desirable but presents a daunting logistical problem. For the two common chemical agents that have available antidotes (organophosphates and cyanide), stockpiling and training in the use of those antidotes is valuable. Deaths that occur with organophosphates and cyanide are due principally to respiratory causes and immediately available antidotes can be of great value. In the case of large-scale events with other agents, the majority of deaths are also from respiratory effects. Most of those deaths occur in the immediate or near term. Useful immediate interventions include oxygen supplementation, intubation, and ventilatory support. In the event of a large-scale chemical disaster with high numbers of exposed and sickened victims, the logistics of providing oxygen supplementation, intubation, and mechanical ventilation may at first appear overwhelmingly difficult. The numbers of individuals suffering acute (and treatable) respiratory failure, however, are relatively few. Rapid identification of those individuals with acute respiratory failure is actually the principal logistical problem. Even if specific antidotes are not available, the character of the acute respiratory failure includes abnormalities of airway and alveolar function for which a variety of increasingly useful interventions are becoming available. The logistics of delivery of those novel interventions will have to be further studied. Much of the following discussion will be directed toward demonstrating the importance of rapid identification and treatment of those individuals with early acute respiratory failure. Several examples of events will be followed by commentaries that will include perspectives on the mitigation, preparedness, response, or recovery efforts for each event.

EXAMPLES OF CHEMICAL EVENTS: IMPLICATIONS FOR DISASTER PREPAREDNESS

Intentional (Nonstate Sponsored) Chemical Events

Arsenic Use in 1946 at Stalag 13

Shortly after the end of WW II, in April of 1946, a small group of Holocaust survivors undertook a chemical poisoning attack on a large group of Nazi SS soldiers held in an American prisoner of war camp. Desiring to avenge the deaths of 6 million Jews, an organization known as "DIN" (an acronym for "Avenging Israel's Blood"-Dahm Y'Israel Nokeam) planned to poison and kill hundreds of thousands of German civilians. Arsenic poisoning of the water systems of several major German cities was first considered. When a British investigation threatened to reveal the plan, it was discarded. An alternate plan to poison the food of Nazi inmates in prisoner of war camps was developed. An American prisoner of war camp (Stalag 13, just outside of Nuremberg, Germany) that contained approximately 15,000 former Nazi SS soldiers was selected. A plan to poison the black bread supply was developed because the perpetrators had noted that the prisoners preferred black rye whereas the American guards and local workers preferred white bread. On the night of April 13th, access was obtained to the bakery. There, an odorless mixture of arsenic and glue was painted on the bottom of up to 3,000 loaves of bread, poisoning a number of the prisoners. The perpetrators escaped. Large numbers of ill prisoners were treated at local medical facilities. Specific data concerning the arsenic effects and numbers of dead and injured are not available. News articles appeared in both the *New York Times* and the Munich newspaper *Suddeutsche Zeitung*. The Munich news of April 24, 1946 reported, "tests taken immediately following the event showed that the bread contained the poison arsenic. Four bottles filled with poison and two empty ones were found in the bakery. Out of 15,000 inmates, 2,283 fell ill from the poisoning, with 207 hospitalized. According to the hospital's records, there were no fatalities." DIN sources report 4,300 sickened, 1,000 hospitalized and 700–800 either paralyzed or dead within weeks of the event. An American official investigation was apparently conducted but casualty numbers were withheld for "fear of causing mass panic."[3,4]

GENERAL COMMENTARY

This attack, despite creating a large number of ill and hospitalized victims, received very little notoriety in the contemporary press. Available records are scant. There is no evidence that any specific action was taken by the U.S. military or German civilian organizations to mitigate any subsequent chemical attacks. Evaluation of the medical response to this event would be of extraordinary value; however, there are no available records of the medical response.

MITIGATION

In Germany, during and immediately after WW II, medical facilities nearby to prison camps maintained minimal if any relationship with those camps. At the end of the war, with the Allied discovery of the prison camps, there was immediate need for nutritional evaluation and medical care of recently released prisoners. Local medical facilities were already overwhelmed with other local needs. Allied medical teams provided most of the medical support for the newly released prisoners. There was no consideration given to the possibility of a large-scale prison illness event.

PREPAREDNESS

There are few available records that detail the type or extent of medical support available to the WW II Allied prison camps. Some "subcontracting" of medical care was arranged with local physicians and hospitals. These resources, however, had few supplies and still fewer personnel. There was no consideration given to the possibility of a large-scale prison illness event.

RESPONSE

In the absence of specific medical records, few conclusions can be drawn from the reports of numbers hospitalized and ill or dead. At that time, British anti-Lewisite (BAL – Dimercaprol) was known to be effective in arsenical poisonings. It is unlikely, however, that any substantial supply of BAL would have been available within the local civilian community. Quantities of BAL might have been available within the (Allied) military medical structure in anticipation of possible German use of the chemical weapon Lewisite. There is no record of BAL use in this event. Respiratory failure, sometimes seen with arsenic poisoning, might have prompted use of ventilator support. An early mechanical ventilator was available in the U.S. at the time (Drinker "iron lung"). There is no record of such ventilator availability or use during this event. Even if some ventilators had been available in Germany, they would have been cumbersome, effort-intensive, and ineffective for the management of pulmonary edema (adult respiratory distress syndrome [ARDS]) associated with arsenic poisoning. There are no specific data regarding the medical facilities within Stalag 13. There is no available record of their response to the arsenic poisoning. The scarcity of public news may have been the result of a concerted attempt to avoid both public fear of the (suspected Jewish) attack and to avoid spread of fear within other prison compounds maintained by the Allied forces.

RECOVERY

There is no available report specifically concerning any (Allied) investigation of the event. No records are available from any of the local hospitals that dealt with the arsenic poisonings.

Thus, no data exist that could be used as a basis for review and planning for similar large-scale events. As a result, an opportunity to review a large-scale arsenic event has been lost.

Nerve Agent Plans in 1974 by Alphabet Bomber

Muharem Kurbegovic was a Yugoslav immigrant to the U.S. Through the years of 1967–1974, he worked in a variety of engineering jobs where he presumably acquired enough training and education to manufacture explosives and chemical agents. He developed a personal terror network that he called "Aliens of America." A series of bomb threats and attacks followed. Three deaths and 35 injuries followed an explosion at the Los Angeles International Airport. His nickname "Alphabet Bomber" came from threats using alphabet letters to designate the next site of attack. His audiotaped threats were sent to the local media and were subsequently widely reported. One of these threats led to particularly widespread public anxiety in Los Angeles during the summer of 1974. In 1974, his attention also focused on nerve agent production and use. By audiotape, he informed the news media of his production of four different nerve agents. He reported his placement of time-release containers of "AA4S nerve gas" in several cities around the world including New York, Miami Beach, London, Paris, Tokyo, and Hong Kong. There was no subsequent evidence, however, that nerve agent actually existed in any of the threatened cities. Other chemical dispersals were threatened including injection of chemical warfare agents into the air conditioning systems of Los Angeles skyscrapers. Ultimately, after his capture, search of his apartment revealed 11 kg of sodium cyanide, and bottles labeled nitric acid and carbon tetrachloride. There was speculation that these substances might have been intended for the production of tabun or hydrogen cyanide gas as lethal agents.[5–7]

GENERAL COMMENTARY

It appears that most of Kurbegovic's knowledge and abilities were acquired through a combination of personal contacts during his work experience (engineering/aerospace industry) and research in numerous books and articles on the subjects of nerve agent and explosives. These resources are much more easily available by Internet search today than they were in the 1970s. The public anxiety that resulted from widespread reporting of Kurbegovic's threats was apparently difficult to control. Kurbegovic presented most of his threats by audiotape delivered directly to the news media. The media, interested in rapid dissemination of their "breaking news," did not appear to interact with the public officials who were interested in controlling public anxiety. As a result, "news" of impending Alphabet Bomber attacks seemed to balloon public anxiety. Public concerns about possible widespread effects of a "lethal" material were the forerunner of similar concerns that sprang up around the U.S. anthrax event of 2001.

MITIGATION

During the time that Kurbegovic was active, U.S. medical establishments had not developed an organized process of risk assessment and analysis. Chemical materials associated with explosive devices were a principal part of the weaponry of WW I and were in fact so "successful" that they have been manufactured, stockpiled, and used by many countries since that time. Despite clear demonstration of the effects of chemical weapons since WW I, U.S. federal, state, and local emergency response organizations generally did not consider that intentional use of chemicals was a significant risk. As a result, the politicians and particularly the medical structure did not anticipate and were unable to control substantial public anxiety about a chemical attack within the U.S. It was only with the advent of the CSEPP that an organized medical preparation for possible large-scale chemical events was developed.

PREPAREDNESS

Substantial public anxiety resulted from the extensive media coverage of Kurbegovic's audiotaped warnings and threats of planned chemical attacks on major U.S. cities. This anxiety was exceptionally difficult to control. Local, state, and federal medical systems were not prepared to provide a coherent and organized presentation to the public about the (medical) validity of the threats or to offer any useful suggestions for medical preparation. News media reports that occur during and shortly after an event of this sort typically contain erroneous and conflicting information, opinions, and suggestions from a variety of often self-proclaimed "experts." The medical community must prepare in advance to provide useful, media-based information to the public (see Chapter 22). A single, well-credentialed spokesperson must be available to the media for public comment. This spokesperson should clearly represent a respected medical organization. This spokesperson should have substantial experience in public relations, and, perhaps most importantly, this spokesperson should be familiar to the public before an event.

RESPONSE

There is no evidence that any local hospital had undertaken specific preparations for a large-scale chemical event.

RECOVERY

There was no chemical event. As was the case during the 2001 U.S. anthrax letter event, the medical established was ineffective in managing a great degree of public anxiety. There was no medical review that assessed the adequacy of public information dissemination. There has been no prepared report that would provide insight into the media-related difficulties experienced by both the political and medical systems involved.

Chemical Weapons Threat in 1975 by Baader-Meinhof Gang

The Baader-Meinhof gang was a revolutionary West German left-wing organization originating from German student movements in the 1950s. By the early 1970s, the group, then calling itself the Red Army Faction (RAF), focused on the U.S. military presence in Germany.

In May 1975, the *Times* of London and a German newspaper *Bild Zeitung* reported that the Baader-Meinhof/RAF gang had stolen chemical munitions. A mustard agent attack, using bombs and SAM-7 missiles, was threatened against the population of Stuttgart, Germany. The attack would occur unless "all political prisoners" (including leaders of the Baader-Meinhof gang) were granted immunity in a pending trial in Stuttgart. There are various accounts of how much and in what form "mustard gas" had gone missing from a depot in Münster. Numerous subsequent investigations revealed scant specifics of this event. There was no subsequent proof that the Baader-Meinhof gang had physical possession of mustard agent or any specific plan for its use. Nevertheless, intense media coverage resulted in the need for substantial military and civilian investigation.[8,9]

GENERAL COMMENTARY

This event stimulated public anxiety that was apparently fueled by media coverage in what has been described as "journalistic sensationalism." It is presented as an example of public fear of the unknown. Despite valiant attempts by chemical warfare and terrorism experts to control public anxiety with rational and scientific reviews of the event, there appeared to be no publicly trusted spokesperson who could effectively assuage public anxiety (see also Alphabet Bomber).

MITIGATION

Chemical weapons storage in Europe during the 1950s was a part of the extensive North Atlantic Treaty Organization planning for possible European Theater warfare. Because public awareness of the European storage of chemical weapons was limited, revelation of this information coincided with the interests of various student and militant groups wishing to disturb the military stability in the country. Although European military medical personnel were extensively trained and prepared for chemical weapon use, civilian hospital personnel had little awareness and even less training. This lack of education was likely a primary contributor to much of the medical confusion that arose from the threatened mustard event.

RESPONSE

Media reports of the threatened combined missile and chemical attack on Stuttgart triggered a public hysteria that was particularly difficult to control despite substantial effort by governmental agencies. As suggested in the Alphabet Bomber example, the medical community must prepare in advance to provide useful, media-based information to the public. A single, well-credentialed spokesperson must be available to the media for public comment. This spokesperson should clearly represent a fully respected medical organization. This spokesperson should have substantial experience in public relations, and, perhaps most importantly, this spokesperson should be familiar to the public before an event.

Cyanide Poisoning of Water Supply in 1985 – The Covenant, the Sword, and the Arm of the Lord

The Covenant, the Sword, and the Arm of the Lord (CSA) was a survivalist group that appears to have been primarily interested in large-scale murder to "hasten the return of the Messiah by carrying out God's judgments." The group was conceived in 1971 by a fundamentalist preacher, James Ellison. The group planned and prepared for Armageddon, which would result in the destruction of the American economic system. On April 22, 1985, an FBI raid of the CSA compound revealed a stockpile of machine guns, ammunition, an antitank rocket and an armored car. The FBI found 114 L of potassium cyanide. The CSA initially explained that the cyanide was to be used for pest poisoning. Further FBI analysis revealed there had been extensive discussions and planning with intent to use the cyanide to poison water supplies in New York, Chicago, and Washington.[10]

GENERAL COMMENTARY

The toxicity of a chemical agent is principally dependent on the quantity delivered. Therefore, cyanide, or other more toxic materials such as organophosphates, if placed in a large community water supply, would be sufficiently diluted as to render the biological effect negligible.

To intentionally achieve an effect through a water system, either extraordinary quantities of agent would be required or the agent would need to be delivered within the system, closer to the victim. Cyanide has often been used in small quantities in criminal tampering with drugs and food products. The Chicago contaminated Tylenol® event in 1982 was the first documented U.S. incident of food tampering with cyanide. Seven deaths resulted from distribution of the poisoned capsules to six stores in the city. A number of subsequent "copycat" events occurred over the next several years with additional deaths. Despite a $100,000 reward offered by Tylenol® manufacturer Johnson & Johnson, the perpetrator has not been caught. Prior to 1982, tamper-proof capsules and packaging were virtually unknown. Subsequent to the tampering events, public anxiety mushroomed. Manufacturers of packaged foods and medicines promptly responded with development and application of an extraordinary variety of complex and protective packaging. It appears that this extra level of "public protection" consumes many millions of dollars yearly. The cost/benefit of the extra packaging has yet to be measured. On such occasions, public anxiety, often fueled by media speculation, may present a far greater problem than the medical issues.

MITIGATION

Communities with public water suppliers routinely participate in a risk assessment and vulnerability analysis concerning possible compromise of their water supplies. Normally problems of environmental disaster or drought are a primary focus. As a result of such notorious industrial poisonings as the Minimata mercury-poisoning event in Japan (resulting in ~400 deaths and 1,000 permanent injuries), many cities have also become concerned about environmental "pollutant" contamination. Risk assessment and vulnerability studies for possible environmental pollution are, in fact, just the type of action that would be useful for mitigation of possible chemical, biological or radiation contamination.

PREPAREDNESS

Specific medical preparations for possible water supply contamination have long been an accepted part of military preparedness. Civilian medical systems, however, rarely have adequate detection equipment or response technology to respond to an intentional water supply contamination. By federal regulation, U.S. communities have developed an interactive disaster preparedness committee, the Local Emergency Planning Committee. Primarily through this type of community-wide organizational structure, such issues as water supply risks can be addressed in a cooperative fashion with appropriate assistance requested from organizations such as the Environmental Protection Agency (EPA) at the state and federal levels.

RESPONSE

Despite threats by many organizations and individuals, at the time of this writing, no such large-scale intentional water supply contamination has occurred. The U.S. EPA has undertaken an extensive public information, planning, and preparation effort to assist in the understanding of the scope of this concern. This is a fine example of national governmental mitigation and preparedness for a perceived risk.

Cyanide at the U.S. World Trade Tower Bombing in 1993

The February 1993 New York City World Trade Center (WTC) bombing killed six people, injured approximately 1,000 and caused nearly $300 million in damage. At the time, there was no clinical evidence that victim illness or death was in any way related to a cyanide exposure. By mid-1994, a mistaken belief that cyanide was a component of the attack began to circulate among medical and law enforcement professionals and others interested in such events. Suspicion that cyanide was an intentional component of the bomb appears to derive from the following

1) Discovery of a single sealed bottle of aqueous sodium cyanide in the bombers' chemical storage shed
2) Discussions with the bombing conspirators revealed that they had considered incorporating sodium cyanide in the bomb but had decided against it because it was "going to be too expensive to implement"
3) Prosecutor questioning during the four bombers' trial raised awareness of the consequences of mixing sodium cyanide with either nitric or sulfuric acid (both of which were known to be in the bomb). There was, however, no specific allegation of such use

During sentencing of four convicted bombers, Judge Kevin T. Duffy stated, "You had sodium cyanide around, and I'm sure it was in the bomb. Thank God the sodium cyanide burned instead of vaporizing. If the sodium cyanide had vaporized, it is clear what would have happened is the cyanide gas would have been sucked into the north tower and everybody in the north tower would have been killed. That to my mind is exactly what was intended."

During the trial, however, the prosecutor's summary statement did not mention sodium cyanide as present in the bomb. Finally, there were no forensic data presented during the trial suggesting that the FBI had found any evidence of sodium cyanide.[11]

GENERAL COMMENTARY

It appears that there was no substantial evidence for use of cyanide as part of the 1993 WTC bombing; however, public anxiety was unduly heightened as a result of the rumor. Perhaps more importantly, much subsequent scholarly and political effort resulted from what appears to be inaccurate "information." Conversely, however, the apparent willingness of terrorists to utilize a chemical weapon should certainly be acknowledged in community defensive planning.

MITIGATION

Prior to the 1993 WTC attack, there was little international concern regarding the possibility that an explosion could be contaminated with chemical, biological, or radiological materials. Environmental disasters have historically and characteristically been associated with both chemical and biological contamination. Hence, first responders and medical personnel have experience working in such contaminated environments. The general public, however, does not seem to appreciate this depth of experience and hence seems more fearful of the prospect of intentional/terrorist chemical contamination of an explosive event. This fear is particularly difficult to dispel. Control of this fear is necessary to mount a successful response to an event. Control of this fear will be best achieved with education. The U.S. Centers for Disease Control and Prevention (www.cdc.gov) provides extensive data regarding mitigation and preparedness for such an event.

Evaluation of the risk of a biologically contaminated terrorist explosion has been incorporated into the routine medical practice policies and procedures of at least one country (Israel).[12] Israeli hospitals' Emergency Department personnel consider the possibility that victims of an explosion may be contaminated with chemical, biological, or nuclear material. Appropriate precautions are taken.

PREPAREDNESS

In 1993, New York City medical systems did not have specific plans to evaluate or respond to intentional use of a chemical contaminant in an explosion. There is no available record of specific preparation for an intentional chemical attack involving the WTC. Although routine firefighting preparations using a self-contained breathing apparatus (SCBA) would be considered adequate for fire department personnel, ambulance and medical personnel were not trained or equipped for such an event.

RESPONSE

Immediately after the bombing, there was no clinical indication of chemical contaminants. Firefighters responding to the scene quickly assessed the possible need for SCBA. While there was no evidence of cyanide at the time, specific testing for cyanide may not have been accomplished. Local hospitals mounted an excellent response within their Emergency Departments; however, this was a trauma response that did not incorporate consideration of possible chemical, biological, or nuclear contamination. Some months subsequent to the bombing, the (mistaken) thought that cyanide was an intended part of the bombing became newsworthy. The cyanide story was quickly embraced by many professional "Disaster Preparedness" consultants and lecturers and incorporated into their public presentations. There was no apparent effort to assess the accuracy of the story. Disclosure of the inaccuracy of the story, as so often happens when media-driven excitement is later found to be unwarranted, was accomplished in a halting and poorly documented fashion, leaving much of the public recalling the erroneous story (if they remembered at all). Accurate, trustworthy information must be expeditiously provided after an event.

RECOVERY

Careful postevent investigation of the 1993 WTC event resulted in a remarkable assessment of evacuation problems. The well-established and experienced U.S. National Institute of Standards and Technology (www.nist.gov) undertook an intensive investigation of the 1993 event. Specific attention was paid to issues of employee evacuation. Severe problems were identified, showing confusion, anxiety, and poor supervision to have contributed to an extremely slow response to the alarm system. A number of changes were introduced in the evacuation process. Designating Evacuation Monitors, each responsible for the supervised evacuation of a particular floor, proved to be an exceptionally innovative and useful change. It has been said that tens of thousands of employees were successfully evacuated during the September 11th event who would not otherwise have escaped if the "old" 1993 plan had still been in effect. A WTC Research & Development Program evolved from this investigation, providing much innovative planning and direction for intervention in future high-rise building fires. There has not been a comprehensive review of the immediate or near-term medical community actions. A critical review of those actions, particularly in comparison to existing emergency operations plans, would be of immense value. Equally desirable would be a review of how the changes enacted in medical emergency operations plans after the 1993 WTC event affected the response to the September 11, 2001 U.S. terrorist attacks.

Nerve Agent Use in 1995 – Aum Shinrikyo

On June 27, 1994, a successful chemical attack was undertaken in Matsumoto, a city (population 200,000) situated in the northern Japanese Alps, 201 km northwest of Tokyo. Aum Shinrikyo, a 40,000 member, well-funded "doomsday" cult perpetrated the attack. The use of sarin, a military organophosphate poison, resulted in seven deaths among nearly 600 victims. Five victims were found dead, two were transported to the hospital in full cardiac arrest, dying within 4 hours, and one victim survived in a vegetative state due to (presumed) hypoxic encephalopathy and died of respiratory failure in August 2008. There were 56 hospitalizations distributed among six hospitals. Several victims required intubation and mechanical ventilation. Generalized seizures were noted in many of the severely affected victims. There were 208 additional outpatient clinic medical evaluations and 277 symptomatic victims who did not seek medical care. The first report of the event came as a telephoned request for an ambulance 2 hours after the exposure. Eight of the 52 rescuers and one doctor providing care showed symptoms of poisoning as a result of (presumed) cross-contamination. One rescuer required hospitalization. Ten years later, a long-term questionnaire-based survey of local residents showed 73% of exposed and 44% of nonexposed residents reporting psychological problems.[13] The intent of the attack, prevention of a legal decision in a local civil suit, was achieved by poisoning the three judges involved. Sarin was specifically identified as the toxic agent in a sample taken from a local pond on July 4, 1994. Those data and other related law enforcement concerns provided sufficient evidence for a police raid of the principle Aum Shinrikyo facilities, planned for March 1995. The Tokyo subway sarin attack, however, occurred first.[14]

On March 20, 1995, Aum Shinrikyo cult members released an estimated 24 L of sarin of approximately 30% purity. The perpetrators may have had atropine sulfate injections available for personal use if necessary.[15] The sarin was distributed into 11 polyethylene bags, although probably fewer bags were actually opened. Five different subway trains were involved, all of which were scheduled to arrive within 4 minutes of each other between 8:00 and 8:10 AM at the Kasumigaseki Station. The station was selected for proximity to Tokyo's National Police Agency and Finance Ministry as part of the cult's plan to signal the beginning of Armageddon and to specifically attack members of a chemically trained police squad. Ultimately, 15 subway stations were involved. The first notification of a medical emergency was directed to the city fire department within minutes of the attack. Some 15 subway stations called within the next several minutes. Area hospitals were notified at 8:16 AM, but the initial report was of a gas explosion. Therefore, the hospitals prepared to receive patients with burns and carbon monoxide poisoning. It was more than an hour before emergency dispatch recognized the disaster as a single event. Ultimately 131 ambulances and 1,364 emergency medical technicians (EMTs) were dispatched to the affected subway stations. Poor communication with the Emergency Operations Center resulted in EMT transport of all nearby victims directly to St. Luke's International Hospital (SLIH). Even though SLIH had a mutual aid agreement with another nearby hospital to take less ill patients, this agreement could not be implemented because all available transportation was otherwise occupied. SLIH saw 649 victims within the first 24 hours. The EMTs attempted on-site triage at the scene of the release and some medical support; however, there was no on-scene clothing removal, decontamination, antidote administration, or intubation of victims with severe respiratory distress. The EMTs had no personal protective equipment. Of the 1,364 EMTs who worked to transport victims to hospitals, 135 developed clinical evidence of sarin poisoning requiring some medical therapy, including at least 25 hospitalizations. SLIH had three entrances, each of which remained open, allowing patients, relatives, television crews, and various onlookers full access. Not all victims arriving at the hospital were directed to disrobe or shower. As a result, 110 hospital staff members at SLIH (23% of the staff) themselves experienced some symptoms of (cross-contamination) sarin exposure. There were 12 deaths as a result of the attack. Six deaths occurred within 2 hours of the event and the remaining six deaths occurred from 20 to 80 days later. Some deaths were among the subway station personnel, who apparently cleared sarin-contaminated waste with bare hands and no respiratory protection. From available medical reports at SLIH (two deaths of 1,000 patients seen), it appears that the two deaths resulted from cardiac arrest. One victim, in full arrest upon arrival, was immediately intubated and provided ventilatory support. She survived to be discharged 5 days later. Of particular interest, this 21-year-old woman apparently received no specific antidote until approximately 90 minutes after her exposure. Notification that sarin was the offending agent did not occur until approximately 10:30 AM, 2.5 hours after the event. Reportedly, a military physician recognized the clinical signs and symptoms as indicative of a nerve agent exposure. Beginning at that time, oxime therapy was provided for those severely affected. SLIH quickly devised a treatment protocol that enabled the victims to be more rapidly treated. An official prosecutor's report puts the number of injuries at 3,938. Of a total of 4,973 people reportedly seen at Tokyo hospitals within the first 24 hours, approximately 1,100 were hospitalized. Of all patients reporting to Tokyo hospitals complaining of chemical agent exposure, some 74% showed no clinical signs or symptoms. These patients apparently presented largely because of media announcements reporting the event and suggesting that civilians who "felt unwell" should immediately go to the hospital. SLIH conducted a postevent questionnaire-based evaluation of 610 victims. At 1 month after the event nearly 60% reported symptoms interpreted as indicative of posttraumatic stress disorder. Repeated studies at 3 and 6 months showed similar percentages of individuals with such symptoms. People reported flashbacks, insomnia, depression, and nightmares. Some individuals' very high anxiety prevented their subsequent use of the subway. Long-term (10 years) follow-up has been reported and shows persistence of long-lasting psychological problems and posttraumatic stress disorder in some victims.[13,16]

On two separate occasions later in 1995, the Aum Shinrikyo undertook a hydrogen cyanide attack in the Tokyo Rail system. On May 5, 1995 an incendiary device intended to release cyanide was placed in a busy train station. On July 4, 1995 similar devices were placed in four different subway stations. Both these attacks were unsuccessful.

Despite legal and political action and subsequent intense investigation of the Aum cult, there is evidence of more recent

Aum activity in the Ukraine, Belarus, Kazakhstan, and Russia. In March 1998, a reported Aum member telephoned the Russian newspaper *Itar-Tass* with a threatened plan to spread a toxic gas throughout the Moscow subway system.[17]

GENERAL COMMENTARY

The Aum Shinrikyo has produced the greatest number of nonstate-sponsored chemical (and biological) attacks on record. Between April 1990 and March 1995, the Aum undertook 10 biological attacks. There were no recorded casualties. Between November 1993 and 4 July 1995 the Aum undertook a total of 12 chemical attacks (one phosgene, two cyanide, five VX, and four sarin) with 20 deaths and approximately 1,300 injured.[18] Reports from various medical facilities in Tokyo have expanded knowledge of the time course and clinical response to sarin vapor. Sarin vapor inhalational exposure produces clinical effects very rapidly, within seconds to minutes. Individuals exposed to sarin, provided the exposure ceases (i.e., removal from the site), typically demonstrate their peak of disease within the first 30 minutes after exposure.[19] Individuals who survive to reach a medical care facility will likely survive even without specific antidotal therapy unless other complications supervene. At SLIH, one individual arrived in full cardiac arrest. Specific antidotal therapy (atropine and pralidoxime chloride) was not provided until more than 90 minutes after exposure. The victim nevertheless survived without complications. Two other victims suffered respiratory arrest in the setting of seizures after hospital arrival. Immediate provision of diazepam and mechanical ventilation were effective preventing their deaths.

Of the more than 5,500 individuals reported to have been involved in the Tokyo event, some 1,100 were hospitalized, mostly with recognized nerve agent–related signs and symptoms. Assuming that this cohort of 1,100 was "truly" exposed, the death of "only" 12 individuals among this group represents an important detail in terms of disaster preparedness for this and in fact many other chemical events. In a large-scale chemical event, sizeable numbers of patients may be transported or self-present to nearby facilities. As was seen in the Tokyo event, likely only a very small number of these individuals suffer immediately life-threatening illness. Importantly, that illness in Tokyo was primarily respiratory. In all cases, immediate identification of severely affected victims with immediate application of respiratory support was sufficient to stabilize the victims even without immediate use of antidote. Certainly, later provision of atropine and oxime appeared to ameliorate the degree and shorten the time of the illness. The rapid application of basic and advanced life support principles appears to have been of critical importance. This observation further suggests that first responders and first receivers should be fully qualified and prepared to provide respiratory support, including ventilation and intubation, possibly even at the scene of the event.

MITIGATION

The medical structure in Tokyo had a complex, well-organized and well-trained disaster preparedness organization in place prior to the nerve agent attacks. The principal threat to the city was considered to be an earthquake. Much of the planning and training therefore was focused on aspects of medical care of large numbers of trauma victims. As is often the case, the nerve agent event was unexpected in size and scope. There had been no education or training for a large-scale chemical contamination event outside of the military structure. Despite the experiences of WW II, there was no repository of medical knowledge or experience of large events upon which civilian disaster planners could draw. Therefore there was no hazard analysis or vulnerability assessment undertaken.

PREPAREDNESS

Equipment designed for deployment in a contaminated environment was scarce and first responders were not well trained in its use. Contamination of a very large percentage of the first responders emphasized the importance of such preparation.

RESPONSE

The local hospitals managed a very large number of individuals within a short period of time. Presumably due to lack of training, further complicated by an overwhelming influx of vapor-contaminated patients, there was little or no attention paid to patient decontamination or to health professional self-protection. Consequently, in some areas of the hospitals, up to 25% of the hospital staff members suffered clinical effects of cross-contamination. Nevertheless, the most severely ill victims were identified expeditiously and treated with appropriate focus on critical components of their illness. Respiratory failure and seizure with associated respiratory failure were the principal life-threatening illnesses. These were handled very competently. Of note was the absence of early specific antidotal therapy. Although the victims presented with evidence of cholinergic excess, the possibility of organophosphate toxicity was not considered for about 2 hours. By this time, individuals with severe illness had either already expired or were significantly improved having been intubated and ventilated.

RECOVERY

The medical structure in Tokyo has, in the years after the event, carefully reviewed the medical response, found associated difficulties and proposed and enacted realistic improvements in the city's disaster preparedness plans. Yanagisawa makes a particularly invaluable recommendation for organized medical evaluation and follow up of such a large-scale event by using an integrated team including epidemiological, neurological, and psychiatric disciplines. Perhaps the most important result of the event has been the development of a National Disaster Center in Tokyo. This facility is a day-to-day resource and training facility for disaster preparedness. In the event of a large-scale disaster, the facility can be converted to provide medical care for disaster victims.[13]

Commercial Production and Sale of Toxic Chemicals in 1997 by Russian Chemist

On August 6, 1997, a Russian chemist, Valery Borzov was arrested in Moscow for the attempted sale of mustard. A former chemist at the Moscow Scientific Research Institute of Reagents, Borzov had branched into the private production and sale of various poisons. In a secret laboratory in Moscow, he reportedly manufactured and sold a variety of poisonous materials to criminals including the Russian mafia. An undercover policeman paid $1,500 US for 2 mL of mustard, subsequently arresting Borzov. Search of his residence revealed 50 L of toxic chemicals including 400 mL of synthesized mustard agent as well as detailed production notes. He has reportedly been incarcerated in a psychiatric treatment facility with a diagnosis of schizophrenia.[20]

GENERAL COMMENTARY

Chemical warfare agent production is often said to be easily accomplished with a high school chemistry background and Internet access for the recipes. Actual production of chemical warfare agent (mustard in this case) is difficult, requiring a substantial investment in equipment and training. Even with the extensive training evident in this case, risks in manufacture are considerable. As "meth labs" across the U.S. have shown, possible dangers associated with chemical production are easily neglected in the face of prospects for wealth. There are no specific data suggesting that Borzov's products were used intentionally, and the quantities involved were not sufficiently great to have created a large-scale event. Public anxiety appears to have been controlled in this setting, possibly due to some degree of media control existing within Moscow at the time.

According to a database compiled by the Monterey Institute's Center for Nonproliferation Studies, 263 incidents were reported worldwide between January 1960 and April 2007 involving criminal, politically, or ideologically motivated use of toxic chemicals.

Of the 263 chemical attacks, the toxic weapon was identified in 183 cases. Of this total, only 13 incidents, most of them linked to Aum Shinrikyo, involved the use of a military chemical warfare agent. Instead, the majority of attacks were conducted with household or industrial chemicals, such as cyanides (41 incidents), butyric acid (35 incidents), tear gas (21 incidents), insecticide or pesticide (14 incidents), sulfuric acid (two incidents), weed killer (three incidents), and more recently, chlorine associated with improvised explosive devices ([IEDs] eight incidents). The delivery system, when known, was often equally low-tech: direct contact with the target (32 incidents), spray or aerosol (13 incidents), contamination of food or drink (36 incidents), consumer product tampering (26 incidents), explosive device (16 incidents), contamination of the water supply (14 incidents), canister/container release (five incidents), letter or package (25 incidents), and insertion into a building ventilation system (three incidents). Importantly, 85 of the 263 attacks occurred in the United States and Canada. Of particular interest, 35 of the 85 North American attacks were specifically directed against medical facilities.

Intentional (nonstate) production of military chemical warfare chemicals is possible and has been accomplished as noted previously. Only the Aum Shinrikyo has accomplished both the production and use of chemical warfare agents. This effort required the extensive resources of a highly expensive and complex laboratory. The actual number of short-term deaths resulting from a total of 12 Aum Shinrikyo chemical attacks was 20. Therefore, the total numbers of events and associated deaths and illness have been relatively small compared with deaths and illness associated with accidental releases of TICs. Perhaps this is due to a small degree to the relative difficulty in the manufacture of military chemical warfare chemicals. The widespread availability of and easy accessibility to TICs, combined with their demonstrated effectiveness as "fear-inducing" entities makes their use as a terrorist weapon much more likely. Perhaps more importantly, however, is the fact that whether intentional or accidental, such chemical events have been occurring with increasing regularity. Many more deaths and associated illness have occurred worldwide as a result of accidental chemical events than have occurred as a result of intentional use of chemical substances in warfare or terrorist attacks. A discussion of the use of cyanide and carbon monoxide as lethal agents during WW I is beyond the scope of this chapter.

Improvised Explosive Devices as Chemical Weapons – Iraq 2004–2007

In 2007, IEDs in various forms became the single greatest cause of death among the U.S. troops in Iraq. Nearly 57% of the 327 U.S. deaths during the first 6 months of 2007 were the result of IEDs. Increasing complexity of the IEDs has been associated with greater difficulty in detecting and defending against them, resulting in an increasing mortality rate. Recent escalation of their complexity has resulted from incorporation of chemicals into the device. Both military (sarin and mustard) and industrial chemicals (chlorine) have been incorporated into the devices, resulting in substantially increased anxiety regarding their danger.

Modern history of the use of IEDs dates to the 1936–1939 Spanish Civil War when General Franco ordered the use of petrol bombs against Spanish Republican Tanks near Toledo, Spain. The burning gasoline often set off secondary fires in the tank's petrol fuel supply or within the turret where ammunition was stored. With the addition of tar to the petrol bombs, thick smoke augmented their effect. Molotov's name (Stalin's Minister of Foreign Affairs) was added to the device during the Soviet incursion into Finland in 1939.

Explosive powder-based IEDs came to be used in an organized fashion during WW II when Belarusian Guerillas used command-detonated and delayed-fuse IEDs to derail thousands of German trains during 1943–1944. The Viet Cong used explosive devices during the Vietnam War. These were typically constructed from scavenged/unexploded American ordnance. Nearly one third of all U.S. Vietnam casualties resulted from "mine injuries" (military statistical reports combined both IEDs and commercial mine casualties). Use of explosive devices by the Provisional Irish Republican Army was widespread during their campaign against the British Army. These explosives initially included classic fuel bombs (Molotov cocktails) and homemade explosives. Later, there was a progression from homemade explosives to use of commercial explosives and eventually sophisticated plastic explosives such as Semtex. The Afghani Mujahideen, utilizing military materials originally from various Muslim states and the U.S., constructed explosive devices principally from antitank mines. Combining the explosives of several mines would result in a more powerful device. Remote-controlled explosion was favored over the pressure-fuse triggers of the original mines. At the time of this writing, these devices are increasingly used in Afghanistan against U.S. troops.

Iraqi IEDs have become more common. Larger sizes, transported by car or truck are known as Vehicle-borne Improvised Explosive Devices (VBIED) and when delivered by a suicide bomber are termed suicide VBIED (SVBIED). These IED explosions have been responsible for an increasing percentage of U.S. deaths – averaging nearly 43% of all U.S. deaths (1545 of 3628) since 2003, with a gradually increasing percentage to 57% over the first 6 months of 2007.[21]

Iraqi IEDS have developed over the years. IEDs were initially placed at the roadside to explode underneath or at the side of vehicles. Improved vehicle armor has resulted in more sophisticated IED placement and further development of the type of IED. Shaped charges were developed to permit a more focused explosion. A refinement of the shaped charge, known as the Explosively Formed Penetrator, produced a fast-moving "bolt" of metal that was particularly effective in penetrating heavier armor. These Explosively Formed Penetrators could be placed at great distances of 40 m or more, rendering their detection and defense difficult.

In May 2004, an IED rigged from a 155-mm artillery round (possibly left from a Saddam Hussein stockpile) was found to contain the military nerve agent sarin. The round exploded before it could be disarmed. Two individuals required treatment for “minor exposure.” During that same month, an IED containing military mustard agent was also found.[22]

In early February 2007 some VBIEDs were found to contain liquefied chlorine canisters. Explosion of these devices produced some victims of chemical exposure and associated illness. The addition of chemicals to the IEDs, in effect produced a weapon similar to the chemical weapons of WW I. Most of the injuries related to the IED were from associated physical trauma. The effects of the chemical component achieved in WW I resulted from much larger quantities of chemicals delivered by munitions specially designed for that purpose. IEDs “accompanied” by chemicals are unlikely to achieve a WW I–equivalent toxic effect. The military/public reaction and associated psychological distress to announced use of a “chemical warfare agent” may have as much effect as the physical damage itself.[23] As has been noted before, the best defense against such public (and medical responder) anxiety derives from education and training. Accordingly, concerns regarding a chemical release associated with IEDs have prompted training responses within the U.S. Of note is the annual Golden Guardian Exercise undertaken in the State of California. There, focus on the traumatic/explosive effects of an IED has been broadened to incorporate concern about the appropriate response to other materials (e.g., nerve agents), which might possibly be incorporated with the IED.[24] The military response to incorporation of chemical (and possibly biological and radiological/nuclear – CBRN) materials with an IED has led to development of various remotely operated robotic devices with detectors capable of identifying chemical, biological, and radiological/nuclear materials (e.g., Talon® Robots).

EXAMPLES OF UNINTENTIONAL CHEMICAL EVENTS

Ammonia Release in 2002 – Minot, North Dakota

At 1:37 AM on January 18, 2002, 31 railroad cars (of 112) derailed in an incident 0.8 km west of Minot, ND, population 36,567. Five cars carrying anhydrous ammonia suddenly ruptured, releasing an estimated 555,300 L of anhydrous ammonia. This vaporized immediately into a large plume. An estimated 11,600 people were resident in the plume-involved area. There were 12 serious injuries, including one traumatic death and 320 additional individuals sustained minor injuries.

The derailment damaged local power lines at the site. Electrical supply to 2,820 residences was disrupted. The conductor notified the central emergency dispatch number (911) in Minot by personal cell phone. The violent rupture of the tank cars caused some sections to be propelled as far as 356 m from the site. Temperature was −21°C and winds were 10–12 km/hour from the west. Very low ambient temperature and slow winds kept the plume from rising. Deleterious health and medical effects were minimized because most residents were indoors asleep at the time. The plume that formed was an estimated 91 m high and 4 km wide as it ultimately drifted downwind to cover 8 km of the valley containing Minot City. Within 10 minutes the local fire department chief, responding to notification by the 911 emergency dispatch operator, arrived on scene and established a command post.

In the involved area, one couple attempted to flee their home. Their truck crashed into a house across the street from their residence. The female passenger returned to their house but the 38-year-old male driver collapsed outside. Ammonia vapors were described as so intense as to severely limit visibility in the immediate area. The Incident Commander prohibited first responders from entering the site due to a substantial risk to personal safety. Approximately 3 hours after the event first responders were allowed entry to begin rescue of victims in the immediate area; 60–65 persons were ultimately evacuated. An attempted rescue of the collapsed driver failed due to rescuers not wearing SCBAs. All other residents were instructed to “shelter-in-place” with notification provided by warning siren, cable television interrupts, and radio notification. Many residents did not hear the siren due to its location, and residents without power did not receive the media notification. The collapsed driver was ultimately rescued approximately 3.5 hours after the event and found to be unresponsive. The 911 system handled over 2,800 calls, instructing people to “stay in their homes and shut down their furnaces and air handling systems, go into their bathrooms and use large amounts of water – turn on their showers and breathe through a wet cloth.” Residents with wells, whose power was interrupted, were unable to operate their showers. At 4:15 AM the plume reached the nearest (Trinity) hospital. The hospital was not evacuated. Closing down the heating, ventilation and air-conditioning system was effective in preventing infiltration of much of the ammonia.

In emergency responders, seven minor injuries requiring hospital evaluation occurred in the 122 firefighters and 11 police personnel, including several dispatchers. These injuries were mostly eye irritation, chest discomfort, respiratory distress, and headaches.

At 2:15 AM, the first casualty reached Trinity Hospital. The hospital disaster plan was activated at 2:30 AM. Ultimately more than 370 persons were evaluated. Eleven individuals required hospitalization, three as the direct result of chemical burns to the eyes and face. Two individuals required mechanical ventilation. The Minnesota National Guard Civil Support Team arrived later that day. The railroad corporation rapidly established a claims and assistance center. The rapidity of this action may have reduced much of the public distress after the event.[25,26]

The National Transportation Safety Board (NTSB) began its activities early that morning, with inspection personnel fully active that same day. Town public meetings were conducted to assure residents that recovery efforts were in full progress. Much of the public commentary, however, focused on the belief that 911 and other portions of the emergency response system appeared to have failed the community. An informal review of public perception was undertaken in September 2004 during a Department of Justice Disaster Preparedness Program in North Dakota. Many residents spontaneously reported their continued dissatisfaction with the Minot emergency response, reflecting, “they just abandoned us.”[27] The NTSB Report noted that Minot had undertaken a Disaster Preparedness drill the prior September that had enhanced the effectiveness of the emergency response and that a three hour restriction of emergency responders from the involved area was appropriate to their personal safety.[28,29]

GENERAL COMMENTARY

An evaluation of the event, conducted per federal regulation by the NTSB, was completed and reported on March 9, 2004. This was a comprehensive evaluation that also included a brief assessment of disaster preparedness within the first responder and medical community. Although the originators of this particular portion of the report were not identified and their medical review qualifications are therefore uncertain, there appears no other publicly available comprehensive evaluation of the medical (hospital and first responders) response to the event. Public anxiety is typically very difficult to control during a large-scale event. In this case, postevent efforts to explain the sheltering-in-place process and address other public concerns regarding feelings of abandonment were not entirely effective. Two years later, there was persistent public perception of inadequate emergency response. Such perceptions can continue to erode necessary public confidence in the emergency response systems of the community. This is an important public relations issue.

MITIGATION

Minot has, for a number of years, performed high-quality hazard analysis and risk assessment in regards to dangers associated with rail transportation of toxic materials.

PREPAREDNESS

A citywide exercise of response capabilities was conducted 4 months prior to the event. Details of the after-action of that exercise are not readily accessible; hence specific identified weaknesses are not available for comment. It does appear that first responder equipment and training issues may have contributed to some travel and work difficulties of first responders within the ammonia cloud.

RESPONSE

Specific details of first responder and hospital response are not readily available. The NTSB Report provides some insight into the disaster response of the first responder and medical system. Although a more complete first response/medical review would be highly desirable, the NTSB Report stands as an example of an available document that allows some degree of retrospective review of the event.

RECOVERY

The city review of the event apparently identified several problems with communications. These reportedly have been addressed; however, important issues of public confidence in Minot's emergency response system still seem to exist.

Methyl Isocyanate Release in 1984, Bhopal, India

On the evening of December 2–3, 1984, at a Union Carbide of India industrial plant in Bhopal (population 900,000), an approximately 27-ton leak of methyl isocyanate (MIC) occurred. Atmospheric conditions included a relatively low wind speed and a nocturnal temperature inversion. These conditions resulted in a gas cloud that moved slowly, primarily close to the ground, ultimately covering approximately 40 km^2 of the surrounding city. The cloud rapidly engulfed the homes of a large number of primarily poor and uneducated residents. The cloud may have contained additional contaminants and decomposition by-products such as phosgene, mono methylamine, hydrogen cyanide, various oxides of nitrogen, and carbon monoxide, although specific data are unavailable. An estimated 500,000 people were exposed and an estimated 3,000–15,000 deaths occurred. Accurate statistics are unavailable for a variety of reasons, but a 2%–3% death rate seems consistent with available information.

Most immediate and near-term MIC deaths appear to have occurred due to respiratory effects of the chemical. MIC produces airway inflammatory changes, contributing to airway obstruction. MIC also appears to produce a delayed pulmonary edema, much like phosgene. This effect may have contributed to the impression that phosgene was also released during the event. Additional concern was expressed about the possibility of cyanide or various decomposition products of MIC acting as contributing factors. There was no direct evidence to support that concern.

On the evening of the event an estimated 400,000 people fled the city in an uncontrolled evacuation. Nearly half of those who lived more than 10 km away from the event site left, reacting out of fear. Approximately 2 weeks later, during attempts to neutralize the remaining MIC at the Union Carbide plant, public fear resulted in a second wave of mass evacuation involving approximately 200,000 people. The local medical system, which consisted of approximately 300 doctors and 1,800 hospital beds, was entirely overwhelmed. An estimated additional 1,500 people are reported to have died in subsequent months due to injuries caused by the release.[30]

Near-term medical care was provided, insofar as possible, by local facilities that were later assisted by Indian government aid. Additional support was provided by a number of non-governmental organizations. Long-term evaluation of medical health and consequences of exposure have been conducted by a variety of individuals and organizations, both private and public. Their data, albeit somewhat compromised by both ongoing legal/political difficulties and substantial difficulty with establishing and reliably following a cohort of exposed individuals, suggest a variety of possible long-term MIC effects that will require further investigation.

GENERAL COMMENTARY

The Bhopal event occurred in a country with limited and poorly developed resources. The sudden release of a large toxic vapor cloud, whether accidental or (as suggested by a Union Carbide evaluation) intentional, resulted in the world's single most catastrophic chemical event to date at the time of this publication. A more careful analysis of the event from a perspective of disaster preparedness is warranted.

MITIGATION

The city of Bhopal at the time of the release had a population of 900,000 people. Nearly 200,000 lived within 10 km of the Union Carbide plant. The majority of these individuals were poor, living in housing that often consisted of no more than tin shacks. Recognizing some risks of residence close to a chemical plant, the provincial government attempted to encourage residents to move away. It appeared, however, that individuals actually preferred to live close to a business that might offer many new, well paying jobs to the local residents. The local government maintained few records of the identities or even the numbers of these individuals. There was no record maintained of any individuals with special needs. No governmental or local political organization existed that collectively represented these individuals. The few city organizations responsible for the health or safety of the local population received no effective citizen input. In the absence of a specific citizen action group, there was no organization able to collect information regarding the potential risks of a disaster in the neighborhood of the chemical plant. Thus, no hazard assessment or vulnerability analysis was performed. The nearby first responder community (fire and police) had little awareness or understanding of the possibility of a large toxic leak. Accordingly, there was little education, training, or equipment acquired for that possibility. The local medical facilities and personnel were equally limited in their awareness or understanding of the possibility of a large toxic leak.

PREPAREDNESS

The nearby residents were unaware of the risks posed to their community by industrial facilities in the area (specifically the Union Carbide Plant). In the absence of an organization like the U.S. model of a Local Emergency Planning Committee, there was no evident effort directed toward preparing for an industrial chemical event. No evidence exists that local hospitals had become aware of the dangers or risks of the industrial plants in their immediate area or had made efforts to understand and prepare for those risks. Union Carbide had established a small clinic at the entrance to the facility. A physician was hired 8 months prior to the event to act as occupational physician for the facility. Evidence is lacking that the physician either initially had or subsequently acquired particular expertise with respect to MIC. Furthermore, there is no evidence that the company physician was active in preparing either the local medical or civilian community for possible chemical exposures.

RESPONSE

Immediately after the incident, notification of the surrounding population was ineffective. There had been no community education or training of appropriate response to the alarm sirens. Accordingly, the neighboring residents did not react to the emergency alarm. Arrival of irritating fumes drove many individuals to escape on foot. Running resulted in the need for deeper respirations – likely causing inhalation of greater amounts of MIC with each labored breath. Some individuals, unable or unwilling to run away, effectively sheltered in place and survived the toxic event. Emergency communications between the Union Carbide Plant, local government, first responders, and local medical facilities and personnel were poor or nonexistent. Confusion with respect to what particular substance was released appeared to play a major role in complicating both medical and logistical response to the event. There was much criticism of the lack of "correct" medical information and training and appropriate equipment. Although there was no specific antidote known, that criticism reflects the deeper problem of failure of education and training. Although MIC has since come to be recognized as an irritating substance with pulmonary edema effects similar to phosgene, this information was not available to the local medical community at the time. Accordingly, life-saving efforts were directed toward immediate symptomatic therapy – principally the control of obvious respiratory failure. Most near-term deaths were clearly respiratory. The actual number of deaths can only be estimated. With the data available, it is not possible to determine the relative importance of the following factors in relationship to those deaths.

1) Inadequate/insufficient medical equipment: although there is no evidence that specific preparations had been made for large numbers of respiratorily compromised individuals – even had hundreds of ventilators been available, appropriately trained personnel would not have been available.
2) Inadequate medical knowledge/experience: some basic education and training of local medical personnel would have been useful. Details of the risks/toxic effects of MIC and other large-quantity chemicals stored at the Union Carbide facility could have been easily provided. This should have been the responsibility of the occupational physician of the facility. As noted, however, the number of victims with respiratory failure would likely have far exceeded even the best preparation with large numbers of ventilators, given the absence of personnel to manage them.
3) Inadequate numbers of medical practitioners: additional numbers of trained medical personnel were needed, but were not immediately available. In some countries such as the U.S., chemical facilities have provided groups of their on-site industrial workers with basic life-saving training. In case of a chemical event, these on-site workers can act as an immediately available group of first responders.

RECOVERY

Subsequent to the event, both the Bhopal government and various private organizations have maintained a roster of exposed individuals. Some of these victims have been compensated. Some private and university medical groups have undertaken "cohort" follow-up assessment of some of the victims. These group studies have revealed some very important medical observations regarding the long-term effects of MIC exposure; however, there appears to be no centralized repository for this accumulated medical information. There is little evidence that information gleaned from such cohort studies has been incorporated into routine medical practice in the local area.

Exposure site clean-up is of concern to local medical facilities. Site clean-up has not been completed, and a variety of toxic materials have been recognized as remaining in residual solid wastes. Local medical personnel and hospitals have been provided little if any information regarding the medical aspects of these materials.

The Bhopal event has prompted international discussion that may ultimately lead to an improved nationally coordinated medical recovery response in India. Similar to the practices of the U.S. NTSB, the following thoughts are proposed.

Shortly after the incident, as part of the recovery, a data collection team (best sponsored by the national government) should undertake responsibility for

1) Victim demographics – immediate recording (names/identifiers) of deaths, injuries, and individuals resident in the area of exposure
2) Clinical demographics – recording of any clinical records established for the individuals noted above
3) Establishment of epidemiological studies for near- and long-term follow-up of victims
4) Establishment of specialty treatment centers for both medical and psychiatric aspects of near- and long-term victim illness
5) Preparation of a report evaluating the quality of pre-event mitigation and preparedness within the local (and perhaps provincial) medical community. The quality of the response should be also evaluated with specific attention to the adherence of the medical system to previously established local emergency plans

MEDICAL RESPONSE TO LARGE-SCALE CHEMICAL EVENTS

In circumstances of large-scale chemical events, early knowledge of the specific materials involved is an ideal medical goal. This is, however, an illusory target. Specific antidotes are available for only two significant types of toxic chemical exposures: organophosphates and cyanide. Commercial/industrial formulations of cyanide and organophosphates typically present as dermal or ingestion exposures. There is a slower onset and progression of the clinical illness, often affording ample time to deliver appropriate antidotal therapy. Military/chemical warfare organophosphates, and cyanide, when presenting as inhaled agents, act very rapidly, often within seconds to minutes. Consequently, antidotal therapy of both organophosphate and cyanide inhalational exposures must be delivered immediately on-site. This implies the necessity of establishing stockpiles of antidote as "far forward" as possible, in locations of actual or suspected risk. Just such a "far forward" deployment of organophosphate (nerve agent) antidote has been accomplished for specific issues by both U.S. Department of Defense and FEMA/CSEPP (see later). An equivalent "far-forward" deployment of cyanide antidote has not been undertaken. In part this is due to issues of cost and effectiveness of the currently available antidote "kits." A hydroxocobalamin-based antidote has been successfully used in Europe since the early 1960s. It appears to have a better risk/benefit ratio than the current U.S. antidote kit, particularly for use in pediatric patients. The U.S. Food and Drug Administration has reviewed and cleared this antidote for use in the United States. Believing that cyanide exposures are not very likely, many U.S. hospitals currently maintain little or no antidote supply, however, the availability of hydroxocobalamin may change this.

Aside from antidotal therapy, medical management of a large-scale chemical event is generally accomplished by syndromic/symptomatic assessment. An extensive medical literature has been produced on the subject of rapid assessment of injured individuals. A large body of medical responders has been educated and trained in a systematic approach to the rapid assessment and categorization of exposed individuals. The Simple Triage and Rapid Treatment system allows very rapid identification of those victims needing immediate, life-saving care. Assessment of three major bodily systems (airway/respiration, circulation, and neurological) can be quickly and consistently accomplished even by nonmedical personnel with minimal training. Cone and Koenig have proposed a modification of this triage system for use for mass casualties exposed to a chemical agent.[31] A pediatric format (JumpSTART) has been developed as well, however, none of these systems have been adequately validated (see Chapter 12). As suggested by the examples herein, the majority of immediate and near-term chemical event-related illness is respiratory. Immediate and near-term toxic respiratory illness caused by a chemical event is very amenable to intervention with relatively simple and inexpensive technology. Thus rapid identification and intervention in these respiratory "Immediates" is of the highest value.

MANAGEMENT OF RESPIRATORY COMPROMISE FROM LARGE-SCALE CHEMICAL EVENTS

1) Identification of immediate (life-threatening) airway/respiratory victims can be very rapidly accomplished (seconds) by individuals with minimal training.
   a) Individuals with apnea may be considered for immediate intubation only if other evidence of viability is apparent. Use of newer technology esophageal obturator intubation devices and portable ventilators is appropriate.
   b) Individuals with upper airway obstruction (hoarseness/stridor/inspiratory wheezes) should be considered for elective intubation. Upper airway inflammatory disorder typically results from exposure to a highly soluble inflammatory chemical with resulting laryngeal/vocal cord edema and rapidly progressive obstruction. Direct vision intubation (or video laryngoscopy) is preferred in this situation. Emergency tracheostomy is often required when failed attempts at direct vision intubation/video laryngoscopy result in further laryngeal edema. Use of a portable ventilator is appropriate.
   c) Individuals with rapid respiratory rates in the range of 30 or higher and other evidence of primary respiratory abnormality (hypoxia or pulmonary edema) should be considered for application of continuous positive airway pressure (CPAP) if available. Otherwise immediate intubation is appropriate. Rapid transition to a volume-controlled ventilator would be appropriate.
2) Medical care (ventilation or intubation) of the identified "immediate airway/respiratory" victim can be very rapidly achieved by individuals with basic medical skills. Using newer technology equipment, intubation should be within the purview of paramedics or the equivalent. Ventilatory support equipment has also become simpler and less expensive. Many U.S. CSEPP community hospitals have stockpiled large numbers of "disposable-portable," pressure-controlled ventilators in preparedness for a possible large-scale chemical event.
3) After airway control has been achieved, additional medical care of chemically induced respiratory illness can then proceed at a more measured pace with attention to the following categories.
   a) Airway bronchospastic disorder. A large percentage of the human population has been shown to possess "hyperirritable airways." Inhalation of irritant or inflammatory chemical materials may trigger bronchospasm in these individuals. Therapy of that bronchospasm should follow normal practice. Use of inhaled and/or systemic bronchodilators is immediately indicated. Systemic steroid supplementation is appropriate for moderately severe levels of bronchospasm. Prolonged use of bronchodilators and steroids may be necessary. Some substances have been shown to engender bronchospasm on an immunogenic basis. Isocyanates found in various industrial settings may act in this way. For this reason, further studies investigating possible methyl isocyanate immunogenic effects are underway in the Bhopal population.
   b) Lower airway inflammatory disorder. Lower airway exposure to toxic/inflammatory chemicals typically results in endobronchial tissue swelling and inflammation. Obstructive signs and symptoms may develop rapidly and be of substantial severity to necessitate long-term volume-controlled ventilator assistance. Underlying bronchospastic disorder further complicates the care of these patients. Exposure to some toxic agents may result in progressive development of increased pulmonary interstitial water (pulmonary edema) as a result of capillary leakage. This produces the radiological and

physiological equivalent of ARDS. ARDS has been observed as a common sequelae of phosgene exposure and also appears as a common complication of high-dose hydrochloric acid, chlorine, ammonia, perfluoroisobutylene, and MIC inhalations. Possible development of ARDS after such chemical inhalational exposure should be anticipated. Symptoms of dyspnea and chest tightness, especially if unexplained by other obvious abnormalities, are a typical early indication of progressive pulmonary edema. Such symptoms often appear 1–2 hours before signs of abnormal physical examination (crackles), or abnormal arterial blood gas levels or abnormal chest x-ray results are noted. Although bronchoalveolar lavage may provide an early and sensitive indication of impending pulmonary edema, use of the technique is impractical in large-scale events.[32] Modern laboratory investigation has suggested that a variety of medical interventions, when applied within 30–90 minutes after exposure, minimize or block the development of toxic chemical–induced pulmonary edema. Specifically, ibuprofen, n-acetylcysteine, aminophylline, salmeterol, and steroid therapy all seem very effective in various animal studies. Human studies have not been performed to confirm a wide variety of excellent animal data.[33–36] Early application of CPAP may be of value. Early intubation is indicated in the event of deteriorating oxygenation. First responders should be trained and equipped for possible on-site intubation. Intubation may be most easily accomplished with the use of newer technology esophageal obturator devices.[37,38]

AGENT-SPECIFIC CLINICAL CONSIDERATIONS AND TREATMENT RECOMMENDATIONS

Health care personnel should suspect an exogenous chemical attack whenever there are multiple patients with similar acute symptoms, especially after exposure to air with an odd smell or color. Chemical agents likely to be used in a large-scale terrorist attack overwhelmingly fall into four categories of compounds: pulmonary intoxicants, cyanides, vesicants, and nerve agents. Two categories, cyanides and nerve agents, have specific antidotes that must be administered in a time-sensitive manner. For the other two categories of agents, only supportive care is available.

Of the four categories, pulmonary intoxicants and vesicants tend to produce delayed effects. Unlike biological agents with incubation periods typically lasting days, the latent period before symptoms appear for these chemical agents tends to be on the order of hours to a day. For cyanides and nerve agents, symptoms are more likely to be immediate or to appear with a latent period of only seconds to minutes.

Certain general principles apply for any suspected mass casualty event involving chemical agents. Decontamination is the most important. Although decontamination of patients exposed to chemical agents may be useful for the patients, it is even more important in order to avoid contamination of other patients, health care providers, and treatment facilities. During the Tokyo sarin attack in 1995, an estimated 10% of the emergency department staff developed miosis, the first sign of vapor sarin poisoning. This was because they had not removed patients' clothes before they entered the emergency department. Sarin vapor, trapped in air cells in those clothes, caused symptoms in the health care workers. A useful concept for chemical agent exposures is to consider patients as contagious without being infectious. This concept will remind properly trained emergency staffs to remove clothing and do at least a brief decontamination of patients suspected of chemical exposure before they enter the facility.

The specific physical state of the agent is an important consideration in determining efficacious decontamination procedures. True vapors or gases require much less attention to full-body decontamination, since clothing removal will eliminate 90% or more of the risk to health care workers. Cyanides and pulmonary intoxicants are likely to be only vapor or gas hazards because they are all vapors at standard temperature and pressure. Mustards and nerve agents, on the other hand, are liquids at standard temperature and pressure. Liquid chemical agent requires full-body decontamination. Thus, it is critical to obtain the exposure history. Even though mustards and nerve agents are liquids at standard temperature and pressure, in many likely scenarios, exposure to patients will be in only the vapor phase. In this case, agents such as the nerve agent sarin, which evaporates rapidly from the liquid phase at standard temperatures, can overwhelmingly cause vapor hazards rather than liquid hazards. In the Tokyo subway attack, 30% sarin solution was spilled out onto the floor and seats of subway cars. Although the agent causing intoxication was liquid, essentially none of the roughly 5,500 people who presented for care were directly touched by the liquid. Instead, they inhaled sarin vapor, which evaporated from the floor of the subway car and was carried throughout the subway system by the movement of the train.

Physical removal of contaminants is superior to all known catalytic or chemical decontaminants. Water or soap and water, if applied quickly and in sufficient quantities, is an appropriate decontaminant for liquid chemical agent on the skin. The U.S. military developed doctrine for tactical situations in which water was not available in sufficient quantities and for decades has fielded 0.5% bleach. This solution is 10-fold diluted from commercially available bleach bottles, which are 5% bleach in concentration, a concentration that is damaging to normal skin. Reactive Skin Decontamination Lotion (RSDL, E-Z-Em Corporation) has been licensed by the U.S. Food and Drug Administration as a skin decontaminant for all chemical agents. It is not approved in wounds. Therefore, if the skin is broken, providers should use sterile saline or sterile water as a rinse. Work done in the 1950's in the Netherlands, however, shows that many household products such as corn oil are equally effective as decontaminants as 0.5% bleach. The key concept is to decontaminate as quickly as possible, using some physical agent that will wash the skin of the patient. Verification of decontamination in a large civilian attack involves confirmation that the patient has been washed. In military settings, detector papers (M8 and M9 paper) that turn specific colors if liquid chemical agent is still present have been applied to patients' skin.

Another general principle revolves around logistics. For pulmonary intoxicants and mustards, which have no specific antidotes, proper management to improve survival requires that severely exposed patients be transported to intensive care settings. In these cases, evacuation to a higher level of care may be more valuable than actual emergency treatment. By contrast, for the more rapidly acting cyanides and nerve agents, immediate care may need to be given even before the patient is properly decontaminated, possibly even in the "hot zone."

For more detailed information on specific agents the reader is directed to the Medical Aspects of Chemical Warfare portion of the *Textbook of Military Medicine*, published by the Borden Institute and Walter Reed Army Medical Center, 2008.[39] This volume, as well as the shorter handbook of treatment published by the Chemical Casualty Care Division of the U.S. Army Medical Research Institute of Chemical Defense, Aberdeen Proving Ground, Maryland (Chemical Casualty Care Division) are available on the Division's web site at http://ccc.apgea.army.mil.[40] Non-military organizations must register for the web site in advance, a process that usually takes 2–3 business days. Emergency personnel who may need to care for chemical casualties should therefore register their organizations during the planning phase so that they can access current data during an event.

The following discussion primarily emphasizes the mustards and nerve agents, which do not generally cause casualties outside of military or terrorist scenarios. Pulmonary intoxicants and cyanides have the potential to result in casualties after industrial accidents in many communities.

Pulmonary Intoxicants

A large variety of agents cause pulmonary toxicity by the inhalation route. Many of these are toxic industrial chemicals or materials. A few have been used in warfare or in terrorist attacks. Space does not permit detailed discussion of the entire list.

Most pulmonary intoxicants primarily affect only the respiratory tree and do not cause systemic or multi-organ toxicity. This generalization allows a further categorization. Highly reactive or water-soluble pulmonary intoxicants cause toxicity in the central compartment of the respiratory tract, the trachea, large bronchi, and larynx. Typical examples of these include hydrochloric acid and ammonia. Among the weaponized agents, sulfur mustard is another good example, although its primary use in terrorism or warfare is as a skin vesicant. By contrast, pulmonary intoxicants which are less reactive or water-soluble do not react with the structures of the central component, and thus are able to reach the alveoli. They exert primary effects upon the peripheral pulmonary compartment, alveoli in the lung parenchyma. Classic examples of this category include phosgene, oxides of nitrogen (the major component of photochemical smog), and perfluoroisobutylene, the combustion product of Teflon. Central agents cause irritation, local edema, and, in severe cases, pseudomembrane formation through sloughing in large airways. Peripheral agents tend to disrupt the alveolar-capillary membrane, causing leakage; this will produce non-cardiogenic, toxic pulmonary edema. Agents differ, but in phosgene intoxication, this occurs due to acylation at the alveolar-capillary membrane. This distinction between primarily centrally and peripherally acting agents, while useful, is inconsistent; a severe exposure to any intoxicant can cause both central and peripheral toxicity. Certain agents, such as chlorine, have mixed effects.

The common industrial and military pulmonary agents are gases at standard temperatures and pressures. While they may be mucous membrane irritants – chlorine is a good example – and thus cause transient tearing and salivation, only their pulmonary effects are life-threatening. Because they are gases, decontamination is a relatively minor issue. Clothing removal and a quick wash-down of the patient should suffice to protect both provider and emergency treatment facilities.

While all pulmonary intoxicants can produce shortness of breath, the peripheral and central syndromes clinically differ. Central pulmonary agent toxicity manifests as stridor, laryngospasm, and dyspnea, often with a latent period which varies according to the specific intoxicant and the amount inhaled but which is typically on the order of several hours. A severe toxic exposure to a centrally acting agent can cause sudden complete airway obstruction either from edema or by the sloughing of pseudomembranes; these patients can deteriorate rapidly.

By contrast, peripheral toxicity manifests first as dyspnea, with or without chest tightness, but without coughing and without any signs of pulmonary compromise, either on direct auscultation or even on X-ray. This is because the initial phase of pulmonary edema involves leakage of fluid from the capillaries only into the interstitial space. Until fluid has penetrated into the alveoli themselves, there will only be symptoms without signs. After that point, there will be rales and crackles, with clear signs of edema on X-ray. As the syndrome intensifies, arterial blood gases will show hypoxemia, and sequestration of up to 1 L/h of fluid in the lungs may lead to hypovolemia and hypotension – very unlike cardiogenic pulmonary edema. Patients die of respiratory failure due to hypoxia, hypovolemia, or a combination. World War I data clearly show that exertion during the latent period of peripheral pulmonary toxicity can exacerbate the situation and turn a minor illness into a life-threatening emergency.

Although the latent period may be long enough that the patient is no longer being exposed at the time of medical evaluation, it is important to confirm that the patient has been removed from the source of agent. The development of symptoms and signs of pulmonary intoxicant toxicity within four hours of exposure is a poor prognostic sign regardless of therapy. This is true for both the central and peripheral syndromes. There is no specific therapy for pulmonary agent toxicity. Therapy is entirely supportive.

For central pulmonary toxicity, the key principle is to maintain the integrity of the airway. In severe cases, where pseudomembranes can form and block off the airway, endotracheal intubation or even emergency tracheostomy may be required. For primarily peripheral difficulties, intubation with positive end-expiratory pressure may be needed. Fluid management should be judicious; these patients, unlike cardiogenic edema patients, are actually hypovolemic, and thus diuretics are relatively contraindicated and intravenous fluids may be required in multi-liter quantities. Treat hypoxia directly as warranted by monitoring blood gas results in expectation that supportive care will allow the respiratory system to recover.

Most patients with isolated toxicity from inhaled pulmonary intoxicants recover if supportive care is provided in a timely manner. A few peripheral pulmonary intoxicants are associated with interstitial fibrosis post-crisis, including oxides of nitrogen. Phosgene and chlorine, the two most common agents in terrorist scenarios, cause acute syndromes from which patients recover with no apparent lasting structural damage on subsequent pathological examination. This implies that management of patients with these intoxications may become more of a logistic challenge than a medical one.

Cyanides

Cyanides are not considered to be useful battlefield agents, but are a high threat for use as a terrorist weapon due to their rapid action. The commonly cited cyanide products, hydrogen cyanide and cyanogen chloride, are close to their boiling points at standard temperatures and pressures. They are occasionally used in criminal scenarios for small-scale attacks – usually against specific individuals – to poison water and food supplies close to the point of consumption.

As a method of large-scale attack against a population, cyanides are not well adapted because the gaseous phase of cyanide ion is lighter than air. Hence, in an outdoor attack, cyanide dissipates rapidly. The reason for the high interest in cyanides as terrorist weapons lies in the possibility of using them in an indoor environment against a large crowd, such as in a sports arena, legislative building, railroad station or airport terminal.

Cyanide, or CN— ion, is a normal part of the environment; there is even a normal human cyanide level. It is present in all organic media; tobacco smokers, for example, average three times the normal human baseline cyanide level in blood. Cyanide ion is also a required cofactor for many human enzymes, including Vitamin B12. Because humans evolved in an environment containing cyanide – unlike any of the other chemical agent classes – people also evolved a mechanism to detoxify small quantities of this ion, based upon the hepatic enzyme rhodanese. This mechanism underpins antidotal therapy for cyanide poisoning.

The mode of action of cyanide is to poison the electron transport chain in mitochondria, at the level of the last enzyme in the chain, cytochrome oxidase or cytochrome A3. Cyanide ion has a high binding affinity for various metals, including iron, which is the central atom in this enzyme. Once cyanide binds to the iron in this enzyme, it shuts down aerobic metabolism; cells can only continue metabolism by switching to the inefficient anaerobic metabolic pathway. With poisoned electron transport chains, cells cannot utilize oxygen to make glucose and carry out other metabolic functions. As a consequence, venous blood is no longer turned blue, and this explains the classic "cherry red" appearance associated with cyanide victims – an ironic twist, since cyanide victims are NOT cyanotic. The term "cyanide" (Greek for blue) comes not from cyanosis but from Prussian blue, from which Von Scheele originally isolated the compound in 1782.

Cyanide causes a primary histotoxic anoxia. It affects cells in direct proportion to their metabolic rate, or to their concentration of mitochondria. Inhaled cyanide crosses the alveolar-capillary barrier and circulates via the blood, giving rise to the old misnomer "blood agent" for cyanide. This term is still in use despite the fact that the blood is only a passive carrier for cyanide. Blood is essentially unaffected by the passage of cyanide, since most blood cells have very few mitochondria. In humans, the most actively metabolic cells are those in the carotid bodies which serve as baroreceptors. Thus, inhalation of a sizable cyanide challenge causes initial hyperpnea, hypotension and syncope. The second most highly metabolic cells are those of the brain. Therefore the next symptom of cyanide poisoning, which in large challenges will be almost instantaneous, is loss of consciousness, followed shortly by seizures, probably caused by hypoxia. Within seconds to minutes, central apnea affects the medullary breathing centers. Cardiac tissue will become affected next, causing vascular instability leading to cardiopulmonary arrest and death within about 8 minutes if there is no treatment.

Via the inhalation route, cyanide is one of two chemical agent classes that can cause a virtually instantaneous loss of consciousness and seizures. The other is nerve agents. Key concepts for the differential diagnosis are detailed later.

Removal of the patient from the source of contamination is crucial and may be life-saving. Because the body has its own detoxification mechanism, humans can metabolize a small challenge of cyanide. Clinical experience has shown that simple removal from the source of cyanide can revive mild cases of poisoning.[41]

Although the mechanism is not well understood, nasal or mask oxygen therapy is helpful acutely in cyanide poisoning. While theoretically implausible since mitochondrial electron transport chains are poisoned rendering cells unable to use oxygen, oxygen therapy should be instituted rapidly as it has been proven clinically effective. In addition to oxygen, specific antidotal therapy is valuable for acute cyanide poisoning, but only if it can be instituted in a timely manner. There are two major forms of antidotal therapy, the multi-component cyanide antidote kit and hydroxocobalamin.

The cyanide antidote kit is based upon beagle dog experiments performed in the 1930s that showed that the components of the kit were capable of saving animals exposed to up to 20 lethal doses of cyanide gas. Conceptually, it consists of two types of antidotes used sequentially. The first antidote is a methemoglobin former, a nitrite (not nitrate). Methemoglobin, with its iron in the Fe^{+3} (ferric) state rather than the Fe^{+2} (ferrous) state of normal hemoglobin, binds to cyanide ion with even greater affinity than does cytochrome a^3. Hence, creation of a methemoglobin pool, which results from therapy with nitrite, will pull cyanide off cytochrome a^3 and rapidly restore normal cell function. Nitrite is given either via inhalation of an amyl nitrite ampule or via intravenous administration of sodium nitrite. The dose in the vial provided in the cyanide antidote kit is 10 ml and if an initial dose requires repeating, half of the second vial (5 ml) should be administered. For children, the U.S. military recommends 0.33 ml/kg of the standard 3% nitrite solution given slowly over 5–10 minutes. Nitrite will cause hypotension, and so patients should be lying down when they receive it, whether inhaled amyl or intravenous sodium nitrite. Additionally, in situations where patients may have reduced oxygen carrying capacity – such as fire victims – the use of nitrite, which will form methemoglobin from the already depleted stores of hemoglobin, may cause hypoxia. In these cases, experts recommend considering omitting the nitrite step and proceeding directly to the second antidote in the kit. The use of nitrite alone, however, will create a pool of cyan-methemoglobin in the blood. This is unstable, and unless the second antidote is given, cyanide will eventually come unbound from methemoglobin and cause subsequent toxicity.

The second antidote, sodium thiosulfate, is necessary because the body cannot tolerate a large pool of cyan-methemoglobin indefinitely. In order to permanently eliminate the cyanide ion from the body, sodium thiosulfate, a sulfur donor, is administered as a cofactor to activate the liver stores of rhodanese, the body's natural cyanide detoxifier. The result of this reaction is that rhodanese forms sodium thiocyanate. Sodium thiocyanate is excreted harmlessly in the urine. Sodium thiosulfate is given via the intravenous route only; the kit contains two 50-ml vials, and if after one is given the patient requires more, half of the second vial (25 ml) should be administered. The U.S. military recommends a pediatric dose of 1.65 ml/kg of the standard 25% solution.

Hydroxocobalamin is commonly used in Europe and in 2007 was licensed by the U.S. Food and Drug Administration as an alternate cyanide antidote. It binds stoichiometrically (1:1) to circulating cyanide and forms cyanocobalamin (Vitamin B12) which the body tolerates well. One disadvantage is that hydroxocobalamin is a huge molecule and 1:1 binding means that large volumes of hydroxocobalamin must be used via the intravenous route. Additionally, unlike the nitrite and thiosulfate solutions in the antidote kit, hydroxocobalamin must be reconstituted from powder. Extensive clinical experience from the Paris Fire Brigade has demonstrated that hydroxocobalamin can be used as on-scene treatment by trained first responders. The adult dose is two 2.5 g vials administered intravenously over 15 minutes after reconstitution, with a second dose of two 2.5 g vials given as needed. The most common side effect of hydroxocobalamin is chromaturia; urine tends to turn purple, although this in itself is harmless. In many of the published cases in which hydroxocobalamin has been used, sodium thiosulfate was also given; these treatments are, therefore, not mutually exclusive. Hydroxocobalamin has advantages over nitrite. It does not cause methemoglobinemia (diminishing oxygen carrying capacity) or hypotension. However, it takes longer to administer and requires the infusion of large volumes.

Vesicants

Sulfur mustard, the prototypical vesicant agent, has been a military threat since it first appeared on the battlefield in Belgium during World War I. In modern times it remains a threat on the battlefield as well as a potential terrorist threat because of simplicity of manufacture and extreme effectiveness. Sulfur mustard accounted for 70% of the 1.3 million chemical casualties in World War I and an estimated 45,000 Iranian casualties during the Iran-Iraq War. Other vesicants of lesser military importance include nitrogen mustard (still used in cancer chemotherapy), Lewisite and phosgene oxime, which will not be discussed in detail.

Sulfur mustard constitutes both a vapor and a liquid threat to all exposed epithelial surfaces. Like peripheral pulmonary agents, mustard's effects are delayed, appearing hours after exposure. Organs most commonly affected are the skin (erythema and vesicles), eyes (ranging from mild conjunctivitis to severe eye damage), and airways (ranging from mild upper airway irritation to severe bronchiolar damage). Following exposure to large quantities of mustard, precursor cells of the bone marrow are damaged, leading to pancytopenia and secondary infection. The gastrointestinal mucosa may be damaged, and there are sometimes central nervous system (CNS) signs of unknown mechanism. No specific antidotes exist; management is entirely supportive.[42]

Mustard dissolves slowly in aqueous media, such as sweat, but once dissolved, it rapidly forms extremely reactive cyclic ethylene sulfonium ions, which react with cell proteins, cell membranes, and especially DNA in rapidly dividing cells. Mustard's ability to react with and alkylate DNA gives rise to the effects characterized as "radiomimetic," i.e., similar to radiation injury. Mustard has many biological effects, but the actual mechanism of action is largely unknown. Mustard reacts with tissue within minutes of entering the body. Its circulating half-life in unaltered form is extremely brief.

Topical effects of mustard occur in the eyes, airways, and skin, in that order of sensitivity. Absorbed mustard may produce effects in the bone marrow, gastrointestinal tract, and CNS. Direct injury to the gastrointestinal tract may also occur following ingestion of the compound through contamination of water or food.

Erythema is the mildest and earliest form of mustard skin injury. It resembles sunburn and is associated with pruritus, burning, or stinging pain. Erythema begins to appear within 2 h to 2 days after vapor exposure. Time of onset depends on the severity of exposure, ambient temperature and humidity, and type of skin. The most sensitive sites are the warm moist locations and thin delicate skin, such as the perineum, external genitalia, axillae, antecubital fossae, and neck.

Within erythematous areas, small vesicles can develop, which may later coalesce to form bullae. The typical bulla is large, dome-shaped, flaccid, thin-walled, translucent, and surrounded by erythema. The blister fluid, a transudate, is clear to straw-colored, which becomes yellow, tending to coagulate. The fluid does not contain mustard and is not itself a vesicant. Lesions from high-dose liquid exposure may develop a central zone of coagulation necrosis with blister formation at the periphery. These lesions take longer to heal and are more prone to secondary infection than the uncomplicated lesions seen at lower exposure levels. Severe lesions may require skin grafting.

Sulfur mustard vapor is a centrally acting pulmonary intoxicant. The primary airway lesion is necrosis of the mucosa with possible damage to underlying smooth muscle. The damage begins in the upper airways and descends to the lower airways in a dose-dependent manner. Usually, the terminal airways and alveoli are affected when death is imminent.

Necrosis of airway mucosa causes exfoliation of epithelial debris, or "pseudomembrane" formation, as with any centrally acting pulmonary agent. These membranes may cause obstruction of the bronchi. During World War I, high-dose mustard exposure caused acute death via this mechanism in a small minority of cases.

The eyes are the organs most sensitive to mustard vapor injury. The latent period is shorter for eye injury than for skin injury and is also exposure concentration–dependent. After low-dose vapor exposure, irritation evidenced by reddening of the eyes may be the only effect. As the dose increases, the injury includes progressively more severe conjunctivitis, photophobia, blepharospasm, pain, and corneal damage, which may lead to severe visual impairment.

Ninety percent of eye casualties heal in 2 weeks to 2 months without sequelae. Scarring between the iris and lens may follow severe effects; this scarring may restrict pupillary movements and may predispose victims to glaucoma. The most severe damage is caused by liquid mustard. After extensive eye exposure, severe corneal damage with possible perforation of the cornea and loss of the eye can occur. In some individuals, chronic eye irritation, sometimes associated with corneal ulcerations, has been described 10 to 20 years after exposure.

The mucosa of the gastrointestinal tract is susceptible to mustard damage, either from systemic absorption or ingestion of the agent. Mustard exposure in small amounts will cause nausea and possible vomiting lasting up to 24 h. The mechanism of the nausea and vomiting is not understood, but mustard does have a cholinergic-like effect. The CNS effects of mustard, likewise, remain poorly defined. Large exposures can cause seizures in animals. Reports from WWI and Iran described the behavior of persons exposed to small amounts of mustard as sluggish, apathetic, and lethargic. These reports suggest that minor psychological problems could linger for a year or longer.

The causes of death in the majority of mustard poisoning cases are sepsis and respiratory failure. Mechanical obstruction via pseudomembrane formation and agent-induced laryngospasm is important in the first 24 h, but only in cases of severe exposure. From the third through the fifth day after exposure, a secondary bacterial pneumonia can be expected due to invasion of denuded necrotic mucosa. The third wave of death is caused by agent-induced bone marrow suppression, which peaks 7 to 21 days after exposure and causes death via sepsis. Early warning of impending marrow suppression is a drop in the lymphocyte count beginning as early as 24 hours. Polymorphonuclear cells may actually rise at first and begin falling at 3–5 days.

A patient severely ill from mustard poisoning requires the general supportive care provided for any severely ill patient as well as the specific care given to a burn patient. Liberal use of systemic analgesics, maintenance of fluid and electrolyte balance and nutrition, use of appropriate antibiotics, and other supportive measures are necessary.

The management of a patient exposed to mustard may range from simple, as in the provision of symptomatic care for a sunburn-like erythema, to complex, as in the provision of total management for a severely ill patient with burns, immunosuppression, and multisystem involvement. Before raw denuded areas of skin develop, especially with less severe exposures, topical cortisone creams or lotions may be of benefit. Some basic research data suggest benefit from the early use of anti-inflammatory preparations. Small blisters (<1 to 2 cm) should be left intact. Because larger bullae will eventually break, they should be carefully unroofed. Denuded areas should be irrigated three to four times daily with saline, other sterile solutions, or soapy water and then liberally covered with a topical antibiotic, such as silver sulfadiazine or mafenide acetate, to a thickness of 1 to 2 mm. Some experts advocate sterile needle drainage of large blisters, collapsing the blister roof to form a sterile dressing. Mustard blister fluid does not contain sulfur mustard, only sterile tissue fluid. Health care staff should not fear contamination.

Systemic analgesics should be used liberally, particularly before patient manipulation. Monitoring of fluids and electrolytes is important in any sick patient, however fluid loss after mustard exposure is not of the magnitude seen with deeper thermal burns. Overly rigorous hydration seems to have precipitated pulmonary edema in a few Iranian casualties sent to European hospitals.

Conjunctival irritation from a low vapor exposure will respond to any of a number of available ophthalmic solutions after the eyes are thoroughly irrigated. A topical antibiotic applied several times a day will reduce the incidence and severity of infection. Animal laboratory data have shown remarkable results with commercially available topical antibiotic/glucocorticoid ophthalmologic ointments applied early. Topical glucocorticoids alone are not of proven value, but their use during the first few hours or days may significantly reduce inflammation and subsequent damage. Ophthalmologic consultation is indicated and further use of glucocorticoids should be at the specialist's discretion. Vaseline or a similar substance should be applied regularly to the edges of the lids to prevent them from sticking together.

A productive cough and dyspnea accompanied by fever and leukocytosis occurring within 12 to 24 h is indicative of a chemical pneumonitis. The clinician must avoid use of prophylactic antibiotics to manage this process. Infection often occurs on the third to fifth day and is signaled by fever, pulmonary infiltrates, and an increase in sputum production with a change in color. Initial antibiotic therapy should await evidence of infection from Gram stain of sputum; regimens can then be tailored according to the results of sputum culture and sensitivity. Studies suggest that Iran-Iraq War veterans may develop a chemical pneumonitis responsive to erythromycin, 400–600 mg/day for 6 months following mustard exposure.

Intubation may be necessary for laryngeal spasm or edema, permitting better ventilation and facilitating suction of the necrotic inflammatory debris. Early use of positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) may be beneficial. Pseudomembrane formation may require fiberoptic bronchoscopy for suctioning of the necrotic debris. Bronchodilators are of benefit for bronchospasm. If additional relief of bronchospasm is needed, glucocorticoids should be used. There is little evidence that the routine use of glucocorticoids is beneficial, except for additional relief of bronchospasm.

Leukopenia begins around day 3 with major systemic absorption. Marrow suppression peaks at 7 to 14 days. In the Iran–Iraq war, a white blood count of $\leq 200/\mu L$ usually resulted in death of the patient. Sterilization of the gut by nonabsorbable antibiotics should be considered to reduce the possibility of sepsis from enteric organisms. Cellular replacement (bone marrow transplants or transfusions) may be successful. In one study, granulocyte colony-stimulating factor produced a 50% reduction in the time for the bone marrow to recover in non-human primates exposed to sulfur mustard and should be considered in human exposure. Antiemetics may be necessary for gastrointestinal side effects.

Lewisite, a chemically unrelated compound, causes a remarkably similar clinical syndrome to sulfur mustard. There are two important clinically differences between Lewisite and sulfur mustard. Lewisite is a direct skin irritant so early detection of exposure is more likely. This means that decontamination is likely to be more effective in preventing systemic damage and the agent is less likely to be used for either a military or civilian terrorist attack. An additional difference is that Lewisite is an arsenical compound so it can be treated with a chelating agent that binds arsenic. The antidote, British anti-Lewisite or dimercaprol, was developed in the 1930's and remains available as a chelating agent. The only U.S. FDA-approved formulation is an intramuscular injection dissolved in peanut oil, to which some patients are allergic.

Nerve Agents

The organophosphorus nerve agents are the deadliest of the chemical warfare agents. They work by inhibition of tissue synaptic acetylcholinesterase, creating an acute cholinergic crisis. Death ensues because of respiratory depression and can occur within seconds to minutes.

The classic nerve agents include tabun (GA), sarin (GB), soman (GD), cyclosarin (GF), and VX. VR, similar to VX, was manufactured in the former Soviet Union. The two-letter codes are a NATO international convention and convey no clinical implications. All of the nerve agents are organophosphorus compounds, which are liquids at standard temperatures and pressures. The "G" agents evaporate at about the rate of water, except for GF, which is oily, usually evaporating within 24 h after deposition on the ground. Their high volatility makes a spill of any amount a serious vapor hazard. In the Tokyo subway attack 100% of the symptomatic patients inhaled sarin vapor that spilled out on the floor of the subway cars. VX, an oily liquid, is the exception. Its low vapor pressure makes it much less of a vapor hazard but potentially a greater environmental hazard. The nerve agents tabun and sarin were first used on the battlefield by Iraq against Iran during the first Persian Gulf war, 1984–1987. Estimates of casualties from these agents range from 20,000 to 100,000.

Acetylcholinesterase inhibition accounts for the major life-threatening effects of nerve agent poisoning. Reversal of this inhibition by antidotal therapy is effective, proving that this is the primary toxic action of these poisons. At cholinergic synapses, acetylcholinesterase, bound to the postsynaptic membrane, functions as a turn-off switch to regulate cholinergic transmission. Inhibition of acetylcholinesterases causes the released neurotransmitter acetylcholine to accumulate abnormally. End-organ overstimulation, manifesting as cholinergic crisis, ensues. Clinical effects of nerve agent exposure are identical for vapor and liquid exposure routes if the dose is sufficiently large. The speed and order of symptom onset however, will differ.

Nerve agent vapor exposure is overwhelmingly the more likely exposure route in both battlefield and terrorist scenarios. Vapor exposure will cause cholinergic symptoms in the order that the toxin encounters cholinergic synapses. The most exposed synapses on the human integument are in the pupillary muscles. Nerve agent vapor easily crosses the cornea, interacts with these synapses, and produces miosis, described by Tokyo subway victims as “the world going black.” Rarely, this can also cause eye pain and nausea. Exocrine glands located in the nose, mouth, and pharynx are exposed to the vapor next, and cholinergic overload here causes increased secretions, rhinorrhea, excess salivation, and drooling. Finally, toxin interacts with exocrine glands in the upper airway, causing bronchorrhea, and with bronchial smooth muscle, causing bronchospasm, the combination of which can cause hypoxia.

Once the victim has inhaled, vapor can passively cross the alveolar-capillary membrane, enter the bloodstream, and, incidentally and asymptomatically, inhibit circulating cholinesterases, particularly free butyrylcholinesterase and erythrocyte acetylcholinesterase, both of which can be assayed. The assay may not be easily interpreted without a baseline, however, since cholinesterase levels vary enormously between persons and over time in an individual healthy patient.

The gastrointestinal tract is usually the first organ system to become symptomatic from bloodborne nerve agent exposure. Cholinergic overload causes abdominal cramping and pain, nausea, vomiting, and diarrhea. After the gastrointestinal tract is involved, nerve agents affect the heart, distant exocrine glands, muscles, and brain. Because there are cholinergic synapses on both the vagal (parasympathetic) and sympathetic sides of the autonomic input to the heart, changes in heart rate and blood pressure are unpredictable. Remote exocrine activity will include oversecretion in the salivary, nasal, respiratory, and sweat glands – the patient will be “wet all over.” Bloodborne nerve agents overstimulate neuromuscular junctions in skeletal muscles, causing fasciculations followed by frank twitching. If the process continues, ATP in muscle will eventually be depleted and flaccid paralysis will ensue.

Due to the wide distribution of the cholinergic system in the brain, sufficient doses of bloodborne nerve agents cause rapid loss of consciousness, seizures, and central apnea, leading to death within minutes. If respiration is supported, status epilepticus may manifest. If status persists, neuronal death and permanent brain dysfunction may occur. Even in mild nerve agent intoxication, patients may recover but experience weeks of irritability, sleep disturbances, and other nonspecific neurobehavioral symptoms.

The time from exposure to development of full-blown cholinergic crisis after nerve agent vapor inhalation can be minutes or even seconds; however, there is no depot effect. Since nerve agents have a short circulating half-life, improvement should be rapid with no subsequent deterioration if the patient is treated with antidotes and supportive care.

Liquid exposure to nerve agents differs in speed and order of symptom onset. A nerve agent on intact skin will partially evaporate and partially begin to travel through the skin, causing localized sweating and then localized fasciculations when it encounters neuromuscular junctions. Once in muscle, it will cross into the circulation and cause gastrointestinal discomfort, respiratory distress, heart rate changes, generalized fasciculations and twitching, loss of consciousness, seizures, and central apnea. The time course will be much longer than with vapor inhalation; even a large, lethal droplet can take up to 30 minutes to have effect, and a small, sublethal dose could continue to take effect over 18 h. Clinical worsening that occurs hours after treatment has started is far more likely with liquid than with vapor exposure. Additionally, miosis, practically unavoidable with vapor exposure, is not always present with liquid exposure and may be the last symptom to present. This is due to the relative insulation of the pupillary muscle from the systemic circulation.

Unless a nerve agent is removed by specific therapy (oximes), its binding to cholinesterase is essentially irreversible. Erythrocyte acetylcholinesterase activity recovers at about 1% per day. Plasma butyrylcholinesterase recovers more quickly and is a better guide to recovery of tissue enzyme activity.

Acute nerve agent poisoning is treated by decontamination, respiratory support, and three antidotes – an anticholinergic, an oxime, and an anticonvulsant. In acute cases, all of these forms of therapy may be given simultaneously. Death from nerve agent poisoning is almost always due to respiratory failure. Ventilation will be complicated by increased resistance and secretions. Atropine should be given before ventilation or as it begins, as it will facilitate ventilation.

In theory, any anticholinergic could be used to treat nerve agent poisoning, but worldwide the choice is invariably atropine because of its wide temperature stability and rapid effectiveness. Atropine can be administered either intramuscularly or intravenously. It rapidly reverses cholinergic overload at muscarinic synapses but has little effect at nicotinic synapses. Practically, this implies that atropine can quickly treat the life-threatening respiratory effects of nerve agents but will probably not reverse neuromuscular and possibly sympathetic effects. In the field, military personnel in some countries are given MARK I kits, which contain 2 mg atropine in autoinjector form for intramuscular use. In addition, some civilian agencies are now stockpiling this product (FDA-approved in the U.S.). One can only give full autoinjector doses and not divide them. The field-loading dose is 2, 4, or 6 mg, with retreatment every 5 to 10 min until the patient’s breathing and secretions improve. The Iranians initially used larger doses during the Iran–Iraq war where oximes were in short supply. Pediatric autoinjectors are now available at dosages of 0.5 and 1.0 mg for rapid intramuscular injection, however intravenous drug administration is the preferred route when this is logistically feasible, especially in small children. There is no upper bound to atropine therapy in a patient either intramuscularly or intravenously. A total average adult dose for a severely afflicted patient usually ranges from 20 to 30 mg.

In a mildly affected patient with miosis and no other systemic symptoms, atropine or homatropine eye drops may suffice for therapy. This will produce roughly 24 h of mydriasis. Frank miosis or imperfect accommodation may persist for weeks or even months after all other signs and symptoms have resolved.

Oximes are nucleophiles that reactivate the cholinesterase whose active site has been occupied and bound to nerve agent. Therapy with oximes therefore restores normal enzyme function. Oxime therapy is limited by a second side reaction, called *aging*, in which a side chain on nerve agents falls off the complex at a characteristic rate. "Aged" complexes are negatively charged, and oximes cannot reactivate negatively charged complexes, so oxime cannot reactivate "aged" complexes. The practical effect of this differs from one nerve agent to another, since each ages at a characteristic rate. VX, for practical purposes, never ages, sarin ages in 3 to 5 h, and tabun ages over a longer period. All of these are so much longer than the patient's expected lifespan after untreated acute nerve agent toxicity that they may be ignored from a clinical standpoint. Soman, on the other hand, ages in 2 min. Thus, after only a few minutes following exposure, oximes are useless in treating soman poisoning. The oxime used varies by country; the United States has approved and fielded 2-pralidoxime chloride (2-PAM Cl). MARK I kits contain autoinjectors of 600 mg of 2-PAM Cl. Initial field loading doses are 600, 1200, or 1800 mg. Since blood pressure elevation may occur after administration of 45 mg/kg in adults, field use of 2-PAM Cl is restricted to 1800 mg/hr intramuscularly. During the time when more oxime cannot be given, atropine alone is recommended. In the hospital setting, 2.5 to 25 mg/kg of 2-PAM Cl intravenously has been found to reactivate 50% of inhibited cholinesterase. The usual recommendation is 1000 mg through slow intravenous drip over 20 to 30 min, with no more than 2500 mg over a period of 1 to 1.5 h.

Dosage recommendations for children are less certain than for adults and are based upon extrapolations from adults; further studies are needed in children.[43] In small children (<25 pounds), autoinjectors, even the pediatric doses, may not be practical. Additionally, the clinical syndromes in children may be harder to recognize; in particular, seizures in children often manifest without tonic-clonic movements and may be missed. The U.S. FDA has approved a dual-dose autoinjector (ATNAA, Autoinjector Treatment Nerve Agent Antidote), containing 2.1 mg atropine and 600 mg 2-PAM Cl. This was shown bioequivalent to the MARK 1 kit, but requires only half as long to administer.

Nerve agent–induced seizures do not respond to all of the usual anticonvulsants used for status epilepticus. The only class of anticonvulsants that has been shown to stop this form of status are the benzodiazepines. Diazepam is the only benzodiazepine approved for seizures in the U.S. in humans, although other benzodiazepines, especially midazolam, work well against nerve agent–induced seizures in animal models. Diazepam is manufactured in 10-mg injectors for intramuscular use and given to U.S. military forces for this purpose. Civilian agencies stockpile this fielded product (convulsive antidote for nerve agent, "CANA"), which is not generally used in hospital practice. Extrapolation from animal studies indicates that adults will probably require 30 to 40 mg diazepam, intramuscularly, to stop nerve agent–induced status epilepticus. In the hospital, or in a child too small to tolerate the autoinjector, intravenous diazepam may be used at similar doses. The clinician may confuse seizures with the neuromuscular signs of nerve agent poisoning. In the hospital, early electroencephalography is recommended in order to distinguish between nonconvulsive status epilepticus, actual seizures, and postictal paralysis. Intravenous lorazepam is also effective.

MEDICAL REVIEW OF LARGE-SCALE CHEMICAL EVENTS

Medical review of large-scale chemical events is necessary for purposes of "quality improvement" and to provide a database record to assist in validation of current medical practice and development of novel medical interventions. Within the U.S., there is no federal structure that provides this type of unified medical review independent of modifying influences of the legal, political, and commercial communities. There is, however, a federal program that has extensive depth of personnel, long-standing experience, and great competence and experience in evaluation of large-scale chemical event exercises. This FEMA-directed program, the CSEPP could easily furnish the building blocks of a national chemical event assessment program.

CSEPP HISTORY

At the time of this writing, there are seven chemical weapons stockpile sites within the United States. In 1986, Congress mandated chemical weapon destruction, at that time also mandating maximum protection for the public, environment, and workers involved in destroying the chemical munitions.

In 1988, FEMA, in cooperation with the U.S. Army, developed an assistance program to enhance the abilities of communities surrounding the seven stockpile sites to respond to the unlikely event of a chemical agent emergency. FEMA is responsible for developing preparedness plans, upgrading response capabilities, and conducting training for these civilian communities. These obligations were integrated into a program called the CSEPP. With the help of FEMA and the Army, the communities surrounding the seven sites have expanded their emergency plans and capabilities to meet the slight but real threat of an emergency involving chemical agents. These communities have plans and procedures in place to manage a stockpile incident. Moreover, they are constantly striving to enhance preparedness. CSEPP has provided funding and technical assistance to

- Improve public warning capabilities
- Build and upgrade state-of-the-art emergency operations centers
- Train emergency managers and first responders
- Hold functional exercises that improve readiness
- Increase public knowledge and understanding of protective actions
- Overpressurize schools to ensure the safety of children (overpressurize = provision of higher than ambient air pressure within classrooms to preclude infiltration of outside toxic fumes/vapors; this is typically accomplished through the use of high-volume, high-flow air to the rooms that has been filtered through chemical [charcoal] filtration systems)
- Study emergency response options to determine the best way to protect communities
- Train doctors and nurses to treat victims of chemical agent exposure

Under CSEPP, federally managed exercises (FMEs) began in 1991. These exercises demonstrated the ability of the communities to respond to a chemical incident. Representatives from the

Department of the Army, FEMA, other federal agencies, state and local governments, the Army installations, and civilian volunteer agencies participated in these exercises. Under the Department of Homeland Security, FEMA administers CSEPP activities occurring outside military installations. There are annual exercises of the community response to a large-scale chemical event. During these exercises, trained and experienced medical observers carefully evaluate the medical response capabilities of local medical facilities. A thorough assessment of the medical response is recorded, and then that response is compared with the existing emergency operations plan of the involved medical structure. Discrepancies are evaluated and new plans are developed. A final report becomes available to medical reviewers for purposes of quality improvement and as a database record to assist in validation of current medical practice and development of novel medical interventions.

The CSEPP program functions in a remarkable fashion. CSEPP observers dispassionately record and then critically review the medical aspects of a community response to a large-scale chemical event. This critical review becomes the basis for future revisions in local emergency operations plans. This program, in existence since 1991, is the sole medical/first responder evaluation system for chemical events within the United States. As a consequence of the CSEPP program, the surrounding communities have developed an extraordinary capability to respond to a large-scale chemical event. These communities represent the U.S. national best in mitigation, preparedness, and (exercised) response. Their "recovery, and after action process" contains exactly the type of critical medical review that is detailed herein. This type of structure should be emulated for intra- and postchemical event evaluations. Direct incorporation of the FEMA/CSEPP program into a national medical review system should be considered.

SUMMARY

The following key points are synthesized from the examples and attached commentaries detailed in this chapter.

1) Chemical events, whether intentional or accidental, often tax the capabilities of the local medical response system. During the early stages of those events, first responders must recognize
   a) There are typically very few individuals who require immediate (life-saving) intervention. Therefore, rapid identification and treatment of those individuals is of highest priority
   b) Most individuals who suffer acute respiratory failure have a type and extent of pulmonary physiological limitation that is amenable to current therapeutic interventions
   c) Best medical care of those individuals involves their very rapid identification among a larger population of exposed and "less ill" victims. "Far-forward" placement of appropriately trained and equipped first responders would allow efficient identification and care of those victims within the first 1–2 hours after an event
   d) Technologies for rapid and successful intubation and ventilation exist. More recent research has demonstrated therapeutic interventions that may minimize or block some aspects of the pulmonary toxicity of certain chemical agents. These specific interventions will be most useful if also placed in the hands of the "far-forward" responders.
2) The release of toxic chemicals typically create a degree of public anxiety and fear that is vastly disproportionate to the medical illness and death involved. Media involvement in reporting chemical events often appears to be a source of further anxiety and fear. Mitigation of that fear can be approached by the following
   a) Public education regarding disaster preparedness and "weapons of mass effect" should commence during elementary school education
   b) Media sensationalism must be modified. Techniques must be developed to ensure that media presentations utilize credible sources and are accurately presented
   c) Public medical information should be principally provided by a single, consistent, publicly recognized, and experienced spokesperson. Much like the presence provided by the Mayor of New York after the September 11, 2001 terrorist attacks, a "parental figure" would have the most success in ameliorating public anxiety and fear
3) Chemical events, particularly those of large-scale, are often reviewed by any (or all) of a number of U.S. federal agencies including the U.S. Chemical Safety and Hazard Investigation Board; the Bureau of Alcohol Tobacco, Firearms and Explosives; the NTSB; the EPA; the Occupational Safety and Health Administration (OSHA); and Agency for Toxic Substances and Disease Registry. Most of these agencies focus to some extent (but not primarily) on medical and first responder disaster response. A large-scale event that involves significant illness or death should be critically reviewed from a medical perspective. Medical review has two principal obligations
   a) The immediate, near- and long-term medical health of exposed individuals should be reviewed by a team of medical professionals. This team should at minimum include specialists in epidemiology, emergency and internal medicine and psychiatry. Careful clinical and laboratory documentation of the medical effects of the event should be collected and reviewed on a regular basis over a long term
   b) The quality of medical response to the event should be reviewed by a team of experienced "disaster review personnel," supplemented by medical professionals with similar experience. Much like the investigations taken by the FEMA/CSEPP structure (see previous mentions), careful review of each of the medical steps surrounding an event should be undertaken and reported. Mitigation, preparedness, response, and recovery should each be reviewed with particular attention to the design of and compliance with already existing local emergency operation plans
4) The importance of such medical review cannot be overemphasized. Careful medical investigation of chemical events is critical to validation of current medical disaster preparedness and to the development of novel approaches to future challenges. Medical reviews of this sort are typically begun with every large-scale chemical event. In the same way, the reviews are typically delayed, diminished, criticized, and sometimes discarded because of direct involvement of legal, political, and/or commercial entities whose goals may be different

from those of the medical community. For this reason the medical reviews suggested must be undertaken outside of the influence of these entities. To a substantial extent, many federal agencies are able to accomplish this; however, the agencies noted previously (e.g., U.S. Chemical Safety and Hazard Investigation Board; the Bureau of Alcohol Tobacco, Firearms and Explosives; and NTSB) do not focus primarily on the medical aspects of the event

5) The medical community must, collectively, assert the importance of such reviews and encourage the development of a single organization to undertake such studies

RECOMMENDATIONS FOR FURTHER RESEARCH

1) Disaster/terrorism-related events must undergo an immediate and careful review of related medical aspects
   a) Individual medical illness referable to the event should be recorded and reviewed
   b) First responder actions should be recorded and reviewed
   c) First provider actions should be recorded and reviewed
   d) The U.S. CSEPP provides an excellent example of a well-trained and thoroughly practiced evaluation system. This existing infrastructure should serve as an example for a proposed national medical incident evaluation team
2) Recognized difficulties that impede expeditious and thorough evaluation of medically related aspects of the event must be mitigated
   a) Corporate responsibility for event-related expenses should include reimbursement of expenses of medical investigation (see 1 above)
   b) Legal entanglements that impede expeditious evaluation and reporting of medical aspects of the event must be bypassed
      i) Any (large-scale/chemical) event should be considered (U.S. OSHA or equivalent) reportable and subsequent investigations should include medical assessment undertaken by trained medical investigators
      ii) Medical evaluators should be free of (current) legal entanglements to offer their written assessments of the event
   c) Peer review of the these evaluations should be followed by proposals for corrective actions (if any)
   d) Corrective actions should be incorporated into first provider (hospitals) system policies and protocols – possibly through Joint Commission regulatory structures
   e) Corrective actions should be incorporated into first responder system policies and protocols – this may require the development of a national/international evaluation/accreditation program for first responders.
3) Disaster/terrorism-related stress is thought to adversely impact the public
   a) Much of this stress appears to derive from the number, quality, and content of media presentations. Recommendations include to
      i) Undertake education of the media regarding the importance of the psychological effects of their work product
      ii) Incorporate local media personnel into training and exercise programs designed to deal with large-scale events
   b) Methods for mitigation of this stress must be investigated
      i) The value of a single, consistent, recognizable public information resource (person) should be emphasized
      ii) This person(s) must be competent in public presentations, competent in the field of knowledge, and recognizable to the public prior to the event
      3) Other real-time accessible information resources should be explored and developed (e.g., Internet/telephone sites)
4) Recognition of respiratory failure as the principal medical issue in large-scale chemical events should prompt national study
   a) First responder use of ventilator support in a large-scale chemical event must be considered from a variety of logistical and ethical perspectives
   b) Alternative initial support tools (including CPAP and disposable ventilators) should be evaluated for their practicality in addition to their associated logistical and ethical perspectives
5) Material safety data sheets have been used as a resource for assessment and therapy of chemical exposures. OSHA mandates their availability in the U.S. There is, however, a need for national or subject matter expert review of the data sheets for consistency of content throughout the United States. An area of future research would be to explore the development of a universal standardized resource with up-to-date information about the assessment and therapy of chemical exposures that could be deployed and maintained globally, perhaps under the auspices of the World Health Organization.

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29

Biological Events

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The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as necessarily reflecting the views of the Department of Defense, the U.S. Department of Health and Human Services, or any of their component institutions.

OVERVIEW

A Brief History of Biological Warfare

Biological warfare is ancient in its origins, dating back at least as far as 1346. In that year, Tatar invaders laid siege to the city of Kaffa, in present-day Ukraine. When an outbreak of bubonic plague afflicted the Tatar invaders, they catapulted bodies of their own victims over the city walls in an attempt to intentionally spread plague within the city. The plan appeared to succeed. Genoese and Venetian merchants stranded within the city contracted plague, fled the city, sailed home, and took the disease with them, thus firmly establishing the "Black Death" in continental Europe.[1] Current understanding suggests that the catapults fail to explain the extension of plague into Kaffa. Bubonic plague is now known to be transmitted by fleas, which rapidly abandon the cooling cadaver, making it unlikely that these corpses would remain infectious. Similarly, the American experience with biological warfare dates back at least as far as 1763. During the French and Indian Wars, the British Colonial Commander, Sir Jeffrey Amherst, allegedly ordered the use of smallpox-laden blankets presented as gifts to his Native American adversaries,[2] apparently resulting in outbreaks of smallpox among these natives.

The advent, in the 19th century, of modern microbiology, germ theory, and Koch's postulates opened the way for a stockpiling of infectious pathogens and more robust efforts at state-sponsored biological weapons programs. During the First World War, Imperial Germany experimented with anthrax and glanders, intending them as antianimal weapons directed at adversaries' livestock food sources and beasts of burden.[3] In the1930s, Japan used dozens of different biological agents in conducting an extensive series of macabre human biological warfare experiments on civilians and prisoners of war in occupied Manchuria.[4] Largely in response to these efforts, the United States, in 1943, established its own biological warfare research center at Camp Detrick in Maryland. In 1953, a defensive medical countermeasures program (which continues to exist today) was added to Camp Detrick's previously offensively oriented efforts. A more thorough review of the history of biological warfare is available elsewhere.[5]

In 1925, in response to the horrors produced by chemical weapons in the trenches of WW I, the "Geneva Gas Protocol" was promulgated, forbidding, among other things, the "practice of bacteriological warfare." Cynics noted that it said nothing about toxin warfare, and it did not prohibit production and storage of agents. Moreover, the United States, for various reasons, was not a signatory to that protocol at the time. In 1969, however, President Nixon, speaking for the nation, unilaterally renounced the use of biological weapons. Moreover, he ordered that the United States offensive program be halted and existing weapons stockpiles be destroyed. This destruction occurred during the period from 1969–1972 and culminated in the signing of the Biological Weapons Convention (BWC) by the Soviet Union, the United Kingdom, and the United States. This treaty has since been ratified by more than 140 nations, and prohibits the possession, stockpiling, and use of biological weapons. In 1975, the United States ratified both the Geneva Gas Protocol and the BWC.

Developing a Threat List

Biological warfare, according to language used during crafting of the BWC, is "the use, for hostile purposes, of living organisms, whatever their nature, or infective material derived from them, which are intended to cause disease or death in man, animals, or plants."[6] Little about the topic of biowarfare and bioterrorism is, in reality, as straightforward as this definition might make it appear. In fact, the wording of the BWC has complicated attempts to develop a universally accepted list of biological agents of concern. For example, the Soviet Union accused the U.S. government of violating the terms of the BWC by using antiplant agents such as "Agent Orange" during the Vietnam War. The U.S. government, for its part, considered this to be a nonprohibited use of a chemical agent. Similarly, during that same war, the United

Table 29.1: Former Components of the (now-Destroyed) U.S. Biological Arsenal

Lethal Agents	*Incapacitating Agents*	*Anticrop Weapons*
Bacillus anthracis	Venezuelan Equine Encephalitis	Wheat-Stem Rust
Botulinum Toxin	Staphylococcal Enterotoxin B	Rye-Stem Rust
Francisella tularensis	*Brucella suis*	Rice-Blast Spore
	Coxiella burnetii	

Table 29.2: "Rating System (Russian) of Bioagent Distribution According to Probability of Use as Bioweapons"

Smallpox Virus
Yersinia pestis
Bacillus anthracis
Botulinum Toxin
Venezuelan Equine Encephalitis Virus
Francisella tularensis
Coxiella burnetii
Marburg Virus
Influenza Virus
Burkholderia mallei
Rickettsia typhi

See text and reference 8 for details.

States accused the Soviets of waging biological warfare by using trichothecene mycotoxins ("Yellow Rain"), a charge the Soviets denied. Moreover, they apparently considered toxins to be chemical, rather than biological, weapons. As science advances, consideration of novel substances such as biomodulators (kinins, leukotrienes, substance P, δ-sleep-inducing peptide) as potential agents of warfare will likely only serve to heighten this semantic controversy.

To gain insight into prospective biological weapons candidates, it is useful to consider those agents contained within the U.S. arsenal during the 1943–1969 period of offensive weapons research and development. Ten agents were weaponized in the 1950s and 1960s and are listed in Table 29.1. These can be divided into three anticrop and seven antipersonnel agents; the antipersonnel agents can be further subdivided into lethal agents and incapacitants.[7] Russian sources have provided different perspectives.[8] A list, in some order of priority, of agents considered for weaponization by Russian (and presumably, Soviet) scientists is provided in Table 29.2.

Biological Warfare versus Bioterrorism

Although the weapons caches of the Cold War Superpowers provide an interesting starting point, it is useful to examine the biological threat on multiple levels. Strategically speaking, biological agents might be used to strike fear into a nation's inhabitants and to diminish the resolve of the citizenry. As such, strategic weapons, in this context at least, need only be effective enough to create such fear. Perception of a weapon's abilities might thus be more important than its actual ability to cause disease. Strategic weapons might also be used against domestic targets important to the conduct of a foreign war, such as command and control nodes, staging bases, and ports of embarkation. Thus, even agents capable of infecting a few key personnel might be strategically beneficial.

Conversely, contagion might be a useful property in a strategic weapon, permitting its propagation among the population. Such contagion, however, might limit a commander's enthusiasm for using the same weapon on the battlefield, where friendly forces might inadvertently contract it. This property of contagion likely explains the inclusion of smallpox, plague, and Marburg virus in the Soviet arsenal (the Soviets favored the strategic use of biological agents)[9] and, perhaps, their exclusion from the U.S. arsenal (as the United States saw these primarily as operational agents).

A number of biological agents might be adapted for operational use. That is, they possess characteristics (such as atmospheric stability) that could enable their use over large geographical areas. The list of such agents is short, enabling public health authorities to concentrate countermeasure efforts on a finite number of threats. Anthrax, plague, tularemia, and perhaps a few other agents might pose viable operational threats. In one regard, the threat posed by tactical use of biological agents is more problematic than the operational threat in that certain viruses and toxins, which lack the stability necessary for effective operational use, might nonetheless be used effectively against smaller, more concentrated targets (such as individual buildings or smaller areas of terrain). Conversely, some strategists would argue that biological agents are a poor choice for such tactical use. This contention stems from a unique characteristic not typically shared by conventional, chemical, and nuclear weapons, namely, the incubation periods inherent with infectious agents. These incubation periods might vary from hours in the case of staphylococcal enterotoxin B to weeks in the case of brucellosis or Q-fever but are more typically several days in duration. Commanders assigned tactical objectives (such as seizing an important terrain feature) would likely balk at the thought of pausing for several days while waiting for biological agents to slowly produce their effects. Even if one could conceive of a tactical use for biological weapons, the list of viable candidates remains short, with only a handful of agents possessing the desirable characteristics.

In addressing the terrorist threat, one, in a sense, comes full circle. Here, public perception is of paramount importance, and any attack capable of generating headlines (and publicity for the cause of a given extremist group) might be considered "viable." Moreover, the delay induced by the incubation periods of biological agents would not likely dissuade the terrorist from their use. The list of potential agents of terrorism thus becomes quite lengthy. Designing effective countermeasures and defensive strategies against such a large list of possible threats becomes a daunting task. Agents and diseases such as human immunodeficiency virus, *Escherichia coli*, "mad cow," rabies, and Ebola, which might otherwise lack characteristics desirable in a weapon, possess the "brand-name" recognition sought by certain terrorists. Similarly, terrorists might select "weapons of opportunity," that is, weapons that might be widely available and/or readily procured by a member of the group. This further lengthens the list of potential agents. The intentional contamination of restaurant salad bars in The Dalles, Oregon, with *Salmonellae* in 1984 highlights this problem as does the 1996 use of *Shigella*-laden pastries in a notable biocrime.[10,11] Although not considered credible military threats by most planners, these two common gastrointestinal pathogens were nonetheless somewhat effective in the hands of criminals. Presumably, dozens of similar organisms and many toxins might be used in an analogous manner. Taking these factors into consideration, many intelligence and law enforcement professionals contend that the magnitude of the terrorist threat surpasses, in some ways, that of the military threat. Moreover, this threat remains nebulous and difficult to monitor. Finally, although response to the military use of such weapons might occupy defense planners, it is the civilian medical and public health community that must shoulder the responsibility of reacting to a terrorist release of a biological agent. Consequently, the remainder of this chapter focuses on this terrorist threat.

CURRENT STATE OF THE ART

The Terrorist Threat

Examples of the terrorist use of conventional weapons abound. Mumbai, Beirut, Oklahoma City, the Khobar Towers, the first World Trade Center attacks, and the bombing of American embassies in Nairobi and Dar es Salaam all highlight the conventional threat. The use of airplanes in the second attack on the World Trade Center and on the Pentagon on September 11, 2001 gives new meaning to unconventional weaponry without requiring access to nuclear or biological arms. The release of sarin in the Tokyo subway system by members of the Aum Shinrykyo cult is a reminder that terrorists have the ability to procure and deploy chemical weapons. By comparison, the intentional mailing of anthrax-laced letters in October 2001 in the U.S. sickened 22 and resulted in a relatively modest (by comparison) death toll of five people.[12] Why, then, might biological weapons interest terrorist factions? There are multiple characteristics that make biological weapons potentially attractive to such groups.

First, biological weapons are relatively easy to procure. *Clostridium botulinum* is ubiquitous in soil and easily cultured by anyone with modest training in microbiology. *Bacillus anthracis* is similarly readily cultivatable from soil in many parts of the world. Ricin extraction from castor beans, readily available throughout the world, is easily accomplished using recipes widely published on the Internet. Many putative biological weapons, such as *Coxiella burnetii*, the encephalitic alpha viruses, the *Brucellae*, *Francisella tularensis*, and even *Yersinia pestis* and *Bacillus anthracis*, continue to cause endemic disease in many parts of the world. Clinical laboratories in those locales handle cultures of such organisms and constitute a potential source for their acquisition. Culture repositories organized for legitimate scientific purposes may be accessed by those with sinister motives. Although the U.S. Department of Health and Human Services (HHS), Centers for Disease Control and Prevention (CDC) managed Select Agent Program seeks to limit access to particularly hazardous pathogens and toxins in the United States (regulated agents are listed in Table 29.3), hundreds of such repositories exist in dozens of foreign nations; many of these sell and ship these hazardous agents.[13,14] Devices able to disseminate biological agents are also widely available. Crop-dusting assemblies may be adapted by terrorists for sinister purposes and can, in some cases, generate aerosolized particles of 2–6 μm in diameter, the ideal size for impinging on the human lower respiratory tract.

Second, biological weapons are potentially inexpensive to produce. In 1969, a United Nations study considered the cost to a belligerent of producing mass casualties (defined as 50%) and found crude biological weapons to be far less costly than chemical, nuclear, or even conventional arms on a "casualties per square kilometer" basis.[15]

Third, unless the terrorists announced the release of a biological agent, detection of an attack would be challenging. Aerosolized biological agents would likely be odorless, colorless, tasteless, and otherwise invisible (in contrast to chemical agents, many of which have characteristic odors and generally cause immediate symptoms in all victims within a confined space). At the time of this writing, standoff detection systems (such as the Joint Biological Point Detection System) are under development, but are expensive, often cumbersome to use, and not yet readily available.[16] Although standoff detection systems are used during certain high-profile public events, their widespread real-time deployment remains limited. In fact, initial detection of a bioterrorist attack will probably not hinge on the finding of explosive devices, missiles, or even crop-dusting equipment. It would not be likely to involve environmental detection or meteorological perturbations. Rather, it more likely will involve the presentation (perhaps widely dispersed geographically) of patients with nonspecific symptoms, to various practitioners, clinics, and emergency departments. This is especially problematic to the clinician because treatment of diseases such as anthrax, plague, and botulism is most effective when begun as early as possible (when such nonspecific symptoms are likely to predominate), ideally during the incubation period. By the time hallmark findings (mediastinitis in the case of anthrax, hemoptysis in plague victims, and neuromuscular symptoms for botulism) appear, treatment is of dubious benefit and prognosis is often poor. Moreover, with easy access to jet travel, incubation periods ensure that perpetrators can safely depart for any foreign land before nonspecific effects are noticed. Additionally, contagious biological agents (e.g., smallpox and pneumonic plague) can continue to propagate among successive generations of victims prior to discovery and diagnosis.

Finally, victims of a biological attack, more so than conventional or chemical casualties, can potentially overwhelm medical response capabilities. Botulism provides an instructive example. In isolated cases with access to modern medical interventions (such as lengthy courses of mechanical ventilation and other intensive care modalities), it is a survivable disease; however, the sudden requirement to provide critical care and ventilation to hundreds or thousands of casualties in a given city would render a large botulism outbreak unmanageable.

With these considerations in mind, it is clear that the specter of biological terrorism warrants a level of planning and preparedness at least as great as that devoted to conventional and chemical terrorism. In fact, it is precisely a lack of preparedness that might amplify the allure of biological weapons in the minds of some terrorists. Capitalizing on this lack of preparedness, a terrorist need not even possess a weapon. The simple threat of release might be enough to influence policymaking and engender a massive commitment of resources. For example, many hundreds of anthrax threats have come to the attention of law enforcement agencies over the past decade. With the notable exception of the anthrax letter attacks of October 2001 in the United States, however, virtually all of these threats have proven to be unfounded.[17] Yet, even the most amateur hoax (or a concerned person calling about a benign substance) has often

Table 29.3: HHS and U.S. Department of Agriculture (USDA) Select Agents and Toxins (7 CFR Part 331, 9 CFR Part 121, and 42 CFR Part 73)

HHS SELECT AGENTS AND TOXINS

Alirin

Cercopithecine herpesvirus 1 (Herpes B virus)

Coccidioides posatfasii

Conotoxins

Crimean-Congo hemorrhagic fever virus

Diacetoxyscirpenol

Ebola virus

Lassa fever virus

Marburg virus

Monkeypox virus

Reconstructed replication-competent forms of the 1918 pandemic influenza virus containing any portion of the coding regions of all 8 gene segments (reconstructed 1918 influenza virus)

Ricin

Rickettsia prowazekii, Rickettsia rickettsii, Saxitoxin

Shigalike ribosome-inactivating proteins

South American Hemorrhagic Fever viruses

Flexall

Guanarito

Junin

Machupo

Sabia

Tetrodotoxin tick-borne encephalitis complex (flavi) viruses

Central European tick-borne encephalitis-Far Eastern tick-borne encephalitis

Kyasanur Forest disease

Omsk Hemorrhagic Fever

Russian Spring and Summer encephalitis

Variola major virus (Smallpox virus) and

Variola minor virus (Alastrim) *Yersinia pestis*

OVERLAP SELECT AGENTS AND TOXINS

Bacillus anthracis

Botulinum neurotoxins

Botulinum neurotoxin producing species of *Clostridium*

Brucella abortus

Brucella melitensis

Brucella suis

Burkholderia mallei (formerly *Pseudomonas mallei*)

Burkholderia pseudomallei (formerly *Pseudomonas pseudomallei*)

Clostridium perfringens epsilon toxin

Coccidioides iritis

Coxiella burnetii

Eastern Equine Encephalitis virus

Francisella tularensis

Hendra virus

Nipah virus

Rinn Valley fever virus

Shigatoxin

Staphylococcal enterotoxins

T-2 toxin

Venezuelan Equine Encephalitis virus

USDA SELECT AGENTS AND TOXINS

African horse sickness virus

African swine fever virus

Akabane virus

Avian influenza virus (highly pathogenic)

Bluetongue virus (exotic)

Bovine spongiform encephalopathy agent

Camel pox virus

Classic swine fever virus

Cowdria ruminantium (Heartwater)

Foot-and-mouth disease virus

Goat pox virus

Japanese encephalitis virus

Lumpy skin disease virus

Malignant catarrhal fever virus

(Alcelaphine rierpesvims type 1) Menangle virus *Mycoplasma capricola/* M.F38/M. *mycoides Capri* (contagious caprine pleuropneurnonia) *Mycoplasma inycoides mycoides*

(Contagious bovine pleuropneumonia) Newcastle disease virus (velogenic) Peste des petits ruminants virus, Rinderpest virus, Sheep pox virus, Swine vesicular disease virus, Vesicular stomatitis virus (exotic)

USDA PLANT PROTECTION AND QUARANTINE (PPC) SELECT AGENTS AND TOXINS

Candidatus Liberobacter africanus

Candidatus Liberobacter asiaticus

Perorws *clerospora phi/ippinensis*

Ralstonia solanacearum race 3. biovar 2

Ciliophora rayssiae var zeae

Synclinorium endobioticum

Xanthomonas oryzae pv. *oryzicola*

Xylella fastidiosa (citrus variegated chlorosis strain)

resulted in a response that forced the expenditure of hundreds or thousands of dollars.

For bioterrorism defense planning and preparedness purposes, it is necessary to be familiar with the specific agents that might be used by terrorists. The agents developed and studied by the Cold War Superpowers (catalogued in Tables 29.1 and 29.2) provide a starting point for consideration. An examination of a terrorist's potential motives permits further refinement of these lists. A study conducted by the World Health Organization (WHO) showed that anthrax was somewhat unique in its ability to produce widespread mortality.[18] Table 29.4 compares the morbidity and mortality figures derived from this study, which considered the release of 50 kg of agent along a 2-km line upwind of a city of 500,000 inhabitants. For a terrorist group interested

Table 29.4: Results of the Hypothetical Aerosol Dissemination of Various Infectious Agents

Agent	*Downwind Carriage*	*Deaths*	*Total Casualties*
Venezuelan Equine Encephalitis	1 km	400	35,000
Tick-borne Encephalitis	1 km	9,500	35,000
Epidemic Typhus	5 km	19,000	85,000
Brucellosis	10 km	500	100,000
Plague	10 km	55,000	100,000
Q-Fever	>20 km	150	125,000
Tularemia	>20 km	30,000	125,000
Anthrax	>>20 km	95,000	125,000

Casualty figures assume 50 kg of dried agent, disseminated along a 2-km line upwind of a population center of 500,000. Adapted from reference 18 with permission.

in producing widespread lethality, anthrax would seem an ideal choice (assuming it could be procured, weaponized, and delivered optimally). Weaponization refers to the process of modifying a biological agent in the laboratory to optimize its dispersal in the environment or its pathogenicity for use as a weapon. Smallpox, a disease not considered in the WHO study, might be expected to pose problems of a similar or greater magnitude. Smallpox and pneumonic plague, and to a lesser degree certain viral hemorrhagic fevers, are noteworthy in that they, in contrast to other agents mentioned in this chapter, are contagious. Terrorists might thus leverage the results of an attack by weaponizing smallpox or plague, infecting a modest number of persons in a first wave, and depend on contagion to assist the agent in propagating through a population, thereby overcoming some of the technical challenges of widespread aerosol delivery.

Although certain assumptions and generalizations can be made in attempting to define and combat the terrorist threat, it is clear that the motives and rationale of terrorists cannot always be elucidated. *Shigellae*, Giardia, and even roundworms have been used as weapons by terrorists, criminals, or other disgruntled persons.[19] Envisioning and preparing for each of these scenarios in advance of their occurrence would have been impossible. Given this factor and the constraint of limited resources, it is not useful to consider those agents most likely to be used (because this cannot be ascertained), but rather those that, *if used*, would produce the most devastating consequences and require the most critical medical responses. In June of 1999, U.S. public health experts met at CDC headquarters and used this rationale to develop a list of "critical biological agents for health preparedness" (Table 29.5).[17,20] Agents in "category A" are those that, if released effectively, would be expected to have a high overall public health impact. Consequently, significant medical intervention would be required and intensive public health preparedness is ongoing. Preparedness measures include medication and supply stockpiling and improvements to surveillance and response capabilities of local, state, and federal health authorities. Category B agents present a somewhat lesser requirement for preparedness, whereas category C agents require vigilance to guard against their future development as threat agents, but can otherwise likely be adequately managed within the framework of the existing public health infrastructure.

CATEGORY A AGENTS

Anthrax

The causative agent of anthrax, *Bacillus anthracis,* is a Gram-positive, sporulating rod-shaped bacterium. Anthrax is primarily an endemic and epidemic disease of livestock. Ungulates such as sheep, goats, and cattle are exposed while grazing through the ingestion of soil-borne spores. These spores germinate within the animal, multiplying rapidly in the bloodstream and leading to death within days. At the time of death, the animal's blood may contain as many as 10^8 bacteria per cubic centimeter; these bacteria, once exposed to oxygen as the animal decomposes, sporulate, enter the soil, and thus continue the cycle.

Table 29.5: Critical Agents for Public Health Preparedness

Category A	*Category B*	*Category C*
Variola virus	*Coxiella burnetii*	Emerging threat agents (e.g., Nipah virus, hantaviruses, pandemic influenza viruses)
Bacillus anthracis	*Brucellae*	
Yersinia pestis	*Burkholderia mallei*	
Botulinum toxin	*Burkholderia pseudomallei*	
Francisella tularensis	Alphaviruses	
Filoviruses and arenaviruses	*Rickettsia prowazekii*	
	Certain toxins (e.g., Ricin, SEB)	
	Chlamydia psittaci	
	Food safety threat agents (e.g., *Salmonellae, E. coli* O157:H7)	
	Water safety threat agents (e.g., *Vibrio cholera*)	

Category A agents have high public health impact requiring intensive public health preparedness and intervention; Category B agents have a somewhat lesser need for public health preparedness. Category C agents are emerging infections that may pose a threat in the future.

Figure 29.1. Cutaneous anthrax. Note the painless black eschar and moderate surrounding erythema. Photograph: Courtesy of the Centers for Disease Control and Prevention, Atlanta, Georgia. www.bt.cdc.gov/agent/anthrax/anthrax-images/cutaneous.asp. See color plate.

B. anthracis has several characteristics that make it a useful biological weapon: 1) it is easy to obtain – the organism can be found virtually anywhere in the world where livestock are kept but are not routinely immunized against anthrax; 2) it grows readily in easily prepared media; 3) it can be easily be induced to form spores, which are not only highly infective via the aerosol route, but can also be stored for an extended time with minimal degradation; and 4) spore size and durability facilitate highly efficient aerosol delivery as a biological weapon.

Human anthrax takes three primary forms – cutaneous, gastrointestinal, and inhalational. Cutaneous anthrax is the most common naturally occurring form of human disease. Approximately 7 days (range 1–12 d) following exposure to infected hides or meat, a painless or mildly pruritic papule forms at the site of exposure. The lesion rapidly enlarges and ulcerates, often developing vesicles or bullae at the margins, and is often accompanied by significant surrounding edema and regional lymphadenopathy. As the ulcer dries, it forms a coal-black scab (hence the name, "anthrax," from the Greek *anthracis* meaning coal), which resolves over 1–2 weeks (Figure 29.1). Up to 20% of untreated cutaneous anthrax cases progress to systemic disease and are fatal. Of note, 11 of the 22 suspected or documented cases of anthrax from the 2001 "Amerithrax" mailings were cutaneous in nature.[12]

Oropharyngeal anthrax is a variation of cutaneous anthrax in which ingestion of contaminated meat leads to an oropharyngeal lesion and associated neck edema and adenopathy; the mortality rate in oropharyngeal anthrax can be much higher than that for cutaneous anthrax, likely due to the increased incidence of systemic spread as well as airway compromise resulting from oropharyngeal edema.[21]

Gastrointestinal anthrax results from consumption of the insufficiently cooked meat of infected animals. One to 6 days following ingestion, fever, nausea, vomiting, and focal abdominal pain develop. Victims then typically develop massive gastrointestinal bleeding and sepsis, with a fatal outcome occurring in more than 50% of cases.

Historically, inhalational anthrax has been an extraordinarily rare disease found only in wool or hide mill workers after exposure to high concentrations of anthrax spores that are aerosolized by manipulation of contaminated animal products. Disease is the result of inhalation of these aerosolized spores, which are then ingested by alveolar macrophages and carried to mediastinal lymph nodes, where they multiply and release toxins. Typically 1–6 days after exposure (but perhaps up to several months later) disease onset is heralded by a nonspecific febrile illness, often accompanied by malaise, fatigue, and drenching sweats. Pneumonia is rare, and an auscultatory examination of the lungs is often normal at this phase of the illness, although radiological studies may demonstrate pleural effusions and the classic widened mediastinum of hemorrhagic mediastinitis (Figure 29.2). Upper respiratory symptoms such as rhinorrhea or nasal congestion are rare in inhalational anthrax. Cough, if present, is nonproductive. If untreated, disease that has progressed this far will typically, within 2–5 days, lead to severe respiratory distress, shock, and death. Historically, mortality for inhalational anthrax was greater than 85%, although only five of the 11 victims (45%) of inhalational anthrax succumbed in the Amerithrax mailings of 2001. This improvement in outcome likely reflects the aggressive modern-day management of these patients. Patients with all forms of anthrax disease should be managed using standard infection control precautions. Person-to-person spread of anthrax is extremely rare, even in inhalational cases. Invasive procedures that can generate infectious aerosols should, however be avoided in patients who may be bacteremic. In addition it is at least theoretically possible for person-to-person transmission of cutaneous anthrax via nonintact skin; therefore, standard precautions should always be followed in individuals with open skin or mucosal lesions.

Effective diagnosis of anthrax relies on a strong clinical suspicion to drive appropriate confirmatory laboratory studies. For systemic febrile disease resulting from any form of anthrax, blood cultures may be diagnostic if performed prior to receipt of antibiotics. For mild cutaneous disease, culture of the lesion (ideally vesicle fluid) may be positive; Gram stain of vesicle fluid may show large, Gram-positive bacilli, and immunohistochemical stains can identify anthrax in culture-negative lesions. In patients with gastrointestinal anthrax, stool cultures can sometimes be positive, and hemorrhagic peritoneal fluid can also be cultured or immunostained for *B. anthracis.* A widened mediastinum with or without pleural effusions on chest x-ray or computed tomography suggests inhalational anthrax. Gram stain of pleural fluid or cerebrospinal fluid (in the presence of meningitis, seen in up to 50% of cases and hemorrhagic in character) can be positive, and specific immunostaining or polymerase chain reaction (PCR) of these fluids can be diagnostic.[21] The first patient diagnosed during the 2001 U.S. attacks presented with fever, confusion, and respiratory distress with hemorrhagic meningitis secondary to *B. anthracis* (Figure 29.3).

Uncomplicated cutaneous anthrax known to have been contracted via infected animal contact can be treated with a number of oral antibiotics. Because naturally occurring strains of *B. anthracis* are nearly always susceptible to penicillin, 500 mg orally every 6 hours (40–80 mg/kg/d every 6 h in children) or amoxicillin 500 mg orally every 8 hours (40–80 mg/kg/d every 8 h in children) would be effective. Ciprofloxacin 500 mg twice per day (20–30 mg/kg divided twice per day for children) or doxycycline 100 mg twice per day (5 mg/kg divided twice per day for children) would be acceptable alternatives.[22]

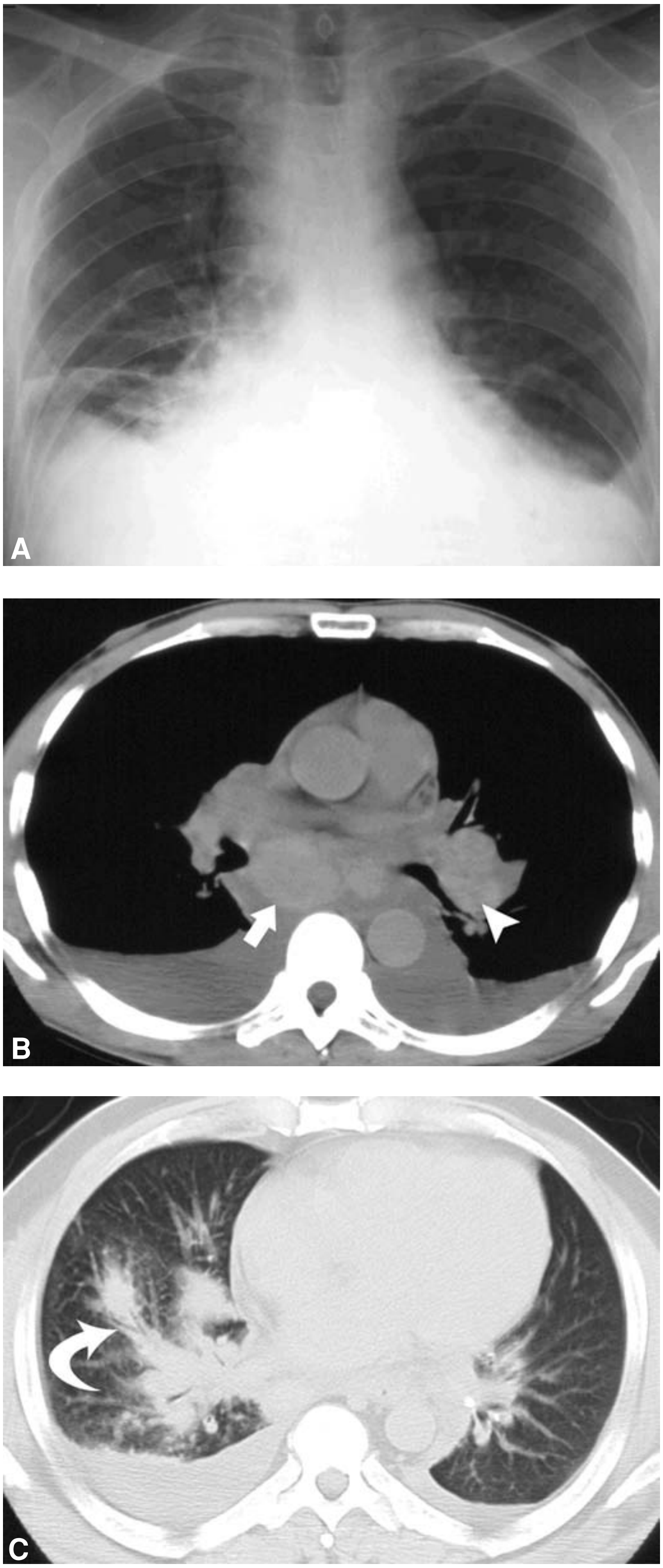

Figure 29.2. (**A**) Chest x-ray demonstrates mediastinal and hilar widening, and bilateral pleural effusions. (**B**) Chest computed tomography scan demonstrates enlarged, hyperdense subcarinal (arrow) and left hilar (arrowhead) lymph nodes probably secondary to intranodal hemorrhage. (**C**) Note the peribronchial consolidation which reflects lymphatic spread of anthrax infection. Radiologic Images: Courtesy of JR Galvin, MD and AA Frazier, MD, Department of Radiologic Pathology, Armed Forces Institute of Pathology, Washington, DC.

Figure 29.3. Meningitis with subarachnoid hemorrhage in a man from Thailand who died 5 days after eating undercooked carabao (water buffalo). Reproduced from: Binford CH, Connor DH, eds. *Pathology of Tropical and Extraordinary Diseases.* Vol 1. Washington, DC: Armed Forces Institute of Pathology; 1976: 121. AFIP Negative 75-12374-3. See color plate.

Although fluoroquinolone and tetracycline antibiotics are generally not recommended for use in children and pregnant women, a consensus group, as well as the American Academy of Pediatrics, has suggested that ciprofloxacin or doxycycline should nonetheless be used as first-line therapy in life-threatening anthrax disease or in disease suspected to be of sinister origin (because penicillin-resistant strains can readily be selected for in the laboratory) until strain susceptibilities are known. The U.S. Food and Drug Administration (FDA) has approved ciprofloxacin for prophylaxis and treatment of anthrax in children, and as the first choice for antibiotics in pregnant women.[23] If the infecting strain later proves to be penicillin susceptible, a switch to oral penicillin VK or amoxicillin can be made in cases of mild cutaneous anthrax.

In the event that the exposure route is unknown or that exposure is potentially related to a biological terrorism event in which anthrax may have been aerosolized, antibiotics should be continued for at least 60 days (as postexposure prophylaxis). Moreover, for all forms of symptomatic anthrax aside from mild cutaneous disease (to include inhalational, gastrointestinal, oropharyngeal, and severe cutaneous forms), combination intravenous antibiotics are strongly advised. Initial empirical therapy should include ciprofloxacin or doxycycline plus one or two additional antibiotics effective against anthrax. Some additional antibiotics to which naturally occurring strains of *B. anthracis* are susceptible include imipenem, meropenem, daptomycin, quinupristin-dalfopristin, linezolid, vancomycin, rifampin, the macrolides, clindamycin, chloramphenicol, and the aminoglycosides. It is at least theoretically possible to induce antimicrobial resistance to any of these antibiotics; however, there are no reports of this in the literature. A switch from intravenous to oral therapy may be made as the patient's clinical course dictates, although in most situations, the optimal duration of therapy and antibiotic combination is not known. At the time of this writing, human anthrax immune globulin, collected from recipients of Anthrax Vaccine Adsorbed (AVA), is in clinical trials and may be available as adjunctive therapy under an investigational new drug (IND) application from the FDA.

AVA (BioThrax™, Bioport, Lansing, MI) is licensed for the prevention of anthrax and has been administered to certain U.S. laboratory workers, selected first responders, and military service members. AVA is a protein vaccine produced from the supernatant of a culture of an attenuated strain of *B. anthracis*. It is administered subcutaneously in an initially six-dose series over 18 months (0, 2, and 4 weeks and then 6, 12, and 18 months) followed by annual boosters. Although AVA is licensed only for preexposure prophylaxis of anthrax in adults aged 18–65 years, it is available under IND protocol for preexposure use in children, and postexposure prophylaxis in adults and children, although its role in such postexposure prophylaxis has not yet been determined.[24] Patients who have had hypersensitivity reactions to previous doses should not receive AVA, and the vaccine should be deferred in those who are: pregnant, currently suffering from a febrile infectious disease, or taking immunosuppressant drugs such as corticosteroids. The U.S. FDA has determined that the AVA is both "safe and effective" in preventing all forms of anthrax disease.[25]

Following an aerosolized attack with *B. anthracis*, exposed persons should receive antibiotic prophylaxis to prevent development of disease. Even previously immunized victims should immediately receive oral ciprofloxacin, levofloxacin, or doxycycline, all of which have been licensed for this application. Should the offending strain later be determined to be penicillin sensitive, penicillin VK or amoxicillin can be substituted in those who cannot tolerate first-line antibiotics. Antibiotics should be continued for at least 60 days because spores can remain dormant within a victim's lungs for extended periods only to germinate later, after the victim may have completed weeks of prophylaxis. Some patients may be noncompliant due to side effects such as diarrhea. Because of this potential spore dormancy, the U.S. Department of Defense (DoD) recommends that, following exposure, previously unimmunized persons receive at least three doses of AVA (under IND, as this is not an FDA-approved use) over 4 weeks prior to discontinuing prophylactic antibiotics. After completing antibiotics, patients should receive close follow-up for return of fever or other signs and symptoms of anthrax infection.[26] A July 2009 New England Journal of Medicine study reported that raxibacumab, a human monoclonal antibody, is effective in the treatment and prevention of inhalational anthrax in two animal models, however it is not yet clear whether this newer modality can be routinely recommended.[27]

Smallpox

Smallpox is a disease limited to humans and caused by the Orthopox virus *Variola major*. *Variola minor* causes a milder form of the disease termed alastrim. Historically, smallpox was a significant cause of human suffering and death worldwide, responsible for as many as 50 million cases per year in the middle of the last century. The World Health Organization declared smallpox to be eradicated in 1980 after a monumental worldwide vaccination campaign. Significant concern remains that existing laboratory-based variola virus isolates could be reintroduced as a weapon into an increasingly susceptible population. Variola is easily grown in cell culture or chicken eggs and is readily dried into a stabile form, which can survive prolonged storage and is suitable for aerosolization. Smallpox is a contagious disease and can spread through a susceptible population, with secondary attack rates as high as 50% in nonimmune household contacts.[28]

People typically acquired smallpox via mucous membrane contact with infectious respiratory droplets from an infected, coughing person. Less commonly, disease was transmitted via direct contact with lesions or secretions, fomites, or via infectious aerosols. Approximately 12 days (range 7–19 d) after inoculation, the patient experienced the sudden onset of high fever (38.8°C–40.0°C), malaise, headache, and shaking chills. The patient would often be bedridden with severe backache, abdominal pain, and vomiting. Two to 3 days after the onset of symptoms the patient would experience a mild improvement in symptoms, with decreased fever, and the onset of an enanthem in the form of small, painful ulcerations of the tongue and oropharynx. Oral secretions at this phase of illness are teeming with variola virus, and the patient is a significant infection risk. Within a day of enanthem onset, 2–3 mm erythematous macules appear on the face and distal extremities (Figure 29.4). The macules progress to papules, and then to clear vesicles over the next 3–5 days, and finally to tense, painful, centrally umbilicated pustules shortly thereafter – often accompanied by a second fever spike. As the lesions evolve, they spread centrally, although they typically remain more pronounced and abundant on the face and distal extremities. Death, if it occurs, typically does so within this second week of infection. Among survivors, pustules further progress to scabs, which separate to leave depressed, hypopigmented, permanent scars that are often quite disfiguring.[29] Scabs contain viable virus; the patient is thus considered contagious and requires appropriate isolation until scabs are entirely shed.

The severity of smallpox disease in the past was quite variable, with several forms of disease described. Severity and ultimate mortality were directly related to the number and concentration of skin lesions; confluent lesions portended a particularly bad outcome. Disease was generally more severe in women (especially if pregnant), children, the elderly, certain ethnic groups (e.g., Native Americans and Pacific Islanders), and immunocompromised individuals. Partially immune individuals (i.e., vaccinated) tended to have mild disease, with few lesions and lower mortality – a syndrome that closely resembled that seen in variola minor. Flat-type smallpox (Figure 29.5) probably represented an extreme form of confluent smallpox in which the skin took on a uniform "crepe rubber" appearance instead of forming classic lesions. This was most commonly seen in children. Hemorrhagic smallpox (Figure 29.6) was a rare form of fulminant disease with associated bleeding diatheses seen predominantly during pregnancy and in immunocompromised individuals. Mortality from classic smallpox varied from 10% to 30% in nonimmune individuals, to approximately 3% in the immunized. Among pregnant women the mortality rate was up to 65%, and flat and hemorrhagic forms of disease were fatal in 95% of cases. Long-term complications of smallpox included blindness from corneal scarring (1%–4% of cases),[30] growth abnormalities in children secondary to variola osteomyelitis (2%–5% of child cases),[31] and disfiguring or even physically debilitating dermal scarring from the pox lesions themselves.

With an increasing immunologically naive population (e.g., routine immunization of U.S. civilians ceased in 1972) and the ease of global travel, there is concern that smallpox would spread faster than it has historically. The degree of person-to-person spread of smallpox in the past varied according to many factors. Such spread was associated with exposure to cases with confluent rash or severe enanthem and to cases with severe bronchiolitis and cough. Typically, close person-to-person contact was required for reliable transmission; however, variola's spread

Figure 29.4. Series of photographs illustrating the evolution of skin lesions in an unvaccinated infant with the classic form of *Variola major*. (**A1, A2**) The third day of rash shows synchronous eruption of skin lesions; some are becoming vesiculated. (**B1, B2**) On the fifth day of rash, almost all papules are vesicular or pustular. (**C1, C2**) On the seventh day of rash, many lesions demonstrate central umbilication, and all lesions are in the same general stage of development. Reproduced with permission from reference 27. See color plate.

via aerosol is well documented in hospital outbreaks.[32] Variola could also spread by contact with contaminated bedding, especially in the hospital setting, although such factors typically played a small role in overall transmission through a population. In past outbreaks, environmental conditions are thought to have factored prominently in disease propagation. Smallpox spread more quickly in conditions of low humidity, and during winter or rainy seasons, when people would crowd together in their homes. The disease tended to spread slowly through partially immune communities, but could become endemic in densely populated regions, even in a population with up to 80% vaccination rates.[28]

Historically, the diagnosis of smallpox was largely based on the characteristic clinical findings, particularly the rash. In some cases, such clinical diagnosis could be problematic. Prodromal smallpox is difficult to differentiate from other febrile syndromes. The early rash of smallpox has been commonly mistaken for varicella and other viral exanthems (e.g., adenovirus), as well as conditions such as erythema multiforme that can cause febrile illness with rash. Flat-type and hemorrhagic smallpox may be difficult to differentiate clinically from other fulminant infectious syndromes presenting with shock and disseminated intravascular coagulation.

Monkeypox, although not classified as a category A threat by the U.S. CDC, is another Orthopox virus closely related to smallpox that occurs naturally in equatorial Africa and presents with a very similar rash. Descriptions of human monkeypox outbreaks

Figure 29.5. Flat-type smallpox in an unvaccinated woman on the sixth day of rash. Extensive flat lesions (**A** and **B**) and systemic toxicity with a fatal outcome were typical. Reproduced with permission from reference 27. See color plate.

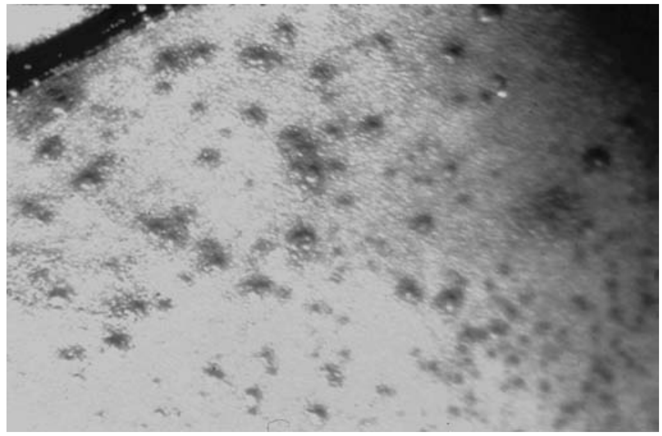

Figure 29.6. Early hemorrhagic-type smallpox with cutaneous signs of hemorrhagic diathesis. Death usually intervened before the complete evolution of pox lesions. Reproduced with permission from Herrlich A, Munz E, Rodenwaldt E. *Die pocken; Erreger, Epidemiologie und klinisches Bild.* 2nd ed. Stuttgart, Germany: Thieme; 1967. See color plate.

in sub-Saharan Africa reveal a disease that could be clinically indistinguishable from smallpox with the exception of a generally lower case fatality rate (11% in nonimmunized people) and notable enlargement of cervical and inguinal lymph nodes manifesting 1–2 days before the rash in 90% of cases.[33] An outbreak involving 81 human cases of monkeypox occurred in 2003 in the United States due to exposure to exotic pets (such as Gambian rats) imported from West Africa. These cases demonstrated only localized lesions and mild disease, with no deaths or secondary transmission occurring among humans.[34]

Early, specific diagnosis is paramount to ensuring appropriate patient isolation and preventing the spread of smallpox. Definitive diagnosis historically required isolation of the virus and characterization of its growth on chicken egg chorioallantoic membrane or in cell culture. More recently, the U.S. CDC, via its Laboratory Response Network, has published guidelines for laboratory diagnosis of acute, generalized vesicular or pustular rash illnesses. These guidelines rely heavily on nonspecific Orthopoxvirus PCR testing, as well as specific variola PCR to identify probable cases, with confirmatory testing then performed at national level laboratories under Biosafety Level 4 (BSL-4) conditions. Acceptable specimens for this protocol include: vesicular “touch-prep,” vesicle roof, vesicular swab or impression slide, and biopsy specimens. Other specimens that could be useful in the prevesicular rash phase of illness include serum or pharyngeal swabs. Providers who collect or process specimens should only do so under the direction of public health officials, should be vaccinated against smallpox, and should exercise both contact and airborne precautions.[35]

There are no proven specific therapies for symptomatic smallpox. Parenteral cidofovir is an antiviral drug (licensed for use in cytomegalovirus retinopathy) that shows in vitro activity against a broad range of poxviruses and potential in vivo benefit in animal studies of poxvirus infections. Additional studies are under way to determine whether parenteral or oral cidofovir analogues, as well as other drugs such as ST-246, might be efficacious in the treatment of human Orthopoxvirus infections.[36] Ocular smallpox may benefit from application of topical antivirals such as trifluridine or idoxuridine. Aggressive supportive care is the cornerstone of successful management of smallpox disease, however, and should include maintenance of hydration and nutrition, pain control, and prevention and management of secondary infections.

Infection control within healthcare facilities could represent a significant challenge; smallpox patients should be isolated under contact and airborne precautions. Caregivers should be immunized and wear appropriate personal protective equipment regardless of their immunization status. Patients should be considered infectious until all scabs separate. Across the United States and elsewhere, communities are currently struggling with development of smallpox and other contagious infectious disease response plans. The CDC maintains planning guidance for states and communities on their bioterrorism website (http://emergency.cdc.gov/agent/smallpox/prep). Victims of an attack using weaponized smallpox, as well as contacts of known smallpox cases, should be immunized and monitored for at least 17 days following the last known exposure regardless of their vaccination status; at the onset of fever they should be immediately isolated using droplet and airborne precautions. Isolation should continue until smallpox is either ruled out or confirmed, and, if confirmed, until all scabs separate.

Two vaccines against smallpox are licensed in the United States: Dryvax™ (Wyeth),[37] a live, dried, calf-lymph-derived, lyophilized vaccinia virus product last manufactured in 1982, and ACAM-2000™ (Acambis), a cell culture–derived preparation derived from the same vaccinia virus strain and licensed in 2007. It is administered via intradermal inoculation using a bifurcated needle – a process known as scarification. The typical reaction to the vaccine includes appearance of a pruritic vesicle at the inoculation site 5–7 days following administration. Local erythema, induration, local pain, fatigue, axillary lymphadenopathy, and mild systemic symptoms including fever, malaise, headache, and myalgias are common. Over the ensuing several days the vesicle progresses to form a pustule, then a 3–10 mm scab that sloughs within 1–2 weeks, leaving a permanent scar. The lesion contains live vaccinia virus and spread of infection via contact is possible until the scab has separated.

Historically, serious adverse reactions have occurred in approximately 1 per 1,000 patients immunized, with 1–5 in 10,000 immunizations leading to life-threatening complications, and 1 in 1 million leading to death. Serious reactions are approximately 10 times more common in those being immunized for the first time than in those undergoing reimmunization. Inadvertent autoinoculation of the virus to distant skin sites, as well as transfer of virus to contacts, has occurred historically in approximately 6 per 10,000 vaccinees; ocular vaccinia is the most common form of inadvertent inoculation and can result in permanent corneal scarring. Generalized vaccinia results from systemic spread of the virus producing lesions removed from the primary vaccination site and occurs in 3 per 10,000 vaccinees. Postvaccinial encephalitis is seen in approximately 1 per 100,000 primary vaccinees and has a 25% mortality rate, with another 25% developing permanent neurological sequelae. Fetal vaccinia is a rare (<50 reported cases) but often fatal complication of maternal vaccination, most commonly reported in the third trimester of pregnancy. Approximately 1 in 10,000 primary vaccinees during modern time U.S. DoD and civilian vaccination efforts experienced acute myopericarditis – a rarely reported adverse event in previous U.S. immunizations campaigns. Eczema vaccinatum (generalized cutaneous spread of vaccinia in patients with eczema), a potentially lethal complication, can occur when patients with a history of eczema (a contraindication to vaccination) are inadvertently vaccinated. Progressive vaccinia is the systemic spread of vaccinia virus in immunocompromised individuals; this is seen in 1 in 1 million primary vaccinees and is almost uniformly fatal.[38–40]

The U.S. CDC's Advisory Committee on Immunization Practices recommends that laboratory workers who directly handle live, unattenuated Orthopoxvirus cultures or infected animals, as well as select healthcare workers who are members of smallpox response teams, receive the vaccine. The U.S. DoD has elected to immunize many healthcare workers, as well as personnel deploying to areas of the world perceived to be at increased risk from smallpox if it were used as a biological weapon.[41] Vaccination with a verified clinical "take" (vesicle with scar formation) within the past 3 years is considered to render a person immune to natural variola.

Preexposure vaccination is contraindicated in persons with the following conditions: immunosuppression (including those taking immunosuppressing drugs such as corticosteroids or alkylating agents), human immunodeficiency virus infection, clinical evidence or a history of eczema or other chronic exfoliative skin disorders, pregnancy or breastfeeding, and age younger than 1 year. Additionally, the presence of household, sexual, or other close physical contacts with the aforementioned conditions would constitute a contraindication to vaccination of a potential recipient. There are no absolute contraindications to vaccination after bona-fide exposure to variola. Vaccination after exposure to weaponized smallpox or a case of smallpox may prevent or ameliorate disease if given promptly. Vaccination is likely to be most effective if given within 24 hours, but may still be somewhat effective up to 7 days after exposure. Newer smallpox vaccine candidates (grown using modern cell culture technology) are being studied with the goal of replacing aging stocks of calf-lymph-derived vaccine.[42] Attenuated live vaccines such as "Modified Vaccinia Ankara," as well as killed virus and protein component vaccines are being explored to develop safer vaccines with fewer side effects and contraindications.[43]

A formulation of intravenous Vaccinia Immune Globulin (VIG) has been licensed for treatment of vaccinia adverse reactions and is available through the Centers for Disease Control. VIG is indicated for treating certain complications due to vaccinia vaccine, including generalized vaccinia with systemic illness, ocular vaccinia without keratitis, eczema vaccinatum, and progressive vaccinia. The dose for prophylaxis or treatment is 100 mg/kg (for the intravenous formulation). Additionally, cidofovir and ST-246 may be beneficial in treating vaccinia adverse events, although the efficacy of both drugs requires further study and both should be administered under the auspices of a compassionate use protocol. Limited data suggest that VIG may also be of value in the postexposure prophylaxis against smallpox when given within the first week after exposure, and concurrently with vaccination. Concomitant administration of VIG may be particularly useful for pregnant and eczematous persons in such circumstances.[44,45]

Questions often arise as to the duration of effective immunity postvaccination. There is no definitive answer to this question; however, there is evidence that some protective immunity remains many years after vaccination particularly if one has received more than one dose during a lifetime.

Plague

Yersinia pestis, the causative agent of plague, is a rod-shaped, nonmotile, nonsporulating, Gram-negative bacterium of the family *Enterobacteriaceae*. Plague is principally a zoonotic disease of rodents. Fleas that live on the rodents can transmit the bacteria to humans via biting. These exposed persons may then contract the bubonic form of plague within the lymphatic distribution after the fleabite. The bubonic form may progress to the septicemic or pneumonic forms, discussed in detail later. Pneumonic plague would likely be the predominant form encountered following the purposeful aerosol dissemination of a weaponized form of *Yersinia pestis*. All human populations are thought to be susceptible to plague, and recovery from the disease is followed by only temporary immunity. *Y. pestis* can remain viable in water, moist soil, and grain for several weeks. It can also remain viable for some time in dry sputum, flea feces, and cadavers, but is killed within several hours on exposure to sunlight.

The United States examined *Y. pestis* as a potential biological warfare agent in the 1950s and 1960s before the offensive biowarfare program was terminated; other countries are suspected of weaponizing this organism as well. The former Soviet Union had more than 10 institutes and thousands of scientists who worked with *Y. pestis*. During WW II, Unit 731, a battalion of the Japanese Army, reportedly released *Y. pestis* infected fleas from aircraft over Chinese cities, but this method of dissemination proved cumbersome and unpredictable. The United States and Soviet Union developed a more reliable and effective method of aerosolizing the organism.[5] Interest in the terrorist potential of plague was brought to light in 1995 when Larry Wayne Harris

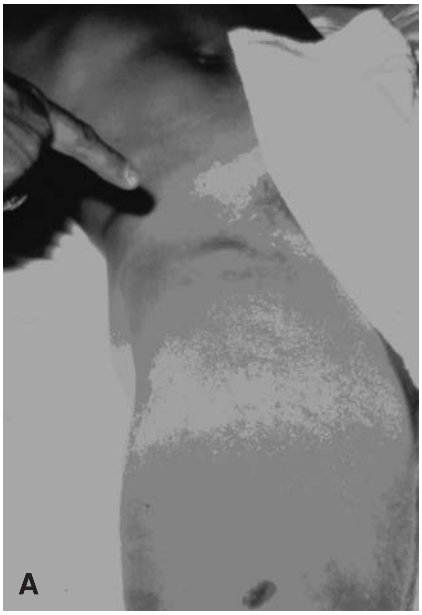

Figure 29.7. A femoral bubo (**A**) is the most common site of an erythematous, tender, swollen, lymph node in patients with plague. The next most common lymph node regions involved are the inguinal, axillary (**B**), and cervical areas. Bubo location is a function of the region of the body in which an infected flea inoculates the plague bacilli. Photographs: Courtesy of Kenneth L Gage, PhD, Centers for Disease Control and Prevention Laboratory, Fort Collins, Colorado. See color plate.

was arrested in Ohio for the illicit procurement of a *Y. pestis* culture through the mail.[19]

The contagious nature of pneumonic plague makes it particularly dangerous as a biological weapon. Plague may present as three distinct clinical syndromes in humans: bubonic, septicemic, and pneumonic plague. The bubonic form begins after an incubation period of 2–10 days, with acute and fulminant onset of nonspecific symptoms, including high fever, malaise, headache, myalgias, and sometimes nausea and vomiting. Up to 50% of patients have abdominal pain. Simultaneous with or shortly after the onset of these nonspecific symptoms, the bubo develops – a swollen, very painful, infected lymph node (Figures 29.7a and 29.7b). Buboes are normally seen in the groin region (femoral or inguinal lymph nodes) because the legs are the most commonly flea-bitten part of the adult human body. The liver and spleen of bubonic plague victims are often tender and palpable. One quarter of patients will have a pustule, vesicle, eschar, or papule (containing leukocytes and bacteria) in the lymphatic drainage of the bubo, and presumably representing the site of the inoculating fleabite. Secondary septicemia is common, and greater than 80% of blood cultures are positive for the organism in patients with bubonic plague; however, only approximately 25% of bubonic plague patients progress to clinical septicemia.[46]

Among those who do progress to secondary septicemia, as well as those presenting septicemic but without lymphadenopathy (primary septicemia), symptoms are similar to those seen in other Gram-negative septicemias: high fever, chills, malaise, hypotension, nausea, vomiting, and diarrhea. Plague septicemia, somewhat distinct from that caused by other bacteria, is also characterized by thromboses in the acral vessels, with necrosis, gangrene, and disseminated intravascular coagulation (DIC). Black necrotic appendages and more proximal purpuric lesions caused by endotoxemia are often present, and organisms in the bloodstream can gain access to the central nervous system, lungs, and elsewhere (Figures 29.8a and 29.8b). Plague meningitis occurs in approximately 6% of septicemic and pneumonic cases.

Pneumonic plague is an infection of the lungs due to either inhalation of organisms (primary pneumonic plague) or spread to the lungs from septicemia (secondary pneumonic plague). After an incubation period varying from 1 to 6 days for primary pneumonic plague (usually 2–4 days, and presumably dose dependent), onset is acute and often fulminant. The first signs of illness include high fever, chills, headache, malaise, and myalgias, followed within 24 hours by a cough with bloody sputum. Although bloody sputum is characteristic, it can sometimes be watery or, less commonly, purulent. Gastrointestinal symptoms, including nausea, vomiting, diarrhea, and abdominal pain, may be present. Rarely, a cervical bubo results from an inhalational exposure. Radiographic findings are variable but chest x-ray most commonly shows bilateral infiltrates, which may be patchy or consolidated. Plague pneumonia progresses rapidly, resulting in dyspnea, stridor, and cyanosis. The disease terminates with respiratory failure, and circulatory collapse. In humans, the mortality rate of untreated bubonic plague is approximately 60% (reduced to $<5\%$ with the prompt administration of effective therapies), whereas in untreated pneumonic plague the mortality rate is nearly 100%, and survival is unlikely if treatment is delayed beyond 18–24 hours of the onset of symptoms.[46]

Nonspecific laboratory findings seen in patients with plague include leukocytosis, with a predominance of polymorphonuclear cells. One also often finds increased fibrin split products in the blood indicative of a low-grade DIC. The serum blood urea nitrogen, creatinine, alanine aminotransferase, aspartate aminotransferase, and bilirubin may also be elevated, consistent with multiorgan failure.[47] Nonetheless, a prompt diagnosis must often be based primarily on clinical suspicion. The presentation of large numbers of previously healthy patients with sudden, severe, rapidly progressive pneumonia with hemoptysis strongly suggests plague. A presumptive diagnosis can be made microscopically by identification of the coccobacillus in Gram, Wright, Giemsa, or Wayson's stained smears from lymph node needle aspirate, sputum, blood, or cerebrospinal fluid samples. When available, immunofluorescence staining can be very useful. Definitive diagnosis relies on culturing the organism from blood, sputum, cerebrospinal fluid, or bubo aspirates. The organism grows slowly at normal incubation temperatures and may be misidentified by automated systems because of delayed

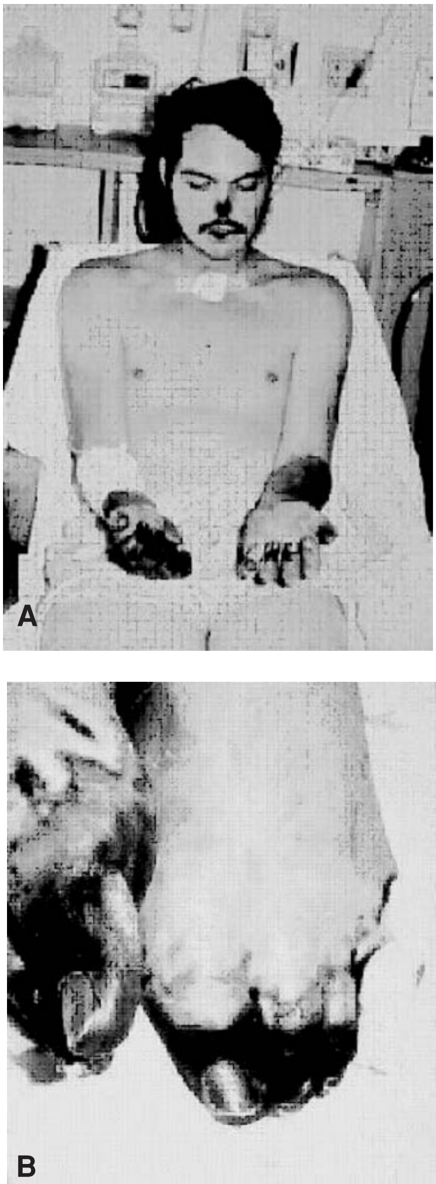

Figure 29.8. (**A**) This patient developed bubonic plague that progressed to the septicemic and pneumonic forms after the causative organism, *Y. pestis*, disseminated from his buboes into his bloodstream. (**B**) Note the necrosis of tissue involving the tip of the nose, the fingers and the toes. This is due to thrombosis of distal arterioles and is a known complication of septicemic plague. Photographs: Courtesy of Kenneth L Gage, PhD, Centers for Disease Control and Prevention Laboratory, Fort Collins, Colorado. See color plate.

biochemical reactions. It can be cultured on blood agar, MacConkey agar, or infusion broth. Most naturally occurring strains of *Y. pestis* produce an F1-antigen in vivo, which can be detected in serum samples by immunoassay. A fourfold rise in antibody titer in patient serum is retrospectively diagnostic. PCR (using specific primers), although not sufficiently developed and evaluated for routine use, is a very sensitive and specific technique, able to identify as few as 10 organisms per milliliter. Most clinical assays can be performed in BSL-2 laboratories, whereas procedures producing aerosols or yielding significant quantities of organisms require BSL-3 containment.[47]

Standard precautions are adequate when caring for bubonic plague patients. Suspected pneumonic plague cases require strict isolation with droplet precautions for at least 48 hours following the initiation of antibiotic therapy or until sputum cultures are negative in confirmed cases. If competent vectors (fleas) and reservoirs (rodents) are present in the environment, measures must be taken to prevent disease from becoming enzootic. These measures might include but are not limited to the use of flea insecticides, rodent control measures (after or during flea control), and flea barriers for patient care areas.

Streptomycin, gentamicin, doxycycline, and chloramphenicol are highly effective in the treatment of plague, if therapy is initiated early. Streptomycin is generally not available in many countries in modern times but gentamicin, doxycycline, and chloramphenicol are acceptable alternatives. Results obtained from animal studies indicate that quinolone antibiotics, such as ciprofloxacin and ofloxacin, may also be effective. Chloramphenicol is recommended for the treatment of plague meningitis.[48] Usual supportive therapy includes intravenous administration of crystalloids and hemodynamic monitoring. Although low-grade DIC may occur, clinically significant hemorrhage is uncommon, as is the need to treat with heparin. Endotoxic shock is common, but pressor agents are rarely needed. Finally, buboes rarely require any form of local care, but instead recede with systemic antibiotic therapy. In fact, incision and drainage poses a risk to others in contact with the patient; aspiration is recommended for diagnostic purposes and may provide symptomatic relief.

At this time of this writing, no vaccine is available for the prophylaxis of plague. A licensed, killed whole cell vaccine was available in the United States from 1946 until November 1998; it offered protection against bubonic plague, but would likely have been ineffective against aerosolized *Y. pestis*. An F1-V antigen (fusion protein) vaccine is in development at the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID). It protects mice against an inhalational challenge, and is undergoing testing in primates.

Persons having face-to-face contact (within 2 m) with pneumonic plague victims, or persons possibly exposed to a plague aerosol during a biological attack, should receive antibiotic prophylaxis for at least 7 days following the cessation of exposure. Doxycycline (100 mg orally twice daily) is the recommended choice of antibiotic for prophylaxis because of its oral bioavailability and relative lack of toxicity. Ciprofloxacin (500 mg orally twice daily) has also been shown effective in preventing disease in exposed mice. Tetracycline (500 mg orally four times daily) and chloramphenicol (25 mg/kg orally four times daily) are acceptable alternatives. Contacts of bubonic plague patients should be observed for symptoms for at least 1 week. Should such symptoms occur, antibiotic therapy should be instituted pending the results of diagnostic studies.

Botulism

Botulism is a toxin-mediated disease (rather than a true infection), which occurs following exposure to one of seven related botulinum neurotoxins (A-G) produced by certain strains of *Clostridium botulinum* and closely related bacteria. These organisms are anaerobic spore-forming Gram-positive bacilli ubiquitously found in soil. The neurotoxins they produce are the most toxic substances known, with an LD_{50} (for type A toxin) of approximately 0.001 μg/kg. On a weight basis, this is approximately 15,000 times more lethal than VX, the most potent chemical warfare agent. The botulinum neurotoxins function at the presynaptic nerve terminal, preventing the release of acetylcholine, interrupting neuronal transmission at cholinergic autonomic (muscarinic) and motor (nicotinic) receptors, and thereby leading to a generalized flaccid paralysis and autonomic dysfunction. Binding of toxin within the presynaptic neuron is permanent; recovery is thus predicated on development of new axons, which may require several months.

Only types A, B, and E toxins are significant causes of naturally occurring human botulism. Exposure to type C toxin appears to be a prevalent cause of botulism among poultry and other avian species, whereas types C and D are associated with disease in cattle. Neither type C nor D appears to affect humans in nature, although all serotypes have the potential to cause human disease. A single small outbreak of botulism due to type G toxin was reported in Argentina.[49] More recently, several cases of neonatal botulism due to type F toxin associated with *C. baratii* have been described,[50] and a few cases of infant botulism (type E) have been associated with *C. butyricum*.[51]

Sinister use of botulinum toxin might involve its aerosolization or the intentional contamination of food and water supplies. Iraq weaponized botulinum toxin for aerosol delivery and declared such weapons under the auspices of the Biological Weapons Convention in the aftermath of the 1990–1991 Gulf War. The Japanese doomsday cult Aum Shinrykyo made several unsuccessful attempts to use botulinum toxin as a weapon prior to their sarin attack on the Tokyo subway system. Naturally occurring botulism, however, is generally acquired in one of three ways.

1) Food-borne botulism occurs as a result of the consumption of improperly canned food. As *C. botulinum* is ubiquitous in soil, contamination of food with small amounts of soil provides the nidus of bacteria. Failure to sterilize food during canning allows for bacterial survival. The canning process then provides for the strict anaerobic environment necessary for bacterial proliferation and toxin production. Subsequent heating or cooking (such as might occur after opening the previously canned goods) may kill bacteria but does not destroy the toxin. Consuming contaminated canned goods, then, allows for the gastrointestinal absorption and hematogenous circulation of toxin, which ultimately reaches its target at the peripheral cholinergic synapse. Although types A and B toxin are traditionally associated with food-borne outbreaks, type E toxin is particularly associated with botulism resulting from improperly canned fish products.
2) "Wound botulism" occurs when soil contaminates a wound and is contained within an anaerobic pocket beneath the skin. *C. botulinum* proliferates in this environment and produces toxin. A large number of wound botulism cases have been associated with the injection of "black-tar" heroin.[52]
3) Infant botulism occurs when infants ingest dirt or substances (e.g., honey) heavily contaminated with *C. botulinum* spores.[53] Under normal circumstances, the acidity of the stomach would destroy these spores, but the relatively weak acid levels of the neonatal stomach are thought to permit some spores to survive and transit the intestinal tract, where the relative lack of competing bowel flora allow them to colonize and germinate in the large intestine and begin to produce toxin, which is then absorbed.

Regardless of the original route of acquisition of botulinum toxin (via any of the three aforementioned routes or via inhalation following a deliberate aerosol attack), the final common pathway is the same. Following exposure to botulinum toxin, a latent period ranging from 24 hours to several days occurs before clinical manifestations develop. Signs and symptoms initially involve cranial nerve dysfunction, manifested as bulbar palsies, ptosis, photophobia, and blurred vision caused by a difficulty in accommodation. The autonomic effects of botulism may include dry mouth, ileus, constipation, and urinary retention. Nausea and vomiting may occur as nonspecific sequelae of an ileus. Hence the combination of neurological and gastrointestinal symptoms should lead clinicians to suspect botulism. Symptoms then progress to include dysarthria, dysphonia, and dysphagia. Finally, a descending symmetrical flaccid paralysis develops and, in the absence of ventilatory support, death results from respiratory muscle failure.

The diagnosis of botulism is principally clinical. The extreme potency of the toxin is such that the LD_{50} is below the threshold of human immune response. Detectable antibody production is thus absent in cases of human botulism, and diagnostic assays using a search for antibodies are fruitless. For this reason, clinical botulism does not confer immunity to subsequent intoxications. It is possible to detect toxin in clinical or environmental samples by using enzyme-linked immunosorbent assays, but the mouse neutralization bioassay remains the gold standard for botulinum neurotoxin detection. In cases of food-borne botulism, then, it is critical to obtain implicated food for testing in such assays.

Clinically, a solitary case of botulism must be differentiated from other uncommon neurological disorders such as myasthenia gravis, tick paralysis, Guillain–Barré syndrome, Eaton–Lambert syndrome, and others. The presence of multiple casualties with similar symptoms clustered in time and space should make elucidation of a botulism outbreak relatively easy. In the setting of terrorism, botulism might superficially be confused with nerve agent intoxication, owing to the preponderance of neuromuscular symptomatology in both conditions. The two are easy to differentiate, however, when one recalls that organophosphate nerve agents inhibit acetylcholinesterase, leading to excessive cholinergic activity at neuronal synapses, in contrast to the lack of cholinergic activity seen in botulism. The paralysis of nerve agents, then, is spastic, rather than flaccid, and autonomic hyperarousal is seen.

Supportive care, including meticulous attention to ventilatory support, remains the mainstay of botulism management. Patients may require such support for several months, making the management of a large-scale botulism outbreak especially problematic in terms of medical resources. Unlike other types of public health emergencies such as pandemic influenza, hypoxia is generally not a concern; therefore, large supplies of oxygen are less critical than ventilation resources. Recognition of the utility of tracheostomy and improvements in mechanical ventilation have reduced the mortality rate from isolated cases of botulism in the United States from greater than 60% prior to 1950 to less than 5% in modern times. Attention to hydration status, as well as bowel and bladder care and cognizance of the need to prevent decubitus ulcers and deep vein thromboses, play a large role in patient outcome. When antibiotics are prescribed in the treatment of wound botulism no aminoglycosides or clindamycin should be administered because of their weak pharmacological effects as neuromuscular blocking agents. This effect worsens paralysis acutely and may precipitate respiratory arrest.

A licensed bivalent (type A and B) botulinum antitoxin is available through the U.S. CDC, as is a separate investigational type E antitoxin. Although administration of antitoxin is unlikely to reverse disease (which is mediated by toxin already taken up in presynaptic nerve terminals and thus inaccessible to circulating antitoxin), it may prevent progression when administered to exposed persons. Botulinum antitoxin is prepared from equine serum; a test dose should thus be administered prior to therapy. Patients reacting to a test dose require desensitization. An investigational heptavalent (type A-G) despeciated (F_{ab2}) antitoxin, also produced in horses, is available through USAMRIID on a compassionate use protocol.[54] Administration of a test dose is also required with this product. Finally, a human-derived anti-botulinum immune globulin (BabyBIG®) is licensed specifically for the treatment of infant botulism due to type A or B toxin.[55]

Although no licensed vaccine is available to protect against botulism, considerable experience exists with an investigational pentavalent (types A–E) vaccine, produced by the Michigan Department of Public Health, and available through the CDC. A theoretical concern, given the expansion of indications for therapeutic use of botulinum toxins, surrounds the possibility that vaccine recipients may be immune to the beneficial effects of such treatment. Of note, therapeutic botulinum toxin is produced from type A (Botox®) or type B (Myobloc®) toxin.

Viral Hemorrhagic Fevers

The term "viral hemorrhagic fever" (VHF) is a clinically descriptive one, referring to a group of widely heterologous diseases caused by lipid-enveloped, single-stranded RNA viruses of four taxonomic families: the arenaviruses, bunyaviruses, filoviruses, and flaviviruses. Although "brand name recognition" (i.e., the notoriety of diseases such as Ebola fever and the consequent ability of these diseases to capture public attention and create concern) is somewhat responsible for their inclusion among the category A agents, actual weaponization of these agents would likely be problematic, owing to difficulties in mass production, and rapid inactivation of the various causative viruses by environmental heat, desiccation, and ultraviolet light.[56] Nonetheless, several have been examined as weapons candidates.

The VHFs would be expected to present as acute febrile illnesses with a host of nonspecific features such as malaise, fatigue, nausea, vomiting, diarrhea, abdominal pain, and headache. Hypotension and shock can rapidly ensue and death occurs frequently among patients with certain VHFs. Vascular involvement constitutes the defining characteristic of this broad group of infectious diseases and can manifest as hypotension, flushing, edema, petechiae, bruising, and bleeding. Such findings can vary from subtle to overt in their presentation.

The pathogenesis of the VHFs is complex and variable (Figure 29.9). Although some hemorrhagic fever viruses cause vascular damage and DIC through direct endothelial infection, others result in immune complex deposition, thereby activating complement and the inflammatory cascades. Vascular endothelial damage, however, is the final common pathway that results in vascular leak, with secondary hypotension, edema, and hemorrhage, often resulting in shock and end-organ failure. Although the VHFs share common manifestations, many clinical findings may vary among the different diseases and among patients with the same disease. Lassa fever, caused by an Old World arenavirus, typically presents with edema, without hemorrhage, whereas diseases due to the New World arenaviruses (the agents of Argentinean, Bolivian, and Venezuelan hemorrhagic fevers) are notable for prominent petechiae, purpura, ecchymoses, and mucosal hemorrhage.

The hantaviruses are members of the bunyavirus family. Hemorrhagic fever with renal syndrome (HFRS), usually caused by Old World (and occasionally New World) hantaviruses, begins with a nonspecific prodrome, followed by the development of facial edema. A morbilliform eruption, flushing of the upper body, and dermatographism may appear. Hemorrhagic manifestations may range from subtle petechiae to massive hemorrhage. Congo-Crimean hemorrhagic fever (CCHF), caused by another bunyavirus, is often characterized by severe ecchymoses and hemorrhage, although some cases may present only nonspecific, minor hemorrhagic manifestations (Figure 29.10).

The filoviral fevers, Ebola and Marburg, are characterized by an acute severe prodrome, followed by a papular exanthem that rapidly progresses into large, coalescent papules, purpura, and ecchymoses. Patients often develop gross hemorrhage and shock. Mortality rates range from 23% in some Marburg disease outbreaks to as high as 90% for certain Ebola outbreaks. Most of these deaths occur during the second week of illness.

Flavivirus infections also produce manifestations that are quite variable. Dengue fever typically presents as a nonspecific febrile illness, sometimes accompanied by a diffuse morbilliform rash. Although infection due to one of the four dengue virus serotypes confers lifelong immunity to that particular serotype, reinfection with another (heterologous) strain may result in "immune amplification." This leads to a more severe clinical outcome, termed dengue hemorrhagic fever or dengue shock syndrome. Severe ecchymoses and hemorrhage can occur in cases of dengue hemorrhagic fever. Two other flaviviral hemorrhagic fevers, Omsk hemorrhagic fever and Kyasanur Forest disease, can also feature a wide range of hemorrhagic manifestations.

Clinical diagnosis is essential in the case of the VHFs due to their highly contagious nature. Because the endemic range of the various causative viruses is often unique and limited, naturally occurring cases can frequently be suspected on geographical and epidemiological grounds, and a detailed travel history should be sought when VHF is suspected. Clinical laboratory findings of proteinuria, thrombocytopenia, leukopenia, elevated serum transaminase levels, and abnormal coagulation studies may be sought but are nonspecific. Specific etiological diagnosis by serological testing or viral isolation would require forwarding clinical specimens to a limited number of laboratories with high-level biosafety containment capabilities. In fact, many of the hemorrhagic fever viruses (the filoviruses and arenaviruses, as well as CCHF, Omsk, and Kyasanur Forest) are assigned to BSL-4 laboratories. Within the United States for example, clinical specimens potentially containing these viruses should thus be handled only at the CDC or USAMRIID, both of which possess BSL-4 laboratories.

Supportive care is the mainstay of therapy in most cases of VHF, and many severely affected individuals will require heroic and intensive support. Vigorous fluid resuscitation, as well as vasoactive agent administration and inotropic support may be necessary; the provision of such modalities is especially problematic in developing nations where many of these diseases are

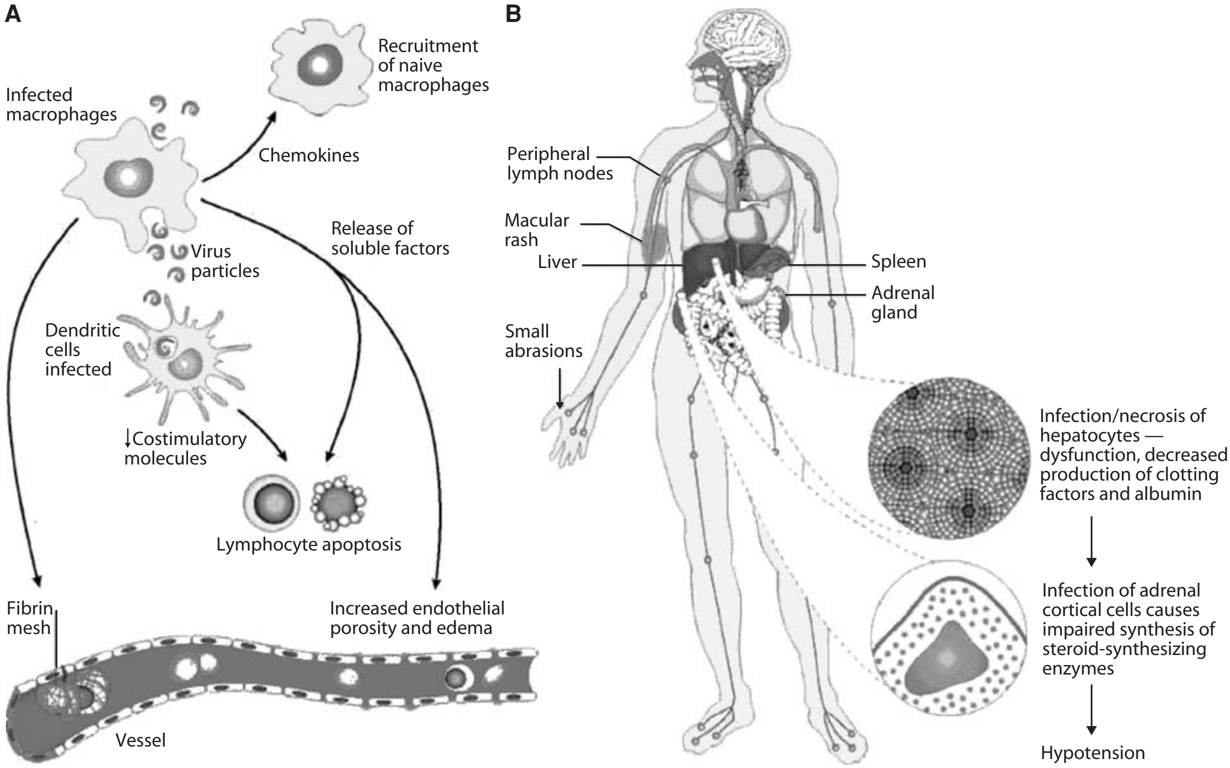

Figure 29.9. Model of VHF pathogenesis. (**A**) Virus spreads from the initial infection site to regional lymph nodes, liver, and spleen. At these sites, the virus infects tissue macrophages (including Kupffer cells) and dendritic cells. Soluble factors released from virus-infected monocytes and macrophages act locally and systemically. Release of chemokines from these virus-infected cells recruits additional macrophages to sites of infection, making more target cells available for viral exploitation and further amplifying the dysregulated host response. Although none of these viruses infect lymphocytes, the rapid loss of these cells by apoptosis is a prominent feature of disease. The direct interaction of lymphocytes with viral proteins cannot be discounted as having a role in their destruction, but the marked loss of lymphocytes is likely to result from a combination of factors, including viral infection of dendritic cells and release of soluble factors from virus-infected monocytes and macrophages. For example, viral infection of dendritic cells impairs their function by interfering with the upregulation of costimulatory molecules, which are important in providing rescue signals to T lymphocytes. Additionally, release of soluble factors from infected monocytes and macrophages results in deletion of lymphocytes, both directly by release of mediators such as nitric oxide, and indirectly by contributing to upregulation of proapoptotic proteins such as Fas and tumor necrosis factor–related apoptosis-inducing ligand. The coagulation abnormalities vary in nature and magnitude among the VHFs. For example, Ebola virus induces the overexpression of tissue factor that results in activation of the clotting pathway and the formation of fibrin in the vasculature. As another example, coagulation disorders are less marked in Lassa fever, and impairment of endothelial function contributes to edema, which seems to be a more prominent finding in Lassa fever than in other VHFs. (**B**) The hemodynamic and coagulation disorders common among all of the VHFs are exacerbated by infection of hepatocytes and adrenal cortical cells. Infection of hepatocytes impairs synthesis of important clotting factors. At the same time, reduced synthesis of albumin by hepatocytes results in a reduced plasma osmotic pressure and contributes to edema. Impaired secretion of steroid-synthesizing enzymes by VHF-infected adrenal cortical cells leads to hypotension and sodium loss with hypovolemia. Macular rashes are often seen in VHFs. Reproduced with permission from: Geisbert TW, Jahrling PB. Exotic emerging viral diseases: progress and challenges. *Nat Med.* 2004;10(12 suppl):S110–121. See color plate.

endemic. Sedative and anxiolytic therapy, pain control, anticonvulsant therapy, antibacterial therapy (for secondary infections), mechanical ventilation, and renal dialysis are often required as well. Because coagulopathy is an integral component of the pathogenesis of many VHF cases, particular attention should be paid to clotting studies, and blood products (e.g., red blood cells, platelets, and clotting factors) should be provided as clinically indicated. As with any case of significant coagulopathy, intramuscular injections and anticoagulating drugs (such as aspirin) should be avoided.

At the time of this writing, intravenous ribavirin is being studied in the treatment of many of the VHFs, and shows promise in cases of Lassa fever, Rift Valley fever, CCHF, and HFRS.[57] As of this writing, ribavirin is not yet FDA-approved for the treatment of any VHF and should thus be used under an IND protocol. Antisense oligomers have shown considerable promise in treating Ebola in a nonhuman primate model.[58] The 17-D yellow fever vaccine is the only U.S. FDA-approved immunization available against a hemorrhagic fever virus.[59] Vaccine candidates effective against Rift Valley fever, Argentine hemorrhagic fever, HFRS, Lassa, Marburg, and Ebola fevers are in various stages of study or development.

Patients with certain VHFs may present infection control and public health challenges because many are highly contagious and are commonly transmitted to healthcare workers. The arenaviruses, CCHF, and the filoviruses are communicable,

Figure 29.10. Ecchymosis associated with late-stage CCHF infection 1 week following development of clinical signs and symptoms. Ecchymosis indicates significant impairment of the patient's coagulation system and loss of vascular integrity. Photograph: Courtesy of Dr. Sadegh Chinikar, Pasteur Institute of Iran, Tehran, Iran. See color plate.

primarily by contact with blood and body fluids. Specific infection control guidelines for hospitalized patients with these diseases include contact precautions, augmented in some circumstances with airborne precautions, with special attention to disposal of body waste. Patients with hemorrhagic fever with renal syndrome and those with flavivirus infections can be managed using standard precautions.

Tularemia

Tularemia, a plaguelike zoonotic illness that occasionally affects humans, is caused by the Gram-negative facultative intracellular coccobacillus, *Francisella tularensis*. First discovered in ground squirrels in Tulare County, California in 1911, two biotypes of *F. tularensis* are now known. *F. tularensis tularensis*, the causative agent of "type A" tularemia, is found only in temperate areas of North America, where it is typically transmitted by ticks among lagomorph reservoirs (hence the moniker "rabbit fever"), although many other wild animals may serve as reservoirs and many insects as vectors. Humans are accidental "dead end" hosts who cannot transmit disease. Natural infection in humans occurs through inoculation by an infected arthropod, contact with contaminated animal tissue, inhalation of aerosolized bacterium, or ingestion of contaminated water or meat. Approximately half of all naturally occurring U.S. cases originate in Missouri, Arkansas, or Oklahoma.[60]

The number of reported cases of tularemia in the United States has decreased from several thousand per year prior to 1950 to less than 200 per year over the past decade. A diminishing fondness for rabbit hunting may be responsible in part for this finding. Occupational exposure and environmental factors are major risk factors for disease acquisition, and tularemia generally affects more men than women, likely owing to its association with hunting. Naturally occurring tularemia occurs in two seasonal peaks: during the summer (when ticks are active) and the winter (during hunting season).

F. tularensis tularensis is an organism of extraordinarily high virulence, and as few as 10 cells constitute the rabbit lethal dose (LD_{50}) and human infectious dose (ID_{50}). *F. tularensis palearctica*, the causative agent of "type B" tularemia, on the other hand, is a low-virulence organism found in Europe and the former Soviet Union. The rabbit LD_{50} of this organism is on the order of 10 million cells. Although these differences have epidemiological and vaccine development implications, immunity against one biotype appears to be cross-protective.

Widespread waterborne outbreaks of tularemia in the former Soviet Union prior to and during the WWII led to a more thorough study of the bacterium and its potential as a biological weapon. Its high infectivity, ability to produce severe or fatal human illness, relative heartiness and ease of dissemination, and nonspecific clinical presentation apparently argued convincingly for such a role. In fact, the United States developed tularemia aerosols during human exposure experiments, and by the 1950s, had stockpiled tularemia as one of the first entries in its biological arsenal. Some, including Ken Alibek, a former Soviet biological weapons scientist, have alleged that tularemia was intentionally deployed by the Soviets at the Battle for Stalingrad in 1942–1943.[61] Unusual epidemiology and an overwhelming preponderance of pneumonic disease, which occurred during a large outbreak between the Don and Volga rivers during that period,[62] lend credence to these allegations, although others dispute a sinister explanation for the outbreak.[63] Finally, Alibek also detailed the Soviet Union's attempts to engineer drug resistance into *F. tularensis* weapons during the 1990s.

Tularemia presents in at least six different clinical forms, all heralded by the onset of a nonspecific flulike syndrome. The terms ulceroglandular, glandular, oculoglandular, pharyngeal, typhoidal, and pneumonic, describe these clinical presentations. In many ways, however, glandular and oculoglandular disease can be thought of as variants of the ulceroglandular form, and the six clinical syndromes can be more simply thought of as constituting two broader clinical pictures, analogous in many ways to plague. Ulceroglandular tularemia is similar in many regards to the bubonic form of plague (or, in some respects, to the cutaneous form of anthrax). Pneumonic tularemia, on the other hand, is likely to be the predominant presentation following an intentional aerosolized release and can be thought of as somewhat analogous to the pneumonic form of plague (or the inhalational form of anthrax).

Ulceroglandular tularemia results from arthropod bites or from exposure of skin and mucous membranes to the hides and meat of infected animals. Onset of fever and systemic symptoms (which may include chills, headache, cough, myalgia, chest pain, vomiting, arthralgia, sore throat, and abdominal pain) occur following a 3–6 day incubation period.[64] Within 48–72 hours an erythematous maculopapular lesion develops at the site of inoculation and soon ulcerates. This characteristic chancrelike ulcer is typically 0.4–3.0 cm in diameter with raised edges. Bacteria present at the ulcer site, subsequently gain access to lymphatic vessels and travel to regional lymph nodes, producing the lymphadenitis, which, in combination with the ulcer, constitutes the hallmark dyad of ulceroglandular tularemia. The lymphadenopathy of ulceroglandular tularemia is often pronounced and persistent. Involved lymph nodes can grow as large as 10 cm in diameter, and frequently become fluctuant whether treated with appropriate antibiotics or not. From the lymph node, bacteria may secondarily gain access to the systemic circulation and ultimately seed the liver, spleen, and other distant organs.

Pneumonic tularemia results from inhalation of aerosolized bacteria but may also occur secondarily following seeding of the lungs in complicated cases of ulceroglandular and typhoidal tularemia. Aerosolization of bacteria can occur intentionally, through the actions of belligerents or terrorists, but may occur naturally in circumstances in which infected blood and other animal products are mishandled. Modern day reports attribute cases of inhalational (pneumonic) tularemia to aerosolization of rabbits by lawnmowers.[65] Symptoms of pneumonic tularemia include cough (which may be productive), dyspnea, and pleuritic chest pain. Pleural effusions, cavitary lesions, bronchopleural fistulae, and pulmonary calcifications occur less commonly.

F. tularensis may be cultured from the blood of infected individuals, but such culturing should only be attempted by experienced technicians in laboratories equipped with BSL-3 safety systems. Testimony to the extreme infectivity of *F. tularensis* in laboratory settings, in fact, can be obtained by considering that this agent was, far and away, the most common cause of laboratory-acquired infection at Fort Detrick, Maryland (home to the U.S. Army Medical Research and Materiel Command) prior to the immunization of laboratory workers.[66] Identification of *F. tularensis* may also be accomplished by microscopic examination of secretions or biopsy specimens by using direct fluorescent antibody or immunohistochemical staining techniques. Although such fluorescence-labeled antibody assays are used in the rapid diagnosis of tularemia at many U.S. state public health laboratories, diagnosis in most clinical settings is best made using bacterial agglutination or enzyme-linked immunosorbent assays. Detectable levels of agglutinating antibodies against *F. tularensis* typically appear in blood within approximately 7 days of infection, although higher levels and improved diagnostic sensitivity may be obtained by sampling 2 weeks following suspected infection. Moreover, the serological response may be blunted by the administration of antibiotics, making diagnosis more problematic. Due to cross-reactivity of *F. tularensis* with *Brucellae*, *Proteus* OX19, and *Yersinia* organisms, acute infection should ideally be diagnosed only in the presence of a fourfold or greater increase in titer following an acute infection.[67]

As with plague, streptomycin (1 g intramuscularly twice daily) has traditionally been considered the drug of choice in the treatment of all forms of tularemia, and a review of the literature reveals a 97% cure rate with no relapses when using streptomycin.[68] Patients treated with streptomycin usually demonstrate a clinical response within 48 hours. Gentamicin (5 mg/kg daily intramuscularly or intravenously) was an acceptable alternative in this same review, and, given the difficulty in procuring Streptomycin in many countries, has become a widely used therapy for this condition. Both should be given for a minimum of 10 days. Ciprofloxacin (400 mg intravenously twice daily) given for 10 days is a potential alternative to aminoglycoside therapy. Bacteriostatic drugs such as chloramphenicol (15 mg/kg intravenously four times daily) and doxycycline (100 mg intravenously twice daily) are effective, but should be administered for at least 14–21 days to prevent relapse. Postexposure prophylaxis of persons thought to have been exposed to tularemia may be accomplished using oral doxycycline (100 mg twice daily) or ciprofloxacin (500 mg twice daily) for 14 days.

The prevention of tularemia among hunters and other persons handling animals, animal hides, or carcasses is best achieved by the wearing of gloves, attention to good hand hygiene, and avoidance of mucosal exposure. BSL-3 precautions, including face masks, rubber gloves, and biological containment hoods should be used by laboratory technicians working with cultures or potentially infectious clinical material. In the event of a laboratory spill or surface contamination, decontamination can be accomplished with ordinary bleach solution. Although over half a century of experience exists with investigational tularemia vaccines, none are licensed in the United States at the time of this writing.[69]

RECOMMENDATIONS FOR FURTHER RESEARCH

Barriers to Research

Developing useful preventative measures, therapeutics, and diagnostics for the myriad of potential agents that could be used as biological weapons is a monumental task, and optimal countermeasures for many of the dozens of potential threat agents contained within the U.S. CDC's and other governments' prioritized lists are currently lacking. In fact, for many of these agents there is an incomplete understanding of the pathogenesis of disease. Compounding the challenges associated with known threat agents is the realization that rogue nations or terrorist groups may be covertly developing new biological weapons. Moreover, organisms can be selected for antibiotic or vaccine resistance, normally benign organisms can be modified to evade host defenses or produce toxins, and chemokines, cytokines, or other biomodulators could be designed for use as weapons. Significant obstacles to the development of an effective biological warfare medical countermeasures research program include

1) The threat is poorly understood or characterized. Those who wish to use biological agents as weapons are likely to keep their arsenals secret, and biological programs, which do not require the massive infrastructure that chemical and nuclear programs do, are much easier to camouflage. As such, intelligence agencies face a daunting task in discovery. The U.S. anthrax attacks in 2001 caught the nation by surprise. Another example is that the extent of the former Soviet program was unknown until former soviet scientists came forward at the close of the cold war. They revealed, for example, that the Soviets had stockpiled a smallpox weapon and had developed a Marburg virus weapon.[9] Even naturally occurring new and emerging infections, such as Nipah, severe acute respiratory syndrome, and avian influenza regularly catch the medical intelligence community unprepared. It is a challenge to determine how to prioritize research to match such diverse and constantly changing threats.
2) Rare diseases are difficult to study. Many of the known threats are difficult to characterize adequately, study, and replicate the resultant human disease. For example, there are no smallpox victims available to test new therapeutic drugs, as natural disease has been eliminated from the human population. Human monkeypox, which exists in tropical Africa, may serve as a viable surrogate for smallpox, but this model has not yet been validated. Although *Burkholderia mallei* occasionally causes disease in humans, it is too rare to allow organization of clinical therapeutic trials. Additionally, naturally occurring human glanders may not resemble the disease that would result from intentional aerosolization of the organism. Consequently, animal models of disease, when available, must play a vital role in any therapeutics research. To address the problem of FDA approval of therapeutics for such rare and dangerous diseases, in 2002 the U.S. FDA enacted the "animal rule." This legislation allows for approval of "certain new drug and biological products based on animal data when adequate and well-controlled efficacy studies in humans cannot be ethically conducted."[70]

3) Resources are limited. Basic scientific preclinical research into novel therapeutic compounds or vaccines can take decades and often fails to result in the discovery of candidate products despite massive expenditures of human resources and money. Of those candidate products entering Phase I testing, only 8% are ultimately approved for use in humans. Between 2000 and 2002 it cost 1.7 billion dollars on average in the United States to bring a new drug from discovery to market.[71] Within the United States, private funding for biological warfare medical countermeasures is virtually nonexistent. The biopharmaceutical industry is in the business of producing medical solutions with a high likelihood of profit. Novel or improved antimicrobials have potential value in treating common infectious diseases as well as biological terrorism threat agents; thus, some privately funded research into these products may ultimately benefit medical response. Nonetheless, prophylactic and therapeutic agents specific to biological threat organisms typically have no market other than the government. Moreover, when government does invest in such products, it may do so in the form of single (or limited) large purchases instead of providing the continuing market demand that drives private investors. In the United States, government funding for bioterrorism agent medical countermeasures has increased over the past decade, as will be detailed later, but resources remain limited, and thus expenditures must be prioritized.
4) Highly specialized laboratory facilities are required. Many of the biological threat agents, including those that are transmissible via aerosol and have high lethality, can be safely studied only within high-containment laboratories. At the time of this writing, there are six operational BSL-4 (the highest level of biocontainment) laboratories in the United States: at the CDC in Atlanta; USAMRIID in Frederick, Maryland; the Southwest Foundation for Biomedical Research in San Antonio, Texas; the University of Texas at Galveston; Georgia State University in Atlanta; and Virginia Commonwealth University in Richmond. The National Institute of Allergy and Infectious Diseases is funding construction of four additional BSL-4 laboratories: at Boston, Massachusetts; Galveston, Texas; Fort Detrick, Maryland; and at the Rocky Mountain Laboratory in Hamilton, Montana. Despite funding for new biosafety laboratories, construction, in some communities, has been slowed or even curtailed over public concern for security of the pathogens to be held within.[73] Limited space, like limited funding, forces the research community to prioritize research.
5) Unique legal issues are involved. Although the 1925 Geneva Gas Protocol prohibited only the "practice" of bacteriological warfare, the 1972 BWC places much more stringent limitations on the handling and manipulation of biological agents. Under the terms of the BWC, production, storage, and transfer of agents are regulated. Such regulation creates potential conundrums for scientists performing defensive work and developing medical countermeasures. For example, enhancing the aerosolization of agents would be considered "offensive" work and is prohibited by the BWC; however, to test a candidate vaccine in animals, those animals must be exposed to agent. Moreover, for such experiments to yield optimal information, challenge of such animals should ideally involve aerosolized agent. For this to happen, small quantities of high-purity agent must be produced, forcing scientists to walk a legal tightrope. As more BSL-4 laboratories proliferate, concerns regarding biosecurity and consequent legal issues are only likely to increase.

Despite these formidable barriers, the past decade has seen a dramatic shift in emphasis on preparedness for biological weapons events and emerging infectious disease outbreaks within the United States and other countries. In the U.S., tens of billions of dollars have been allocated and a rapidly evolving massive reorganization of federal preparedness and response organizations has been undertaken in an attempt to develop a sound solution to this very complex problem. In the last half of the 20th century, the military performed the vast majority of research in the United States to enhance preparedness for a biological attack. Recent world events, however, have increased civilian awareness of the threat of biological weapons, and publicly identified a "critical need for cutting-edge technology that can quickly and effectively detect, analyze, facilitate interdiction of, defend against, defeat, and mitigate, the consequences of weapons of mass destruction (WMD)."[70] As an example, the United States has developed parallel, although somewhat complimentary, WMD medical countermeasure research programs led by DoD and the Department of Homeland Security (DHS). To understand current biological warfare medical countermeasures research strategy and progress within the United States, it is useful to review these two programs.

U.S. CIVILIAN BIOLOGICAL WARFARE MEDICAL COUNTERMEASURES RESEARCH

1) Organizational Structure. Within the U.S. government, the Secretary of the DHS is responsible for developing a strategic chemical, biological, radiological, and nuclear (CBRN) threat assessment. DHS issues Material Threat Determinations (MTDs) for those CBRN threat agents thought to present a material threat to U.S. security. DHS then performs a population threat assessment (PTA) on each identified threat agent to determine the number of individuals who could be exposed in what are believed to be plausible, high-consequence attack or outbreak scenarios. The Department of Health and Human Services (HHS) leads efforts to "research, develop, evaluate, and acquire public health emergency medical countermeasures to prevent or mitigate the health effects of CBRN threats facing the U.S. civilian population,"[74] a responsibility delegated to the Assistant Secretary for Preparedness and Response (ASPR) at the time of this writing. The ASPR oversees the HHS Public Health Emergency Medical Countermeasures Enterprise (HHS PHEMCE), which is assigned to develop and acquire medical countermeasures for the list of CBRN threats determined by DHS. The HHS PHEMCE is composed of members from three HHS agencies (CDC, the FDA, and the National Institutes of Health), with ex officio membership from DoD, DHS, the Department of Veterans Affairs, and other agencies. After analyzing MTD and PTA information for each threat agent, PHEMCE performs its own medical and public health consequence assessments, which include modeling the effects of medical countermeasures. Based on their findings, PHEMCE identifies and prioritizes near-, mid-, and long-term development and acquisition programs for medical countermeasures. These priorities are communicated to the National Institute of Allergy and Infectious Diseases,

Table 29.6: U.S. Biodefense Research Priorities

	Near-Term (FY 2007–2008)	*Mid-Term (FY 2009–2013)*	*Long-Term (FY 2014–2023)*
Civilian Priorities	1. New antibiotics for treatment of: *B. anthracis* *B. mallei* *B. pseudomallei* *R. prowazekii* *F. tularensis* 2. Next generation vaccines: Anthrax Smallpox	1. Broad spectrum antibiotics 2. Point-of-care, rapid diagnostics 3. Anthrax antitoxin 4. Filovirus countermeasures 5. Smallpox antivirals	Broad spectrum antivirals effective against: Ebola Junin Marburg Smallpox
Military Priorities	1. *Yersinia pestis* vaccine 2. Recombinant botulinum (A/B) toxin vaccine 3. Multiagent vaccine platforms 4. Demonstration of immunotherapeutics for filoviruses, bacteria, and toxins 5. Licensure of intravenous therapeutics for smallpox 6. New oral therapeutics for smallpox	1. Continued development of: *Y. pestis* vaccine Recombinant botulinum (A/B) toxin vaccine Multiagent vaccine platforms 2. Licensure of oral smallpox therapeutics 3. Licensure of an antisepsis drug for filovirus shock 4. Advanced development of monoclonal antibody for filovirus infection 5. Advanced development of botulinum toxin small molecule therapy	1. Licensure of: Botulinum (A/B) vaccine *Y. pestis* vaccine Filovirus vaccine(s) 2. Alternate delivery methods for vaccines and immunogens 3. Development (and licensure) of vaccines for: VEE, EEE, WEE filoviruses 4. Development and licensure of multiagent vaccines against multiple BW threats 5. Licensure of novel therapies using antisense or similar technologies

which uses them to determine the allocation of federal funds to research potential biological weapons medical countermeasures. In 2004 the BioShield program was created to acquire medical countermeasures for the U.S. CDC Strategic National Stockpile.[75] A $5.6 billion "Special Reserve Fund" was appropriated to DHS for use through 2013, with HHS designated as the acquisition agent. Finally, the *Pandemic and All-Hazards Preparedness Act*[76] of 2007 created the Biomedical Advanced Research and Development Authority to select promising candidate medical countermeasures for funding through the late-stage research and development phase.

2) Funding. Between fiscal years 2001 and 2008 almost $40 billion was allocated for civilian biodefense in the United States.[77] Perhaps a quarter of this funding has furthered research that could lead to new medical countermeasures or diagnostics for biological agents. Some $3.4 billion of this total has been allocated through Project BioShield for procurement of countermeasures for the Strategic National Stockpile.

3) Priorities. To date, DHS has issued MTDs and PTAs for the following biological threat agents: *Bacillus anthracis*, Marburg virus, botulinum toxins, multidrug-resistant *Bacillus anthracis*, *Burkholderia mallei*, *Burkholderia pseudomallei*, *Rickettsia prowazekii*, Ebola virus, Variola virus, *Francisella tularensis*, Junin virus, and *Yersinia pestis*. Thus, it is only for these 12 threat agents that PHEMCE can currently prioritize medical countermeasure research. PHEMCE's stated priority is to focus development of medical countermeasures on postexposure prophylaxis and postexposure treatment. Preventive measures such as vaccines and pre-exposure treatments are considered primarily for threats of "potential catastrophic consequence."[78] Thus, although Project BioShield has resulted in the acquisition of large amounts of smallpox and anthrax vaccines,[79] and although it continues to fund research into next-generation vaccines, the HHS deployment strategy, for the most part, reserves these vaccines for use following an initial attack or disease outbreak. Thus far, few U.S. civilians outside of the research and public emergency response communities have been vaccinated against anthrax or smallpox.

The PHEMCE strategy is divided into near-term (fiscal years 2007–2008), mid-term (2009–2013), and long-term (past 2013) programs; the goals of these programs are outlined in Table 29.6. The PHEMCE implementation plan states the HHS intention is to promote research to address emerging, enhanced, and advanced threats by adding flexibility into research programs for traditional agents.

U.S. MILITARY BIOLOGICAL WARFARE MEDICAL COUNTERMEASURES RESEARCH

1) Organizational Structure. Within the U.S. DoD, biological defense research, development, and acquisition programs are overseen within the Office of the Secretary of Defense by the Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs. DoD's biodefense research requirements are developed by a separate and independent organization, the Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense (JRO-CBRND), under the Chairman of the Joint Chiefs of Staff. The JRO-CBRND coordinates with the combatant commands and the individual military branches to develop a joint set of CBRN requirements that fit into an overarching CBRN defense architecture and strategic plan for implementation. Finally, the Defense Threat Reduction Agency's Joint Science and Technology Office for Chemical and Biological

Defense manages the funding for DoD biodefense research projects meeting the requirements and priorities set forth by the JRO-CBRND. The U.S. Army Acquisition Executive oversees product acquisition via the Joint Program Executive Office for Chemical and Biological Defense.

2) Funding. The Chemical and Biological Defense Program budget request for fiscal year 2008 was $1.57 billion. Several hundred million dollars of this is earmarked for biological medical countermeasures research. Both DoD and civilian researchers can apply for project funding from either DoD or civilian sources.
3) Priorities. In contrast to the civilian research program, DoD's biodefense medical countermeasures research embraces preventive measures such as vaccines (Table 29.6). Although the public may be somewhat unwilling to accept the perceived risks of vaccines and other preventative treatments for what are thought to be rare, unlikely, or nonlethal threat events, the military recognizes unique value in prevention for "preserving the fighting strength" of its personnel. In this regard, DoD is pursuing a vaccine for Venezuelan Equine Encephalitis virus, a nonlethal threat agent that has the potential to incapacitate, realizing that a military incapable of responding, even temporarily, could have dire consequences for national security. The DoD biodefense research budget, however, is challenged to fund vaccine research from discovery to acquisition, and purely preventive vaccines (i.e., not useful for postexposure prevention or ameliorization of disease, such as vaccines for *Yersinia pestis*) may not meet criteria for HHS funding.

CONCLUSION

Biological warfare has been a threat to humanity since ancient times and crude attempts at bioterrorism have been a growing concern for several decades. A renewed appreciation of the sinister potential of biological weapons has resulted from the glasnost that followed the end of the cold war and the migration of ex-Soviet scientists to the west. Similarly, an escalation of terrorist capabilities in the area of CBRN weapons was brought to public attention with Aum Shinrykyo's use of sarin in the Tokyo subway system, and the subsequent use of anthrax-contaminated letters in the United States in October 2001. As a result of this latter event, occurring as it did, on the heels of the September 11 terrorist attacks in New York and Washington, U.S. federal efforts in the area of biodefense have taken on a new sense of importance and urgency. Such efforts have evolved to include a wide spectrum of surveillance initiatives, security and biosecurity measures, countermeasures research and development, intelligence gathering, public health preparedness, and education. Other countries have initiated similar programs. Over time, these efforts have become more organized, better supported, and more focused.

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30

Nuclear and Radiological Events

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OVERVIEW

Large-scale Radiation Events: An Evolving Risk

Mass exposure to radiation does not occur frequently but when it does such events present significant logistical, operational, and medical challenges that may be compounded by the lack of familiarity most first responders and other medical personnel have with the manifestations and management of radiation injury. Because of the proliferation of nuclear states, the occurrence of at least one well-documented case of smuggling of nuclear technology, the widespread availability of radioactive materials, and continuing concerns about the risk of nuclear or radiological terrorism, the risk of deliberate mass exposures to radiation has likely increased in recent years. Additionally, there is an ever-present risk of mass radiation exposures, such as occurred after the Chernobyl accident and the ^{137}Cs dispersion event in Goiânia, Brazil.[1,2] The recent efforts of the United States and other nations to improve their capabilities to prevent or interdict nuclear smuggling, to enlarge the armamentarium of radiation countermeasures, and to disseminate information about the management of radiation casualties suggest the seriousness with which the threat of deliberate attack is regarded.[3] Numerous authors have summarized the publicly available information related to this threat, and the interested reader is referred to these sources for more detailed accounts.[4–7]

SCENARIOS OF CONCERN

Mass exposures to radiation may be accidental or deliberate in origin. Heretofore, all such incidents have been the result of accidents, with the notable exceptions of the exposures occurring as a result of the atomic bombings in Hiroshima and Nagasaki and the exposure of more than a hundred people to ^{210}Po in the wake of the Litvinenko poisoning.[8] The causes of accidental exposures have varied dramatically, as might be expected, ranging from criticality events (or "excursions," in which transient fission occurs) to the dispersion of radioactive materials (whether on a small or large scale) to the misadministration of radiation therapy. Selected incidents that are representative of the types of accidental exposures that may be encountered will be discussed in detail later in this chapter. Presented here are the general features of such accidents. Many of the deliberate exposures that could occur as a consequence of acts of terrorism are comparable in scope and effect to some of the accidents. Therefore it is useful to summarize the nature of such threats. The threat of nuclear terrorism, however, is unique. The detonation of a moderate-sized (10- to 15-kT) device in a densely populated urban area would essentially reproduce the effects of the bombings of Hiroshima and Nagasaki and result in thousands or tens of thousands of fatalities.

Criticality Accidents

Criticality accidents ("excursions") have occurred during the assembly or disassembly of nuclear weapons, the processing of solutions containing fissionable materials, and as a result of accidents within nuclear reactors.[9–11] Criticality accidents are typically associated with significant mixed-field exposures (i.e., neutron and gamma radiation) but are not associated with blast or thermal injury. In and of themselves, criticality accidents do not result in contamination of the environment or geographically extensive exposures and pose a threat mainly to workers in the immediate vicinity of the causative nuclear materials. Victims of some criticality accidents have received exceptionally high doses (>40 Gy), and these cases have been associated with highly accelerated mortality, with death occurring 1–7 days postexposure.[9] Since 1945, approximately 60 such accidents have occurred, not all of which have resulted in significant human exposures.[9] Mettler and colleagues cite 18 known deaths from acute radiation syndrome caused by such accidents over this period.[12] Several of these accidents will be summarized at the end of the chapter.

Nuclear Power Plant Accidents

At the time of this writing, the explosion and subsequent fire in a graphite-moderated reactor at the Chernobyl nuclear power station on April 26, 1986 remains the most significant radiation accident in history in terms of the amount of radioactivity released, the area affected, and the number of people exposed.

Approximately 50 MCi of radioactivity (representing <4% of the reactor's total radionuclide inventory) were released into the environment before the fire in the reactor was extinguished on May 6, 1986, resulting in serious contamination of local regions and trace contamination throughout Eastern and Western Europe. The primary contributors to the released radioactivity were radiocesiums and radioiodines. Within ten days of the accident, elevated levels of radioactivity were detected as far away as Israel, Kuwait, China, Japan and the United States.[13] Following is a summary of the salient features of the accident; the acute and long-term health effects of the accident have received comprehensive assessment elsewhere.[1,13]

The accident and subsequent release of radioactivity at Chernobyl were directly related to the design of the reactor, which had a water-cooled graphite core. In such reactors, graphite is used to moderate the chain reaction initiated by the decay of ^{235}U, slowing the emitted neutrons and increasing their propensity to strike other ^{235}U nuclei. Graphite is a very efficient moderator and offers two advantages over water, which can also be used as a moderator: first, it is such an efficient moderator that it can sustain fission in naturally occurring, unprocessed uranium (water-moderated reactors require enrichment of ^{235}U from its natural 0.7% up to at least 3%); second, graphite-moderated reactors produce more weapons-grade plutonium than water-moderated reactors, and the plutonium is easier to recover. Water has one major advantage over graphite as a moderator: reactors using water as a moderator have a built-in fail-safe mechanism. Whereas graphite-moderated reactors use water as a critical coolant to slow down and control the chain reaction, such that a failure in the water-cooling system can lead to an escalation of fission (as occurred at Chernobyl), the water in a water-moderated reactor directly facilitates the fission itself. Any change in conditions within the reactor resulting in increased fission and heat causes the water to boil, reducing its availability to serve as a neutron moderator, slowing down the chain reaction and reducing the temperature. Water-moderated reactors thus have a natural negative-feedback mechanism built into their design that functions independently of any human operator.[14] Types of reactors and regulations governing reactors vary by country. For example, by regulation, all nuclear reactors operating in the United States use water as a moderator. Other regulations mandate broader shutdown margins, more robust containment structures, and more stringent procedural controls than were operative at Chernobyl.[15] These layered safety mechanisms are the basis of the common assertion that a Chernobyl-like accident could not occur in the United States.

Two other significant nuclear power plant accidents have resulted in the release of radioactivity into the environment. The first, a fire in the graphite-moderated, air-cooled Windscale facility in Cumbria, England in October 1957, resulted in the release of approximately 20,000 Ci of radioactive material, primarily ^{131}I, ^{137}Cs, and ^{210}Po, into the surrounding countryside, although no acute injuries were attributed to the accident.[16] The U.S. Nuclear Regulatory Commission attributed the partial meltdown of the water-moderated Three Mile Island 2 reactor in March 1979 to a sequence of equipment malfunctions, design-related problems, and human errors. Although approximately one half of the core melted in the accident, the meltdown did not result in a breach of the containment system and the amount of radiation released had trivial medical and health consequences, with the average dose to populations in the area being approximately 1 mrem and the maximum doses estimated at less than 100 mrem (a computed tomography [CT] scan, by comparison, can result in an effective dose of up to 1 rem).[17]

The potential for the accidental release of spent nuclear fuel from its temporary storage facilities has led to plans for the establishment of a centralized geological repository. Currently within the United States, more than 50,000 tons of high-level nuclear waste and spent fuel is stored in pools or dry casks at 72 sites in 33 states.[18] Three quarters of these locations are within 50 miles of major population centers and more than 160 million people live within 75 miles of a nuclear waste storage facility.[19]

Radionuclide Exposures

As described previously, nuclear power plant accidents leading to the release of radioactive materials could cause widespread environmental contamination with a variety of radionuclides. There are also numerous nonnuclear scenarios that could lead to the dispersion of radionuclides and the internal or external exposure of affected populations. Three such scenarios were the exposures that occurred in Lilo, Georgia; Goiânia, Brazil; and along the Techa River in Russia.

The accident in Lilo, Georgia involved orphan (abandoned) radiation sources that had been left behind at a civil defense training site by the Soviet Army when Georgia gained its independence in 1991. Between July 1996 and October 1997, 11 young military recruits presented for evaluation with nausea, headache, weakness, and skin lesions that evolved to ulceration and necrosis requiring prolonged medical care. Because they received medical care in a variety of facilities, there was a significant delay in the recognition of the links between the cases and the location of the lost radiation sources. Ultimately, investigators discovered multiple ^{137}Cs, ^{60}Co, and ^{226}Ra sources during radiation surveys of the training facility. Apparently the Georgian recruits found some of these sources and at least one was placed into the pocket of a soldier's winter jacket, which evidently was shared among several recruits who subsequently developed symptoms of radiation sickness.[20]

More widespread dispersion of radioactive material occurred as a result of an accident involving another orphan source in Goiânia, Brazil in 1987. On September 13 of that year, two peddlers removed a medical teletherapy source containing 50.9 TBq (1,375 Ci) of ^{137}Cs from an abandoned radiotherapy clinic. They removed the rotating assembly of the shielding head of the device and subsequently ruptured the source canister itself before selling the assembly containing the damaged source to the owner of a junkyard. This individual, noticing the blue glow emanating from the device, brought it home, where the CsCl salt it contained became widely dispersed. In addition, this new owner of the device showed it to multiple people in the local community because a glowing object like this was considered special in Brazilian society. Sixteen days passed before health authorities recognized that a radiation exposure had occurred, during which time a significant number of homes, public places, and vehicles became contaminated. Recognition of the accident generated significant public anxiety and ultimately almost 113,000 people, of a local population of almost 1 million, presented for health screening; 249 showed evidence of contamination and 49 required medical treatment. Four persons died as a result of the accident.[21]

During the period 1949–1956, exposures along the Techa River in the former Soviet Union occurred as a result of the continuous discharge of radiochemical waste, primarily ^{90}Sr and ^{137}Cs, into the river from the Mayak weapons processing facility, with the most significant exposures (≤2 Gy/year for some individuals) occurring prior to 1952. Nearly 30,000 people were exposed, with the average effective equivalent dose assessed to be 320 mSv in the Chelyabinsk region and approximately 70 mSv in the Kurgan region. Inhabitants of villages along the upper Techa River were relocated over several years beginning in 1951, and affected populations have been followed medically since that time, now forming (with the atomic bomb survivors in Hiroshima and Nagasaki) one of the most important cohorts for the study of radiation carcinogenesis.[22]

These incidents varied tremendously in the duration and magnitude of the exposures that occurred and provide valuable data about the possible scenarios that could result from the accidental or deliberate release of radionuclides into the environment in the future.

Radiotherapy and Industrial Radiography Accidents

Accidents may occur if procedural safeguards against excess exposure during legitimate uses of radiation sources fail. Dozens of radiotherapy accidents, some involving hundreds of patients, have occurred in the last several decades, with some of these incidents resulting in iatrogenic deaths. One incident, for example, caused by an error in maintenance of a linear accelerator in a radiotherapy clinic in Zaragoza, Spain, resulted in significant exposure of 27 patients with 15 deaths. Another notable accident, in Costa Rica, attributed to the miscalibration of a ^{60}Co teletherapy device, resulted in the overexposure of at least 114 patients and 17 deaths.[23] Accidents at commercial irradiator facilities have occurred sporadically, typically involving one or at most a few individuals and have occasionally resulted in fatalities.[24]

Terrorist Threat Scenarios

Authorities have frequently expressed concern that motivated terrorists could use radioactive materials in attacks on civilian populations. Radiation sources are comparatively accessible and many of the scenarios of concern would not require a great deal of technical sophistication on the part of the perpetrators.

Radiological Terrorism

A frequently discussed scenario is the detonation or deployment of a so-called radiological dispersal device. Such dispersion could be overt, as would be the case with the detonation of a "dirty bomb" (an improvised explosive device containing radioactive material), or covert, as would be the case if radioactive materials were dispersed surreptitiously, perhaps through ventilation systems or through food and water supplies. Some experts have argued that the public health threat from "dirty bombs" is mainly related to the conventional explosives they contain, and that the medical and health effects of any radioactive materials dispersed by a "dirty bomb" would be minimal. Such experts have classified "dirty bombs" as "weapons of mass disruption" rather than "weapons of mass destruction." Other authorities have disagreed, believing that such weapons, if properly constructed and delivered, would pose a significant radiation risk to affected civilian populations.[25] In any case, timely and appropriate crisis and emergency risk communication will be an important factor in minimizing the public health impact of a dirty bomb.

The surreptitious placement of a radiation source in environments where people are likely to have prolonged exposures (such as on airplanes or subways or in movie theaters) could result in the exposure of a significant number of people before the hidden source (a radiological exposure device or RED) is recovered. In an unusual demonstration, Chechen rebels surreptitiously placed a ^{137}Cs radiation source in a park in Moscow in 1995, then notified authorities. No one was harmed in this incident, which nevertheless remains one of the most well-known acts of radiological terrorism.[26]

Nuclear Terrorism

The most ominous scenario involves the detonation of an improvised nuclear device. Although it is unlikely that a terrorist group would ever have the wherewithal to establish a uranium enrichment program (such programs being phenomenally expensive and requiring a great deal of specialized equipment and technical expertise), it is not impossible that terrorists could acquire fissionable materials in quantities sufficient to fashion a crude nuclear device (a so-called improvised nuclear device). It is also theoretically possible that terrorists could obtain a device from a sympathetic, corrupt, or incompetent regime that possessed such weapons. The possibility that such illicit transfers might occur in the period immediately following the collapse of the Soviet Union inspired the U.S. Nunn–Lugar Cooperative Threat Reduction Program, which has helped secure and deactivate thousands of nuclear warheads since its inception in 1991.[27] More recently, the activities and Islamist sympathies of A.Q. Kahn, the "father" of Pakistan's nuclear weapons program, raised concerns about the possibility of al-Qaeda's obtaining a nuclear device.[28] In terms of casualties and economic costs, the detonation of a nuclear weapon in an urban environment would dwarf the events of September 11, 2001. Although the likelihood of such an event is undoubtedly remote, the potential consequences have led many elected officials to regard nuclear terrorism as the single greatest threat to U.S. national security.[29]

Nuclear Detonation Effects

This section summarizes the prompt and delayed effects of fission explosions in the range of energy yields (10–15 kT) expected from an improvised nuclear device. Almost uniformly, nuclear security experts believe that the need for specialized and strictly controlled nuclear materials and highly sophisticated, industrial-level engineering capabilities preclude terrorists from obtaining, constructing, or using high-yield (megaton-range) thermonuclear devices and consequently the effects of these devices are not discussed here.

General Considerations

The yield of a nuclear detonation is described in terms of the mass of conventional high explosives (TNT) required to produce comparable effects. The detonation of a 1-kT device generates 10^{12} calories, releasing neutrons and gamma radiation from the fissioning nuclei and heating the other weapon components to tens of millions of degrees.[30] This intense heat causes any matter in the immediate vicinity of the detonation to emit radiation, mainly in the form x-rays, which heat the surrounding air. These x-rays produce an expanding sphere of heated gas, which in turn heats and vaporizes materials, releasing additional radiation, for a considerable distance from the detonation point. The shock wave produced by the detonation topples or severely damages buildings, shatters windows, turns loose objects into projectiles, and causes profound trauma to

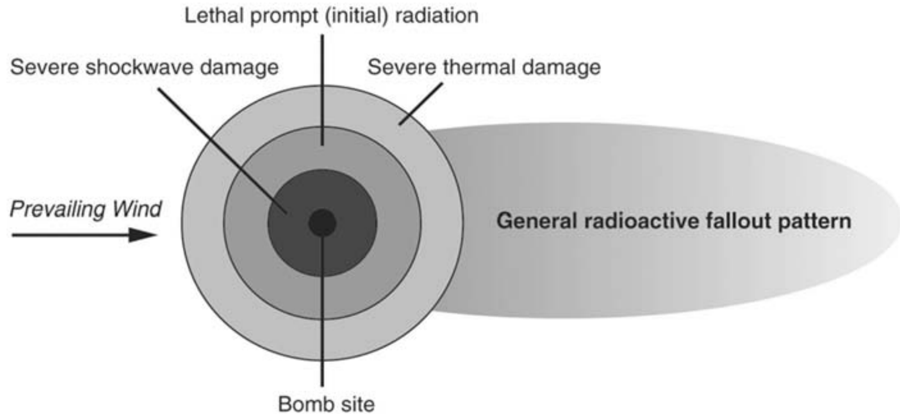

Figure 30.1. Flat-plain damage patterns from a ground-level nuclear detonation (viewed from above). See color plate.

persons in its path. Simultaneously, radioactive fission products and neutron-activated debris are propelled upward into the atmosphere by the explosion. This material ultimately deposits downwind of the detonation as radioactive fallout.

A nuclear detonation will produce two kinds of casualties: victims with "prompt" injuries, reflecting the immediate blast, thermal, and radiation effects of the detonation, and victims with radiation injuries occurring as a result of exposure to fallout. Although the prompt and fallout effect areas partially overlap, in general they demonstrate significant spatial separation (Figure 30.1).

Exposures to fallout after a nuclear detonation will vary according to distance, meteorological conditions, and the available shelter. If the graphic depicted in Figure 30.1 represented a 10-kT ground detonation, fallout would arrive at a location 2.5-km downwind after approximately 1 minute. Approximate dose rates that might be measured 2.5 km downwind at different time intervals after the detonation are provided in Table 30.1.[31]

As Table 30.1 demonstrates, dose rates decline rapidly over time as fission products with short half-lives decay, so the importance of obtaining shelter cannot be overstated. Underground shelters can substantially reduce doses from fallout, but if basement shelters are not available sheltering away from the ground in the upper floors of buildings (assuming windows are closed and intact and heating and ventilation systems are turned off) can also provide enhanced protection when compared with ground-level shelters. The quality of a shelter's building materials influences the degree of protection it affords, with stone office buildings, for example, providing more shelter than a wood frame house.

Table 30.1: Estimated Dose Rates at Different Time Intervals at Point 2.5 km Downwind from a 10-kT Nuclear Detonation

Time Postdetonation	*Outdoor Exposure Rate From Fallout*
1 min	300 Gy/min
15 min	0.25 Gy/min
120 min	0.03 Gy/min
480 min	0.001 Gy/min

Prompt Effects

Prompt effects are those occurring as a direct result (and within the first minutes) of the detonation. They encompass radiation, blast, and thermal effects, which are described briefly herein.

RADIATION EFFECTS

Prompt radiation includes neutrons and gamma rays emitted as a direct result of fission, alpha and beta particles and gamma radiation emitted by unstable fission products, and radiation emitted by neutron-activated debris swept up into the fallout cloud from the immediate vicinity of the detonation. Prompt radiation doses decline according to the inverse square law, but are sufficient to produce signs and symptoms of acute radiation syndrome at distances up to approximately 1.5 km from a 10-kT detonation. Within this radius, terrain and building structures may provide shielding from the thermal radiation but will not greatly attenuate the neutron and gamma radiation.

BLAST EFFECTS

The blast wave accounts for approximately 50% of the energy released by a nuclear detonation. Consequently, blast effects make the greatest single contribution to the immediate damage caused by the detonation. The blast wave moves outward from the point of detonation at supersonic velocity, generating winds of up to several hundred kilometers per hour. Injury and lethality due to blast effects are very difficult to predict because of the varied and complex mechanisms whereby the shock wave can interact with structures and people. Modeling suggests that many or most casualties receiving a prompt radiation dose exceeding a few hundred centiGray will probably die from blast effects.

THERMAL EFFECTS

Thermal radiation (heat) accounts for approximately 35% of the energy released by air bursts such as those at Hiroshima and Nagasaki (this percentage will be reduced if the detonation occurs at ground level). Thermal radiation will produce primary and secondary burn injuries, with primary burns caused by direct exposure to the thermal pulse, and secondary burns occurring as a result of the incendiary effects of the thermal radiation on inflammables. In certain environments, firestorms may ensue as a result of the coalescence of individual fires. Modeling suggests that burns will be severe at distances of up to 1 km for a 1-kT burst and up to 3–4 km for a 10-kT detonation. Within these

Table 30.2: Yield of Fission Products

Element	*Percentage Yield*
Strontium-90	5.8
Cesium-137	6.2
Xenon-135	6.5
Rubidium	7
Cerium	9.3
Molybdenum	11.3
Zirconium	12.5
Barium	12.6
Iodine	21.7
Yttrium	24

zones, burn lethality will be enhanced in victims experiencing blast and radiation effects.

Fallout

Ground bursts aerosolize more radioactive debris, with a wider range of particle sizes, than air bursts with the particles of larger size tending to precipitate sooner. Ground bursts thus produce more (and more concentrated) fallout than air bursts. Such fallout poses an extreme radiological hazard to downwind populations. The deposition of fallout will be heavily influenced by weather patterns and may not be uniform, with some areas ("hotspots") receiving greater amounts than others as a result of local meteorological conditions.

FALLOUT COMPOSITION

Fission of nuclear weapons materials may generate more than 300 isotopes of 36 different elements, with each isotope having a unique specific activity and half-life (precise fission yields are dependent on the fissioning isotope and the energy of the neutrons causing fission).[30] In addition to these fission products, the fallout cloud produced by a ground burst will carry a substantial amount of neutron-activated debris. Table 30.2 provides estimates of fission yields for some of the more prevalent elements produced by the fission of ^{235}U by slow neutrons (the combined yield exceeds 100% because each fission results in two products).[32] Elements listed by name only are represented by multiple isotopes. Due to the differential radioactive decay as the fallout cloud travels downwind, the isotopic composition of deposited fallout will change from location to location and over time.

Most of the isotopes occurring in fission products emit beta particles and a high percentage of the beta emitters also emit gamma radiation. Beta particles emitted by the fallout can produce cutaneous burns when fallout particles remain in contact with skin for extended periods. Beta burns were the most prominent clinical manifestation in Marshall Islanders after exposure to fallout in the early 1950s, for example. Because beta particles are not penetrating, however, beta exposure will not contribute significantly to bone marrow doses and thus will not produce many of the systemic features of radiation exposure. Gamma rays, which are penetrating, will constitute by far the greatest contributor to bone marrow dose from fallout. Few if any of the fission products are alpha emitters, but alpha emitters will be represented in fallout in the form of unfissioned ^{235}U or ^{239}Pu. That

Table 30.3: Fallout Doses in First Hour

Range (km)	*1 kT detonation (Sv)*	*10 kT detonation (Sv)*
1	4,100	32,000
2	58	930
4	14	79
8	3.3	13
10	1.9	7.3
20	0.12	0.64
40	minimal	minimal

being said, the radioactivity of the fission products is far greater in aggregate than the activity of the dispersed fissile material and constitutes a much greater threat to downwind populations. Neutron radiation is not a component of fallout.

Among the isotopes in fallout of greatest concern are ^{90}Sr, which has a long half life, concentrates in bones and teeth, and emits a high-energy beta particle; ^{137}Cs, which has a long half-life, emits gamma rays, and behaves biologically like potassium (and thus, if consumed by grazing animals, can be passed up the food chain in contaminated meat or milk products); and the iodine isotopes, which have moderate half-lives (e.g., 8 days for ^{131}I) and are avidly taken up by the thyroid, producing a significant cancer risk in younger individuals.

DYNAMIC DOSE RATES DUE TO FISSION PRODUCT DECAY

Doses and dose rates due to fallout reflect its patterns of deposition and thus are heavily influenced by meteorological conditions and other factors. The behavior, and to some extent the composition, of fallout produced by a ground burst in an urban environment affected by microclimate features is difficult to model precisely. Table 30.3 gives approximate predicted radiation doses received by fully exposed individuals directly under the fallout plume at various distances from the point of detonation for the first hour following a 1- or 10-kT surface detonation.[31] It is clear from the calculated doses, rough approximations that they are, that the initial dose rates produced by fallout are extremely high (the low doses at large distances will increase as the major part of the fallout plume passes over). Early evacuation and/or sheltering, if feasible, are thus among the most important and effective strategies for reducing exposure.

Fortunately, most of the radioactive isotopes in fallout decay rapidly. Table 30.4 shows the rate of fallout decay, expressed as a

Table 30.4: Fallout Decay[172]

Time after Detonation (h)	*Percentage of Dose Rate at 1 h*
1	100
2	43
4	19
6	11
8	8
10	6
12	5

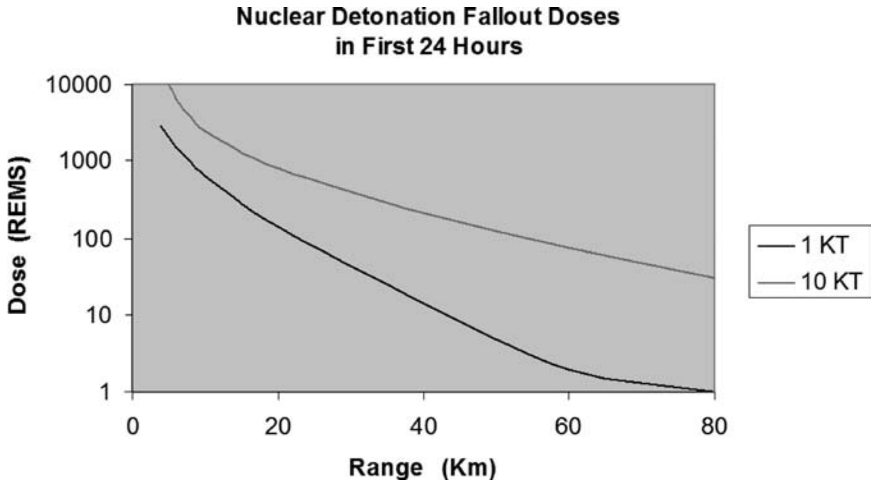

Figure 30.2. Estimated cumulative 24-hour fallout dose from HOTSPOT model.

percentage of the dose rate at 1 hour, during the first 12 hours following detonation.[30]

Because of the high early dose rates, however, the cumulative doses observed in exposed populations can still be quite elevated. Figure 30.2 shows estimated cumulative doses at different distances for fully and continually exposed populations for the first 24 hours following a detonation.[31] Such dose estimates have to be considered merely illustrative because individuals almost certainly will move in and out of shelters and through areas with different degrees of fallout deposition during this time period.

BENEFITS OF SHIELDING

The most effective way to reduce exposure to fallout is evacuation, but for a variety of reasons this may be difficult to accomplish within the appropriate timeframe. Sheltering in place may be more feasible and can provide substantial protection against exposure. Table 30.5 shows the estimated dose reduction factors for different types of shelter.[30]

CURRENT STATE OF THE ART

Basics of Radiation Biology

Ionizing radiation may be electromagnetic (gamma rays or x-rays) or particulate (alpha particles, beta particles, and neutrons) in origin. Both electromagnetic and particulate forms of ionizing radiation can contribute to the radiation injury sustained after accidental or deliberate exposures. Depending on the nature of the precipitating event, the radiation exposure for a given individual may be classified as localized or whole body and may, where the dispersion of fallout or other radioactive materials is involved, result in internal or external deposition of radioactive materials.

Table 30.5: Shelter Dose Reduction Factors[173]

Type of Shelter	*Dose Reduction Factor*
0.3 m underground	0.0002
Frame house	0.3–0.6
Basement	0.05–0.1
Upper stories of apartment	0.01
Shelter with 0.6 m earth cover	0.005–0.02

The acute radiation syndrome (ARS) encompasses a set of complex pathophysiological processes precipitated by exposure to high doses of radiation. The latency, severity, and duration of the various manifestations of ARS are a function of the organ system affected, the radiation dose and dose rate, and the "quality" (particulate or electromagnetic) of the precipitating exposure. Much of the immediate damage at the cellular level caused by radiation is nonspecific and mediated through the generation of free radicals and peroxides. Nonspecific lipid peroxidation, DNA damage, and protein oxidation lead to alterations of gene transcription and mRNA translation as part of the cellular stress response, ultimately resulting in changes in the tissue microenvironment promoting inflammation and precipitating cell death. Inflammation and cell death, in turn, result in tissue and organ damage which in patients receiving sufficiently high doses of radiation can trigger a cascade of events leading to multiorgan failure and death. It is clear from both animal experiments and accidental high-dose exposures in humans that the kinetics of lymphocyte, neutrophil, and platelet depletion – and the time course of ARS symptoms in general – are accelerated at higher doses.

Knowledge of the acute effects of ionizing radiation on human subjects has been derived from

1) Animal studies
2) Studies of Japanese populations exposed to radiation from atomic weapons
3) Studies of normal tissue injury in patients receiving radiation therapy, typically for cancer
4) Accidents involving radiation workers, radiotherapy patients, and (rarely) civilian populations

The value of the first source of data is limited by inherent uncertainties about interspecies extrapolations. Studies of Japanese atomic bomb survivors have helped quantify the risk of secondary malignancies and other late effects of radiation exposure, but this population has provided less insight into ARS because few detailed clinical or laboratory data were collected immediately after the attacks. Radiation oncologists have gained extensive experience managing side effects in radiotherapy patients, but such patients are typically treated with fractionated and

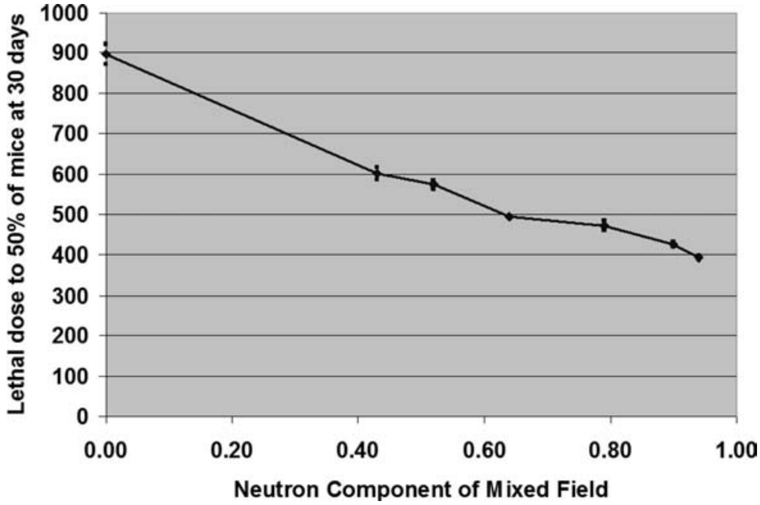

Figure 30.3. Effect of fission–neutron dose fraction on LD_{50} in mice. Data provided by the Armed Forces Radiobiology Research Institute.

highly focal therapy (minimizing systemic effects), are often heavily prophylaxed prior to treatment, and may experience symptoms or side effects related to their primary diseases or other concurrent therapy, so it has been difficult to use this clinical experience to develop protocols for the management of ARS. The most reliable information about ARS is derived from victims of radiation accidents. Not surprisingly, accidental exposures have been highly variable, ranging from the inhalation of alpha emitters in plutonium production and processing facilities to exposure to mixed gamma/neutron fields produced by criticality accidents. The most nearly contemporary large cohort of patients with ARS consisted of Chernobyl emergency workers who received high-dose exposures during the initial response to the accident These workers were subjected to the combined effect of radiation from several sources: 1) short-term external gamma/beta radiation from the gas emission cloud (in the case of persons in the immediate area of the accident zone at the time of the explosion); 2) external gamma/beta radiation of decreasing intensity, from fragments of the damaged reactor core scattered over the site; 3) inhalation of gases and aerosol dust particles containing a mixture of radionuclides reflecting the radionuclide inventory of the reactor core at the time of the accident; and 4) deposition of these particles on the skin and mucous membranes.[33] Few of the accidents that have occurred have been good surrogates for the types of exposures that would be encountered following the detonation of a nuclear device or the deposition of fallout. A notable exception was the accidental exposure of inhabitants of the Marshall Islands to fallout from the detonation of a nuclear device in 1954. Exposures prior to evacuation were estimated to be less than 2 Gy in the most severely exposed, with beta burns and mild depression of blood counts being the predominant acute effects.[34]

Estimates of the gamma dose lethal to 50% of persons exposed within 60 days of irradiation (the $LD_{50/60}$) range from approximately 350 cGy for unsupported adults to 600–700 cGy in persons receiving optimal supportive care, antimicrobials, and transfusion support.[35] In medically austere environments, or in the presence of combined injuries, the $LD_{50/60}$ will likely decrease substantially. For example, it has been estimated that the LD_{50} for victims of the atomic bombings was approximately 220 cGy.[36]

Determinants of Biological Effects

Dose Rate

The rate and degree of fractionation with which a radiation dose is delivered is an important determinant of the overall biological effects and this fact is exploited by radiation oncologists who seek to maximize tumor kill while minimizing normal tissue effects by administering the prescribed radiation to target tissues in a series of small doses delivered daily over several weeks. In terms of lethality, studies in small animals have demonstrated that for continuous exposures the gamma/x-ray $LD_{50/30}$ declines as dose rates increase.[37] For example, Neal found that the $LD_{50/30}$ in mice declined from 1100 cGy to 790 cGy as the dose rate increased from 2.5 cGy/minute to 706 cGy/minute.[38] These findings are generally consistent with observations in humans, although it has not been possible to test this hypothesis systematically.[39]

Radiation Quality

The quality of radiation received is an important determinant of the biological effects observed for a given dose. Neutron radiation, for example, consists of unbound neutrons and is more penetrating than alpha or beta radiation but less penetrating than gamma radiation. Because neutrons are comparatively heavy particles with a moderate degree of penetration, neutron radiation has a high relative biological effectiveness (RBE). The RBE in canines for an exposure with a mixed radiation field having a neutron/gamma ratio of 5.4:1 is approximately 1.7 (i.e., the ratio of the $LD_{50/30}$ with gamma radiation alone to the $LD_{50/30}$ of the mixed field is 1.7:1).[40] Consistent with the higher RBE observed for neutrons, increasing the neutron/gamma ratio at a fixed exposure has been shown to accelerate and prolong the suppression of white blood cell counts.[41] The effect of increasing fractions of fission neutrons on survival in rodents is illustrated in Figure 30.3.[42,43]

Alpha particles, which consist of two protons and two neutrons (and thus are identical to the nucleus of a helium atom), are charged and relatively heavy. They interact intensely with atoms in materials they encounter, dissipating their energy over a very short range, and thus are not highly penetrating. As such, adequate shielding against alpha particles can be provided by a single sheet of paper and external exposures do not present a significant hazard. Because they are highly ionizing, however, their RBE is substantially greater than that of gamma rays and they can significantly damage cells and tissues if internalized.

Beta particles are electrons emitted from the nucleus of a radionuclide by the decay of a neutron into a proton, an electron, and an antineutrino. The energy of the ejected beta particle can vary. Some energetic beta particles may penetrate tens of millimeters into the skin and thus pose both an external and an internal hazard. "Beta burns" are characteristic of exposure to fallout, which contains a high number of beta-emitting radionuclides.[34]

Differences in radiation quality may have implications for the development of radiation countermeasures. Neutrons, for example, are more likely to cause damage by direct effects on cellular macromolecules than gamma radiation (which mediates its effects indirectly through the generation of free radicals). Consequently, fission-spectrum neutrons appear to be significantly more mutagenic and thus potentially more carcinogenic than gamma radiation. In hybrid B6CF$_1$ mice, a 97% neutron exposure of 150 cGy is approximately equivalent in mutagenic potential to 750 cGy of ^{60}Co gamma rays. For this strain of mice, amifostine administered prior to neutron exposure had a dose reduction factor of 1.4 for mutagenic endpoints, whereas for gamma exposures, the dose reduction factor was 2.4.[44]

Physiological Variables

Cells are most sensitive to ionizing radiation during mitosis and one of the chief determinants of the sensitivity of individual tissues (and thus of organs) is the rapidity of cell division occurring at the time of irradiation. Consequently, tissues with high rates of cellular turnover, such as bone marrow and the gastrointestinal (GI) epithelium, are exquisitely sensitive to radiation whereas tissues with low rates of turnover (e.g., muscle, kidney) are intrinsically radioresistant.

In individuals, specific genetic defects that cause impaired DNA damage recognition and repair, such as mutations in the *ATM* (ataxia-telangiectasia mutated) or *NBS1* (Nijmegen breakage syndrome) gene loci, are associated with profound hypersensitivity to ionizing radiation and a predisposition to malignancy. Ataxia-telangiectasia and Nijmegen breakage syndrome are both autosomal recessive disorders, and it is possible that some degree of heightened radiosensitivity could occur in persons heterozygous for mutations in these genes. The incidence of heterozygosity for such diseases, however, is low, representing no more than 1%–2% of the population for *ATM* mutations and significantly lower than that for *NBS1* mutations.[45,46] Other genetic lesions associated with radiosensitivity have been identified, but all such diseases are rare and most of the variability observed in radiosensitivity between individuals is not associated with known single nucleotide polymorphisms or other genetic defects.

Studies (primarily in rodents) of the contribution of physiological variables to radiosensitivity demonstrate that significant differences are observed between strains in this regard, confirming that complex genetic factors are important determinants of radiosensitivity. Age and sex also appear to account for observed differences in the lethality of radiation exposures, with older and younger animals and females exhibiting lower $LD_{50/30}$ values.[47–49] Whether such variables influence outcomes after acute exposures for large animals or humans has not been determined.

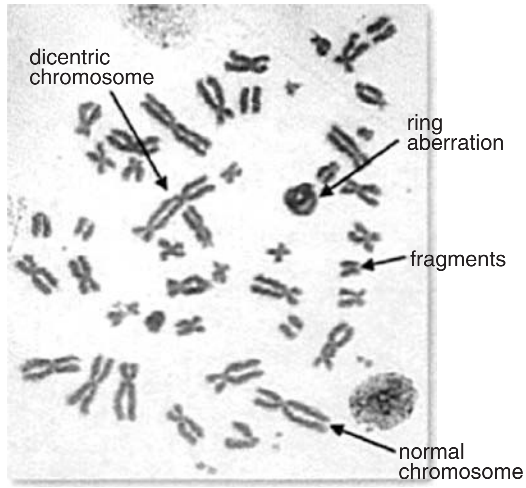

Figure 30.4. Cytogenetic abnormalities noted after irradiation in peripheral blood lymphocytes of a patient exposed to high-dose radiation. Dicentric chromosomes and ring abnormalities are relatively radiation-specific and are characteristic of changes observed. See color plate. Used with permission from REAC/TS.

BIODOSIMETRY AND RADIOLOGICAL TRIAGE

Cytogenetic Biodosimetry

The major determinant of clinical outcome following an acute radiation exposure is the dose received by the affected individual. Estimating this dose (in a process termed "biodosimetry") thus becomes a critical part of clinical management of such individuals. Of the many biodosimetry techniques that have been evaluated, the measurement of cytogenetic changes has been and remains the gold standard for radiation dose estimation (Figure 30.4). The current gold standard for cytogenetic biodosimetry is the lymphocyte metaphase-spread dicentric assay, in which lymphocytes are stimulated to divide and then incubated with colcemid to arrest the dividing cells in metaphase. Metaphase chromosome spreads are then prepared on microscope slides and radiation dose is estimated by quantifying the incidence of dicentric chromosomes. This assay is extremely labor intensive and sample preparation and scoring take a minimum of 72 hours. With the advent of concerns about radiological or nuclear terrorism and the potential that such attacks could result in large numbers of casualties, the need for more rapid and more accurate forms of radiological triage has increased. To address this and other challenges in triage, the U.S. government sponsored an International Conference on Biodosimetry and the 7th International Symposium on ESR Dosimetry at the Uniformed Services University of the Health Sciences in 2006. The following discussion has been adapted from papers presented at that conference.[50]

Prior to 1960, determination of dose relied on the reconstruction of the accident (including health physics studies and time and motion simulation) and analysis of any physical dosimeters that might have been present. Medical management was reactive, heavily weighted toward clinical response to the evolution of various syndromes characteristic of ARS or of acute local cutaneous injury. Since that time, the dicentric chromosome assay has been extensively developed and harmonized to international standards.

Table 30.6: Proposed Biodosimetry Technique as a Function of Expected Dose

Dose Range (Gy)	*Proposed Validated Dosimetry Method*	*Prodromal Effects*	*Manifest Symptoms*	*Survival Expectancy*
0.1–1	Dicentric/PCC	None to mild (1–48 h)	None to slight decrease in blood count	Almost certain
1.0–3.5	Lymphocyte depletion kinetics/ dicentrics/PCC	Mild to moderate (1–48 h)	Mild to severe bone marrow damage	0%–10% Death
3.5–7.5	Lymphocyte depletion kinetics/ PCC	Severe (1–48 h)	Pancytopenia, mild to moderate GI damage	10%–100% Death within 2–6 wk
7.5–10.0	Lymphocyte depletion kinetics/ PCC	Severe (<1 h–48 h)	Combined BM and GI damage	90%–100% Death within 1–3 wk
>10.0	PCC	Severe (mins to <48 h)	GI, neurological, cardiovascular damage	100% Death within 2–12 d

BM, bone marrow; GI, gastrointestinal; PCC, chromosome condensation. Used with permission from NATO/RTO and Prasana.

Because cytogenetic analysis is time-consuming and labor intensive, other, less precise techniques have been developed that enable the treating physician to estimate the relative magnitude of a patient's exposure fairly quickly and with some degree of confidence. The early initiation of therapy based on such techniques may offer critical benefits, as studies indicate that the likelihood of survival can be significantly increased with appropriate aggressive medical intervention and care.[51] For purposes of acute triage after a radiation event, some authorities have recommended that medical personnel rely heavily on clinical signs, lymphocyte kinetics, the time to emesis, and, as resources permit, cytogenetic biodosimetry.[52,53] The Biological Dosimetry Team at the U.S. Armed Forces Radiobiology Research Institute (AFRRI) has developed a multiparameter triage scheme that provides an immediate statistical evaluation of dose.[54] These techniques have been incorporated into a diagnostic program adapted for the laptop computer and, more recently, for handheld PDAs (Biodosimetry Assessment Tool, available online at http://www.afrri.usuhs.mil/outreach/biodostools.htm).

Standardized international protocols have been established for the conventional lymphocyte metaphase-spread dicentric assay, which has been used over several decades to guide the management of victims with severe radiation exposure. More recently, another cytogenetic test, the premature chromosome condensation (PCC) assay, has been shown to offer certain advantages over conventional metaphase-spread chromosome-aberration biodosimetry techniques.[55] The latter techniques are robust, but as mentioned previously they are laborious and time-consuming. In addition, for potential high-dose irradiation above the median lethal dose, it is expected that radiation-induced cell death and delay in cell cycle progression into mitosis will interfere with dose estimation. To overcome this limitation, quantitative analysis of radiation-induced damage may be performed using resting peripheral lymphocytes in lieu of metaphase spreads. Use of interphase cytological assays, such as the PCC assay, can eliminate the inherent problems associated with the use of metaphase-spread cytogenetic assays. The PCC assay requires only a small amount of blood (~0.5 mL) and chromosomal damage may be visualized within a couple of hours of the blood sample becoming available. A modification of the PCC assay, the interphase-based rapid interphase chromosome aberration assay, is a simple alternative to the metaphase-spread based dicentric assay. In the rapid interphase chromosome aberration assay, damage involving specific chromosomes is analyzed in chemically induced PCC spreads after fluorescence in situ hybridization with specific whole-chromosome DNA hybridization probes. The use of fluorescence in situ hybridization greatly expands the dose range over which the PCC technique can be used and facilitates the recognition of chromosome exchange aberrations.[56] In summary, PCC techniques are reliable at a wide range of doses and may be used to characterize low-dose exposures as well as life-threatening acute high doses of both low-linear energy transfer radiation, such as gamma rays, and high-linear energy transfer radiation, such as neutron or alpha particle radiation.[57] In addition, PCC assays can discriminate between total- and partial-body exposures.

In 2000-2001, radiation experts suggested that the dicentric assay could be adapted for the triage of mass casualties.[58,59] Lloyd and colleagues described an ex vivo simulation of an accident with mass casualties receiving whole- or partial-body irradiation in the 0- to 8-Gy range. Faced with a hypothetically urgent need for rapid results, clinical triage was accomplished by scoring as few as 20 metaphase spreads per subject, compared with the typical 500–1,000 spreads scored in routine analyses for estimating dose. In such a situation initially 20 cells could be scored per person and a preliminary dose communicated to the treating physicians. If the patient's clinical symptoms suggested a dose significantly higher than the preliminary screening estimate, the estimate could be improved by scoring up to 50 cells. Using the dicentric assay in this triage mode, a throughput of 500 or more patient samples per week per laboratory may be feasible.[60] Achieving such throughputs would facilitate rapid, accurate dose assessment for victims of all but the largest radiological incidents.

Table 30.6 lists AFRRI recommendations on the type of definitive biodosimetry to use when a preliminary estimate of a given dose has been obtained.[61]

Historical Experience with Early Phase Acute Biodosimetry

Table 30.7 lists selected radiation accidents where the dicentric and PCC biodosimetry techniques have played an important role in the clinical management of radiological casualties. More detailed summaries of some notable recent applications of the techniques are provided herein.

Table 30.7: Selected Use of Acute Phase Cytogenetic Assays in Radiation Accidents

Accident Location	*Year of Accident*	*Number of People Exposed*	*Dicentrics (Chromosomal Abnormalities)*	*PCC*
Cuidad Juarez, Mexico[62]	1984	7?	7?	N/A
Chernobyl, Russia[63]	1986	116,000	158	N/A
Goiânia, Brazil[64]	1987	250	129	N/A
Lilo, Georgia[65]	1986–1987	Multiple	4	N/A
Kiisa, Estonia[66]	1994	4	4	N/A
Istanbul, Turkey (multiple cases)[67]	1995	21	21	?18
Tokai-mura, Japan[68–70]	1999	3 Unknown	1 43	3
Meet Haifa, Egypt[71]	2000	7	5	N/A
Bangkok, Thailand[72]	2000	28?	28	28
Ghent, Belgium[73]	2005	1	1	1
Referral Laboratory – incident summary[74]	2003–2005	23	18	Uncertain
Referral Laboratory – incident summary[74]	1968–2003	996	996	Uncertain

Adapted from reference 50. Adapted from earlier work by Prasanna and colleagues (Prasanna et al., 2004).

Sevan'kaev has summarized the results of the cytogenetic studies of the 1986 Chernobyl incident.[63] Cytogeneticists used chromosomal aberration dosimetry in the acute phase of the Chernobyl accident as a method of dose assessment. A good correlation between doses calculated based on chromosomal aberrations (dicentrics) and severity of ARS was observed clinically.

Soon after the Chernobyl accident, a radiation accident involving a ^{137}Cs therapy source occurred in Goiânia, Brazil, in September 1987, in which more than 50 individuals were exposed to moderate to high doses (0.2–7 Gy) of gamma radiation. Radiation experts applied a cytogenetic technique (i.e., frequencies of dicentrics and rings in peripheral lymphocytes) in the acute phase to estimate absorbed dose.[64] Ramalho and Nascimento have described a follow-up study in which they found a two-log decline in the dicentric lymphocyte frequency. They reported an average disappearance half-time of lymphocytes containing dicentric and centric rings of approximately 130 days, which is significantly shorter than the value of 3 years usually cited in the literature.

The radiation accident at Tokai-mura in 1999 is a famous and well-studied uranium criticality accident that is important both because it was witnessed (allowing careful reconstruction of the event) and because physicians used multiparameter triage techniques in the acute phase medical management of the victims. Despite the very high radiation doses received by two of the victims (∼8 and 20 Gy, respectively), the frequency of chromosome aberrations in circulating lymphocytes was found to be a reliable indicator of the absorbed dose of radiation. Chromosome painting techniques were found to be accurate in the evaluation of both dicentrics and translocations.[68,70]

Table 30.8 presents a comparison between various acute phase techniques for this criticality event. All table entries represent data contemporaneous with acute patient care and not from a retrospective analysis. The physicians who attended the victims of this accident evaluated lymphocyte kinetics and other parameters in real time, and the results of chromosome biodosimetry were available quickly enough to impact clinical decisions when taken in the context of the patients' evolving ARS. These different techniques provided useful and generally consistent dose estimates that allowed meaningful inferences about each patient's prognosis. A general symposium proceedings including a retrospective improved analysis of the source term, power spectra, and medical treatment in this accident is available.[75]

Several groups have proposed modifications of cytogenetics protocols that would facilitate the use of such techniques after mass casualty incidents.[54,76] Standardization and validation of cytogenetic biodosimetry protocols between laboratories will be critical for the enhancement of overall capacity.[77]

Electron Paramagnetic Resonance Physical Dosimetry

Electron paramagnetic resonance (EPR) or electron spin resonance (ESR) spectroscopy is a technique for studying chemical

Table 30.8: Acute Phase Estimates of Dose (Gy) After the Tokai-Mura Event (1999)

Method	*Patient O*	*Patient S*	*Patient Y*
Na-24 blood (n only)	9.1	5.0	1.2
Rings + dicentrics	21	6.6	2.8
PCC (γ equivalent)	>20	7.8	2.6
Na-24 WBC			1.6
Lymphocyte kinetics	>10	6–10	1–4.5
Survival	Death 82 d postexposure	Death 210 d postexposure	Survival

Original work by Goans from reference 78.

Table 30.9: Selected Use of Acute Phase EPR in Radiation Accidents

Place of Accident	*Date*	*Type of Accident*	*Materials*
USA[78–81]	1991	Accelerator; various radiation accidents	EPR (bone; digits)
San Salvador[82]	1991	^{60}Co irradiator	EPR (bone; femur)
Tammiku, Estonia[85]	1994	RED	TL (quartz pots) EPR (sugar samples)
Georgia[83]	2001	RED	EPR (bone; vertebra, ribs)
Review of general and combined acute phase accident dosimetry[54,76,86–88]	2005	Overview of acute phase dosimetry	

RED, radiological exposure device; TL. Used with permission from Elsevier.

species that have one or more unpaired electrons. Paramagnetic centers (molecules or atoms with unpaired electrons) are produced by the action of radiation on materials. The paramagnetic centers created by ionizing radiation are proportional to the absorbed dose and EPR can be used as a nondestructive probe of the structure and concentration of these paramagnetic centers. In the EPR measurement, irradiated materials are placed in a magnetic field and electron spin transitions are induced by an electromagnetic field of the appropriate frequency (typically in the gigahertz range) and then quantitated.

Electron paramagnetic resonance differs from nuclear magnetic resonance in that with EPR electron spins are excited rather than the spins of atomic nuclei. Most stable molecules have all their electrons paired and thus are not detected by EPR techniques, which are sensitive only to paramagnetic species. From the perspective of biological dosimetry, this limitation is actually an advantage in that ordinary chemical solvents and matrices do not give rise to EPR spectra. Thus, the EPR technique is one of great specificity, and bone and teeth, serving in this capacity as natural physical dosimeters, have been found to provide the EPR signals of the greatest stability.

EPR dosimetry has been used primarily in the retrospective analysis of radiation accidents and has been quite valuable in this regard. It has been particularly helpful when an amputation has occurred and when bone fragments have been available from a site of severe local irradiation. These samples have often been obtained through surgical amputation days to weeks postaccident. Table 30.9 presents selected cases in which EPR has been useful in radiation accidents.

For at least the last 10 years, EPR has increasingly been considered a health physics and medical tool for the acute phase analysis of radiation incidents. In the United States, various reports are available describing accelerator accidents and cases of severe, acute local injury in which EPR dosimetry has been performed.[78–81] A 1991 San Salvador accident involving a ^{60}Co source was characterized by significant heterogeneity of exposure, with the highest doses being delivered to the feet and lower legs of the victims. Desrosiers presented a detailed EPR analysis of a femur available from that accident.[82] More recent analysis of the multicasualty radiation accident in Lilo, Georgia has used EPR techniques to reconstruct the dose received by one victim by using one vertebra and two rib samples removed from the victim for medical reasons.[83]

In the 1994 radiation accident in Tammiku, Estonia three brothers stole a large amount of ^{137}Cs from a poorly guarded radioactive waste depository and took it to their home. Various members of the family were exposed to this source, chronically and in a nonuniform manner. In particular, the most severely injured patient received 1,830 Gy to the femur and thigh, and an approximately 4 Gy acute whole-body dose. He soon died of multiorgan failure. Other members of the family received 0–4 Gy whole-body dose over 28 days and up to 20–30 Gy of acute local dose to the hands. This case is interesting because various acute phase modalities were used in dose reconstruction: 1) chromosome aberration dicentric analysis, 2) Glycophorin A somatic mutation assays, 3) thermoluminescence dosimetry, 4) optically stimulated luminescence, 5) EPR, 6) chemiluminescence, and 7) Monte Carlo modeling of spatial effects. The use of EPR in this event was a valuable adjunct to clinical analysis of the ARS and of acute local injury.[84,85]

ACUTE RADIATION SYNDROME

General Considerations

ARS or "radiation sickness," occurs when individuals are exposed in a short period of time to high-energy penetrating radiation with doses of 1 Gy or more (or equivalent dose) to the whole body. Some experts suggest that ARS begins at 6–7 Gy with severe manifestations at levels of exposure above 7 Gy. Significant partial body exposures can also result in the development of ARS. ARS affects multiple organ systems, with symptoms from different organ systems predominating at varying doses. The most frequently recognized components of ARS are the hematopoietic, GI, and neurovascular syndromes, which result from cellular dysfunction or cell death within each of these tissue compartments. Cutaneous injury from trauma, radiation, and/or thermal burns is also frequently encountered in radiation accidents. This so-called cutaneous radiation syndrome, in which cutaneous injury is solely attributable to radiation exposure, represents a clinical entity distinct and separate from systemic ARS.[89] In other cases, radiation injury in conjunction with trauma or thermal injury will directly impact multiple organs, resulting in the extremely complicated physiological state of "radiation combined injury." Radiation combined injury is associated with high mortality and the multiorgan failure syndrome. The complexities presented by individual patients notwithstanding, categorizing the syndromes is still useful, both for discussion purposes and because such categorizations enable the clinical team to identify the most life-threatening injuries and thus make better triage and management decisions.

Table 30.10: Phases of Radiation Injury

Dose (Gy)	*Prodromal Phase*	*Manifest Phase*	*Prognosis without Supportive Care*
0.5–1.0	Mild	Modest decline in blood counts	Survival
1.0–2.0	Mild–moderate	Some bone marrow damage	Survival >90%
2.0–3.5	Moderate	Moderate–severe bone marrow damage	Probable survival
3.5–5.5	Severe	Severe bone marrow damage; modest GI damage	Death within 3.5–6 wk (50% of victims)
5.5–7.5	Severe	Pancytopenia and moderate GI damage	Death probable within 2–3 wk
7.5–10.0	Severe	Severe GI and bone marrow damage	Death probable within 2 wk
10.0	Severe	Severe GI damage, radiation-induced lung injury, altered mental status; at higher doses (>20.0 Gy), cardiovascular collapse, fever, shock	Death within 2 wk

Adapted from Reference 89.

In the absence of cutaneous injury or nonradiation-related injuries, ARS follows a relatively predictable (or deterministic) course for each of its constituent syndromes, with the lowest threshold dose for the hematopoietic syndrome and the highest for the neurovascular form (Table 30.10). In general, the severity of ARS is directly proportional to dose, whereas the timing of the onset of symptoms is inversely proportional.[90,91] For example, ARS has a hematological threshold dose of approximately 0.7 Gy with severe reductions in blood counts occurring above 3 Gy.[92] As previously noted, the LD_{50} for persons receiving no supportive care is approximately 3.5 Gy, due primarily to infection in the setting of neutropenia or hemorrhage in the setting of thrombocytopenia, but increases to 6–7 Gy with optimal supportive care (e.g., antibiotics, hematopoietic growth factors, and transfusions). Human mortality resulting from hematological insult has a peak incidence at approximately 30 days but continues through day 60. Because humans recover from hematological damage more slowly than other mammals, an $LD_{50/60}$ is used, in contrast to the $LD_{50/30}$ for animals.[93] A marked reduction of both the LD_{50} and the time from radiation exposure to death would likely occur following a nuclear detonation. This would be due to the complex patterns of ARS, radiation combined injury, and cutaneous radiation syndrome that would occur.

Clinical Progression

In terms of its temporal progression, ARS is divided into four sequential phases: prodromal, latent, manifest (illness), and recovery or death. The stages are described in detail.

Prodromal Phase

As detailed in Table 30.11, a variety of symptoms and signs may result within minutes to hours depending on the dose received. These symptoms and signs can be divided into two main groups: GI and neuromuscular. The GI symptoms include diarrhea, intestinal cramps, dehydration, and anorexia, whereas the neuromuscular symptoms include fever, sweating, headache, hypotension, apathy, and easy fatigability.[93] The prodromal symptoms that are indicative of doses that would be fatal to 50% of the population are nausea, vomiting, anorexia, and easy fatigability. The presence of initial fever, headache, immediate vomiting and diarrhea, hypotension, and/or disorientation after exposure portends a fatal outcome. As a rule, persons who vomit within 2 hours of irradiation have likely received a dose sufficient to cause at least moderate ARS. Using the 2-hour emesis rule for triage decisions (i.e., to determine which patients have been exposed to significant doses when there are multiple casualties) however might be problematic because it is difficult to distinguish radiation-induced vomiting from emesis due to psychological factors relating to the stressful situation.

Latent Phase

The latent stages of ARS (Table 30.12) are characterized by a relatively asymptomatic period. With 2–3 Gy, the prodromal symptoms abate after a few days and the latent period ensues for 2–3 weeks with continued declines in lymphocytes, neutrophils, and platelets. When the dose is high enough to induce the GI and neurovascular forms of ARS, the phase is frequently shortened or eliminated, respectively.

Manifest (Illness) Phase

During this stage (Table 30.13) the tissue compartments that are damaged become dysfunctional, thereby dictating the form of ARS. At very high doses (e.g., 100 Gy) all organ systems are severely compromised and death quickly ensues from neurovascular dysfunction.

Recovery or Death

Recovery or death follows the manifest (illness) phase. At higher doses, the time to recovery can be prolonged, with substantial residual deficits due to late fibrosis and other complications. Patients receiving high doses of radiation may experience other delayed effects of acute radiation exposure, such as radiation pneumonitis, radiation nephropathy, cataracts, and cognitive decline.[94,95]

Acute Hematopoietic Syndrome

The hematopoietic syndrome is usually encountered with doses that exceed 2 Gy, although the dose thresholds may be lower under compromising conditions, for example, significant cutaneous damage.[96] This syndrome has the four well-characterized sequential phases described previously. The prodromal symptoms are nonspecific and include nausea, vomiting, and anorexia. Rapid declines in lymphocytes herald the onset of full-blown hematopoietic syndrome. A latent period follows over 1–2 weeks with continued declines in peripheral blood cell counts, possibly

Table 30.11: Prodromal Phase: Severity/Dose and Medical Response

Signs/Symptoms After Exposure	*Mild (1–2 Gy)*	*Moderate (2–4 Gy)*	*Severe (4–6 Gy)*	*Very Severe (6–8 Gy)*	*Lethal* (>8 Gy)*
Vomiting					
Onset	≥2 h	1–2 h	<1 h	<30 min	<10 min
Incidence (%)	10–50	70–90	100	100	100
Diarrhea	None	None	Mild	Heavy	Heavy
Onset	–	–	3–8 h	1–3 h	<1 h
Incidence (%)	–	–	<10	10	~100
Headache	Slight	Mild	Moderate	Severe	Severe
Onset	–	–	4–24 h	3–4 h	1–2 h
Incidence (%)	–	–	50	80	80–90
Temperature	Normal	Increased	Fever	High fever	High fever
Onset	–	1–3 h	1–2 h	<1 h	<1 h
Incidence (%)	–	10–80	80–100	100	100
Consciousness	Normal	Normal	Normal	Possibly altered	Unconscious s–min
Onset	–	–	–		
Incidence (%)	–	–	–		100 (>50 Gy)
Medical Response	Outpatient	Observation or treatment at a specialized hospital if needed	Treatment at a specialized hospital	Treatment at a specialized hospital	If dose <10–12 Gy consider treatment; ≥12 Gy palliative care

* Individuals with exposures as high as 12 Gy may survive for more than 6 months with appropriate medical management. Modified from the International Atomic Energy Agency, Diagnosis and Treatment of Radiation Injuries, Safety Report Series No. 2, Vienna; 1998.

resulting during the manifest phase in infection, fatigue, and hemorrhage.

Hematopoietic cells are among the most radiosensitive cells in the body due to their rapid turnover. Mitotically active precursor cells are substantially reduced after 2–3 Gy, resulting in a decreased supply of red blood cells, white blood cells, and platelets. At these doses, the supply of mature cells from the diminished precursor pools may be insufficient to maintain an adequate number for proper physiological function, thereby resulting in the cytopenias characteristic of the hematopoietic syndrome. Certain subpopulations of the precursor cells are more radioresistant, presumably because the cells are in the non-cycling (G0) or radioresistant stage (late S) of the cell cycle.[97] This population may play a vital role in hematological reconstitution

Table 30.12: Latent Phase

Signs/Symptoms After Exposure	*Mild (1–2 Gy)*	*Moderate (2–4 Gy)*	*Severe (4–6 Gy)*	*Very Severe (6–8 Gy)*	*Lethal* (>8 Gy)*
Latency period (d)	21–35	18–28	8–18	≤7	None
Lymphocytes (10^9 cells/L), days 3–6	0.8–1.5	0.5–0.8	0.3–0.5	0.1–0.3	0.0–0.1
Granulocytes	>2.0	1.5–2.0	1.0–1.5	≤0.5	≤0.1
Diarrhea	None	None	Uncommon	Days 6–9	Days 4–5
Epilation (d)	None	Moderate, ≥ 15	Moderate, 11–21	Complete, <10	Complete, <10
Medical response	Outpatient	Hospitalization recommended	Hospitalization required	Hospitalization required	Hospitalization required, palliative treatment if ≥12 Gy

* Individuals with exposures as high as 12 Gy may survive for more than 6 months with appropriate medical management. Modified from the International Atomic Energy Agency, Diagnosis and Treatment of Radiation Injuries, Safety Report Series No. 2, Vienna; 1998.

Table 30.13: Manifest (Illness) Phase

Signs/Symptoms After Exposure	*Mild (1–2 Gy)*	*Moderate (2–4 Gy)*	*Severe (4–6 Gy)*	*Very Severe (6–8 Gy)*	*Lethal* (>8 Gy)*
Onset (d)	21–35	18–28	8–18	≤7	0
Lethality (%)	0	0–50	20–70	50–100	~100
Onset (wk)	–	6–8	4–8	1–2	≥1 d–2 wk
Clinical Manifestations					
Fatigue	Yes	Yes	Yes	Yes	Yes
Epilation	–	Yes	Yes	Yes	Yes
Infection	–	Yes	Yes	Yes	Yes
Bleeding	–	Yes	Yes	Yes	Yes
Shock	–	–	–	–	Yes
Coma	–	–	–	–	Yes
Lymphocytes (10^9 cells/L)	0.8–1.5	0.5–0.8	0.3–0.5	0.1–0.3	0.0–0.1
Platelets (10^9 cells/L)	60–100	30–60	25–35	15–25	<20
Medical Response	Outpatient	Hospitalization recommended	Hospitalization required	Hospitalization required	Hospitalization required, palliative treatment if ≥12 Gy

* Individuals with exposures as high as 12 Gy may survive for more than 6 months with appropriate medical management. Modified from the International Atomic Energy Agency, Diagnosis and Treatment of Radiation Injuries, Safety Report Series No. 2, Vienna; 1998.

with exposures as high as 7–8 Gy, although at the cost of a compromised capacity for self-renewal. Fortunately, most individuals involved in radiation accidents receive inhomogeneous exposures, because of the radiation mixture (e.g., photons, and beta or alpha particles), the energy of the radiation (i.e., penetrating or not), the individual's distance from the source, the physical environment, and/or the degree of internal or external contamination that occurs. As a consequence, persons receiving potentially lethal doses of radiation may still survive due to sparing of small areas of bone marrow that can serve as a reservoir for the rapid reestablishment of hematopoiesis.[95,98]

The rates of decline for the various circulating cells depend on the sensitivity of the cell type (i.e., stem, precursor, and fully differentiated cells) and their turnover time. Lymphocytes, which undergo apoptosis, decline the most rapidly, whereas platelet and other leukocyte counts are depressed less quickly. Figure 30.5 illustrates lymphocyte depletion kinetics (discussed later). Having the longest circulating half-life and being resistant to apoptosis, erythrocytes demonstrate the slowest declines. Thus, the acute hematopoietic syndrome predisposes an individual to infection, hemorrhage, and anemia, which follow the decline of the leukocytes, thrombocytes, and erythrocytes from as early as 10 days to several weeks after a high-dose exposure.[94] Due to the long circulating half-life of erythrocytes, the body's compensation mechanisms, and the general availability of transfusions given that there is time to organize them, anemia, if it occurs, is seldom life threatening unless other trauma or bleeding results secondary to thrombocytopenia.

Lymphocytes demonstrate a somewhat unusual response to radiation. Terminally differentiated cells (e.g., rhabdomyocytes) are usually more radioresistant than intermitotic cells (e.g., intestinal crypt cells, erythroblasts). Lymphocytes, which are long-lived and the chief cells responsible for adaptive immunity, are highly radiosensitive and undergo rapid apoptosis when exposed to comparatively low doses of radiation. Lymphopenia therefore occurs more rapidly than the other cytopenias, and assuming no other insult, a predictable dose-dependent decline is expected after radiation. For example, a potentially lethal dose is characterized by a 50% drop in lymphocyte count within the first 24 hours followed by a more severe decline over the next day.[96]

Neutrophils are part of the innate immune system and are the first responders to infection. Thus, they are the most critical blood cell type in combating acute infection. Circulating neutrophils have a half-life of approximately 7 hours before marginating and entering the tissue pools where they survive for an additional 1–2 days (in the case of infection, these cells are recruited from the circulation into the tissue and consumed resulting in a marked reduction in their half-life). Maturation of neutrophil precursors in the bone marrow until their release into the circulation as mature neutrophils normally takes approximately 2 weeks. Following irradiation, declines in circulating neutrophils result from depletion of the marrow reserves of mature cells and death of rapidly dividing, early progenitor cells in the bone marrow. Thus, the loss of progenitor cells and the unusual kinetics of neutrophil production and release account for the delayed onset of the hematopoietic syndrome.[99] To complicate matters, a transient increase in the granulocyte count frequently occurs within the first 24–48 hours due to remobilization from the venous, splenic, and bone marrow pools. This transient increase in the granulocyte count is followed by a decline and eventual recovery if the radiation dose the victim receives is survivable. Some observers have reported that with doses of less than 5 Gy, a second abortive rise or stabilization in the granulocytes counts may occur approximately 10 days postexposure, followed by the true nadir. This abortive rise, if observed, reflects the production and release of granulocytes from residual hematopoietic tissue and suggests a better prognosis.[100]

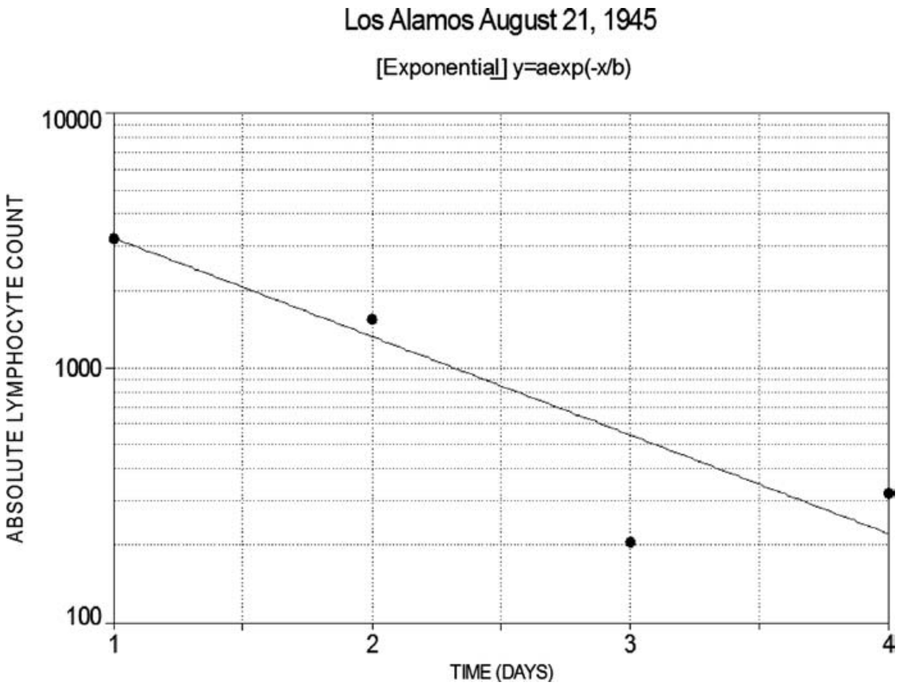

Figure 30.5. Lymphocyte depletion kinetics in the 1945 LANL-1 criticality accident. Reprinted from reference 144. See color plate.

The loss of progenitor cells with radiation exposure also results in a decrease in platelets, which have a mean survival time of 8–11 days. The resultant thrombocytopenia contributes to hemorrhage that occurs with the hematopoietic syndrome. Most authorities recommend platelet transfusion to reduce the risk of spontaneous hemorrhage when platelet counts fall below 10,000/μL in asymptomatic patients and in the range 10,000–50,000/μL if there is clinical bleeding or if invasive procedures are anticipated. The final component of the hematopoietic syndrome, anemia, is characterized by a hemoglobin mass of less than 10 g/dL. The long mean lifespan of red cells (which approaches 120 days) makes anemia less of an immediate concern in the hematopoietic syndrome than the other cytopenias.

Acute Gastrointestinal Syndrome

The GI syndrome also has four sequential stages but occurs at higher radiation doses than the hematopoietic syndrome (typically becoming manifest at total body irradiation doses of ≥7 Gy). The GI mucosa is a self-renewing tissue and the morbidity and mortality observed in the GI syndrome reflect the denudation of the epithelial lining of the GI tract in the setting of concurrent myelosuppression. The prodromal stage is characterized, again, by prompt nausea, vomiting, and diarrhea, which because of the higher initiating radiation doses are typically more severe than the symptoms observed with the hematopoietic syndrome. In some cases, this may be followed by a latent period lasting several days, although the duration of latency declines as the exposure dose increases. The manifest stage then follows with severe diarrhea, nausea, vomiting, and fevers. Other systemic effects may include dehydration, ileus, malabsorption, electrolyte derangements, GI bleeding, renal impairment, and eventual cardiovascular collapse. As with the hematopoietic compartment, the dividing precursor cells are more radiosensitive than the differentiated cells. The radiosensitive epithelial stem cells are confined to the crypts and provide a continuous supply of new cells. These new cells differentiate as they move up the villi or luminal surface to become functionally mature cells, which are then extruded. Hence, sufficient radiation sterilizes the dividing crypt cells with eventual disruption of the mucosal barrier resulting in septicemia and usually death.[93,98] Kolesnick, Fuks, and colleagues have argued that endothelial damage is the primary lesion regulating crypt cell survival and intestinal injury, but this hypothesis remains controversial.[101–103]

Acute Neurovascular Syndrome

The neurovascular syndrome may be observed at acute doses of greater than 20–30 Gy and is thought to reflect cerebral edema and cardiovascular collapse, although hypotension may also be seen at lower doses. As with the hematopoietic and GI syndromes, the prodromal phase is characterized by nausea, vomiting, and diarrhea, but this typically occurs within minutes of exposure in persons suffering the acute neurovascular syndrome. Disorientation, confusion, and prostration are characteristic of the prodromal phase and loss of balance and seizures may occur. Papilledema, ataxia, and reduced or absent deep tendon and corneal reflexes may be noted during the physical examination. This phase is followed, possibly without a latent period, by a severe manifest phase of fever, respiratory distress, disorientation, ataxia, persistent diarrhea, seizures, cardiovascular collapse, and coma. The course is inexorable and death invariably follows within a few days. The clinical course of rapid deterioration mimics that of acute sepsis and septic shock, both of which must also be considered in the differential diagnosis.[91,98]

Acute Cutaneous Radiation Injury (≤90 days)

The skin is composed of the epidermis and dermis. The epidermis provides a durable waterproof protective barrier of stratified squamous epithelium between the body and external environment. The stratum germinativum (or basal layer) containing the basal stem cells is the innermost layer of the epidermis. Cells produced in the basal layer differentiate and migrate toward the surface, where they maintain some proliferating potential in the stratum spinosum (squamous layer). The cells then pass through additional layers where they finally make their way to the stratum corneum, where they eventually slough off. The turnover time ranges from 4 to 7 weeks. The dermis, connected to the epidermis by a basement membrane, contains a dense network of connective tissue, hair follicles, capillaries, lymphatics, sweat glands, nerve endings, sebaceous glands, and apocrine glands. The highly radiosensitive epithelial stem cells, follicular, sebaceous, and sweat germinal cells provide a continuous supply of new cells to their respective structure. These new cells differentiate as they become functionally mature cells and are eventually lost. With irradiation a large proportion of these cells may die and without replenishment result in disruption of skin integrity, epilation, dry skin, and if the dose is high enough, loss in thermal regulation. The late effects of radiation are mainly attributable to the death of the endothelial cells within the papillary vasculature and are discussed in detail elsewhere.[104,105]

Radiation, whether from the blast or fallout from an improvised nuclear device, conventional nuclear bomb, or radiological dispersal device, has the potential to cause life-threatening injury as a direct result of radiation and nonradiation-related cutaneous injury. Significant cutaneous radiation injury independently predicts lethality, thus increasing the risk of death when combined with other trauma.[89,98,106] Cutaneous radiation injury will usually be combined with other aspects of ARS but it may occur in isolation if the exposure is restricted to low energy x-rays or beta radiation. Mechanical, chemical, and thermal injuries frequently accelerate and exacerbate the cutaneous radiation injury (in cases in which multiple mechanisms have contributed to the injury a more appropriate term for the clinical syndrome encountered might be "combined skin injury"). Moreover, the damage to the skin is almost invariably inhomogeneous due to factors such as the position of the individual in relationship to the blast or source and/or the presence of physical barriers providing partial body protection.

The effects of radiation on the skin are dose, depth, and volume dependent. Most individuals receiving a radiation dose to the skin of 5 Gy or higher will experience a transient skin reaction of erythema, edema, itching, and/or tingling within 24 hours of the causative exposure. This prodromal period is followed by a latent period of 2–3 weeks. This period is followed by an orderly progression of erythema, hyperpigmentation, and dry and wet desquamation if the focal doses to skin are approximately 15–24 Gy. In the case of extremely high doses (≥50 Gy), the period of latency may not occur and the injury may progress from erythema to necrosis within days (Table 30.14).[104] Figures 30.5A–E demonstrate the progressive stages of cutaneous injury in a victim receiving a focal high-dose exposure to the right hand. Clinicians should remember to include radiation injury as part of the differential diagnosis of desquamation or ulceration of unclear etiology, particularly when the patient lacks a history of a burn injury.

Table 30.14: Skin Injury and Time of Onset

*Stage/Symptoms**	*Dose Range (Gy)*	*Time of Onset (d)**
Epilation	3	14–18
Erythema	>3–10	14–21
Dry desquamation	8–12	25–30
Moist desquamation	15–20	20–28
Blister formation	15–25	15–25
Ulceration (without skin)	>20	14–21
Necrosis	>25	>21

* The time to progression of each stage (e.g., epilation, erythema, dry desquamation) is shortened with increasing dose (not shown). Modified from the International Atomic Energy Agency, Diagnosis and Treatment of Radiation Injuries, Safety Report Series No. 2, Vienna; 1998.

Radiation Combined Injury

In many of the scenarios of concern, burns or other wounds in combination with radiation are highly likely. It is estimated that 60%–70% of persons exposed to significant doses of radiation from the atomic bombings of Hiroshima and Nagasaki also sustained traumatic injury. Similarly, in the Chernobyl accident, approximately 10% of the 237 acutely exposed first responders received both significant radiation doses and burns.[107] The combination of radiation injury with other injuries, whether blast, burn, trauma, or infection, results in high lethality. The $LD_{50/30}$ for a given radiation exposure and the time to death for exposed animals both decrease significantly in the setting of combined injury.[108] This effect has been observed for the combination of radiation injury with burns, wounds, and experimentally induced infections across multiple species. Data derived from studies involving the combination of sublethal radiation exposure and thermal injury are summarized in Table 30.15 and are representative of findings with other permutations of radiation combined injury.[109]

Delayed Effects of Acute Radiation Exposure

In persons surviving the initial phases of ARS, or receiving substantial partial body exposures, tissue and organs other than

Table 30.15: Effect of Combining Sublethal Total Body Irradiation and Burns on Mortality

Model	*Injury*	*Mortality (%)*
	20% burn	12
Dog	100 cGy total body irradiation (TBI)	0
	Combined burn + TBI	73
	10%–15% burn	0
Pig	400 cGy TBI	20
	Combined burn + TBI	90
	31%–35% burn	50
Rat	250 cGy TBI	0
	Combined burn + TBI	95
	1.5% burn	9
Guinea pig	250 cGy TBI	11
	Combined burn + TBI	38

those mentioned previously can manifest late radiation effects, referred to collectively as the delayed effects of acute radiation exposure (DEARE). For example, persons exposed to high doses of radiation (typically in excess of 6–8 Gy) often develop impairment of lung or kidney function, starting approximately 3 months after the exposure event. Acute, subacute, and chronic radiation syndromes may present as a clinical continuum or there can be a prolonged latency between exposure and the manifestation of radiation-produced organ dysfunction. Although the hematopoietic and GI syndromes are largely attributable to the direct cytotoxic effects of radiation on rapidly dividing tissues, the DEARE are thought to reflect chronic inflammation induced by vascular damage or other injury to the connective tissue. The interested reader may refer to several reviews on this topic for additional information.[110–112]

Radiation-induced Malignancy

Individuals exposed to doses of radiation that do not produce immediate acute effects are still likely to be concerned about their risk of developing radiation-induced cancer. In general, the risk of secondary cancer increases with increasing dose, although outcomes for specific individuals cannot be predicted with any certainty. This is in contrast to organ injury in which the severity of dysfunction increases with increasing dose once the threshold dose for injury is surpassed. In the future it may be possible to estimate an individual's risk of radiation-induced cancer more precisely by assessing the radiation exposure in light of other pertinent factors, such as the volume of tissue irradiated, the individual's history of exposure to other carcinogens (e.g., cigarette smoking), and the victim's age and family history. At present, however, there is no way to reduce an individual's risk of radiation-induced cancer after the radiation exposure has occurred.

TREATMENT OF ACUTE RADIATION SYNDROME

Medical Management of Acute External Radiation Injury

Treatment for ARS in the absence of combined injury is usually only required in those who have received radiation doses of 2 Gy or more.[113] Such pure radiation injury is comparatively rare, however, and patients who present with combined injuries due to mechanical, thermal, and/or chemical causes should be triaged as described elsewhere in the chapter and managed using relevant burn or trauma protocols. Because radiation is not immediately life threatening, nonradiation-related injuries should be addressed first. The management of acute radiation injury depends on multiple factors including the location of exposure (external or internal), the extent of exposure (partial or whole body), the dose and type of radiation, concurrent injuries or illnesses, age and weight of the patient, pregnancy status, and (if internal contamination is suspected) the particular radionuclides involved.

Infection is a major cause of death in patients with ARS, so supportive care including wound care, antimicrobial treatment and prophylaxis for infection, and mitigation of cytopenias and immune suppression with cytokines, and possibly stem cell transplantation, all play vital roles in proper management.[89,94–96,98,100,113] Several recent cases of high-dose exposure illustrate that with aggressive supportive care restoration of bone marrow function may be possible even after exposures as high as 10–12 Gy, although such recovery has not translated into long-term survival because of progressive GI and pulmonary dysfunction.[11] In the case in which a person receives a supralethal dose of radiation, it is appropriate to withhold aggressive treatment, especially in a setting of mass casualties, where resource constraints may be significant.[114]

General skin management guidelines have emerged with the goal to minimize desquamation and infection.[104,105,115] Areas of acute erythema and dry desquamation (Radiation Therapy Oncology Group [RTOG] Grade I) should be washed with lukewarm water or with mild soap and water, whereas temperature extremes and mechanical irritation should be avoided. Moisturizing cream, such as nonscented, lanolin-free hydrophilic cream, may be helpful in early or minor reactions, but should be discontinued if wet desquamation occurs. Moist desquamation (RTOG Grade II–III) is managed by keeping the wounds clean and using antiseptic dressings to minimize infection, desiccation, and further trauma to the wound. Skin necrosis and ulceration (RTOG Grade IV) may require skin grafts with nonirradiated skin. Alternatively, smaller defects may be treated with hyperbaric oxygenation to stimulate reepithelialization.[104]

Radiation injury management can be divided into three categories: acute ($\leq$ 72 hours), intermediate (3–30 days), and late ($>$ 30 days). Here, radiation management during the acute and intermediate periods is discussed.

Acute Management

Both external and internal decontamination should be performed along with medical and surgical stabilization as soon as possible. Prodromal symptoms such as nausea/vomiting, diarrhea, and headache may be controlled with conventional agents such as 5-HT3 receptor antagonists and fluids, loperamide, and acetaminophen (paracetamol), respectively. All blood products should be leukoreduced and irradiated to minimize graft-versus-host-disease (GVHD), which could pose a clinical dilemma as some of the signs and symptoms of GVHD are similar to those of severe ARS (e.g., diarrhea, fever, hyperbilirubinemia, and pancytopenia). Herpes simplex virus serum titers should be determined, and if positive, acyclovir should be initiated for prophylaxis and maintained until hematopoietic recovery occurs. In addition to addressing the victim's physical symptoms and injuries, treating physicians should be sensitive to the potentially profound psychological impact of radiation injury. Patients and their families are likely to have concerns and anxieties that need to be addressed, particularly in the case of high-dose exposures when the prognosis may be poor.

In those who are expected to develop severe neutropenia, hematopoietic colony-stimulating factor (CSF) treatment should be initiated within 24 hours assuming that the radiation and nonradiation-related injuries are potentially survivable (Table 30.16).[89] The only U.S. Food and Drug Administration (FDA) approved cytokines for management of treatment-associated neutropenia at the time of this writing are the recombinant forms of granulocyte CSF (G-CSF, filgrastim), the pegylated form of G-CSF (pegfilgrastim), and granulocyte macrophage–CSF (GM-CSF, sargramostim). G-CSF (filgrastim or pegfilgrastim) has a favorable toxicity profile compared with GM-CSF, with equal efficacy. These hematopoietic factors have enhanced neutrophil recovery following chemotherapy, resulting in a reduction of neutropenic fevers and hospitalizations, decreased duration of neutropenia in radiation accident victims, and also increased survival in irradiated animal models.[89,116] Several other cytokines

Table 30.16: Treatment Guidelines for Radiation Exposure

	Gy		
	Cytokine Treatment	*Antibacterial/Viral/ Fungal Treatment#*	*Consider Stem Cell Transplant (SCT)*
>100 Casualties			
Healthy person, no injuries	3–7*	2–7#	7–10 (12?) for allogeneic SCT; 4–10 (12?) for autologous or syngeneic graft
Combined injuries	2–6*	2–6#	–
≤100 casualties			
Healthy person, no injuries	3–10*	2–10#	7–10 (12?) for allogeneic SCT; 4–10 (12?) for autologous or syngeneic graft
Combined injuries	2–6	2–6#	–

^ Prophylactic antibiotic, antiviral, and antifungal therapy: fluoroquinolone; acyclovir if seropositive for HSV or with an underlying medical condition, and fluconazole, respectively.
* In the elderly (>60 years) and nonadolescent children, consider initiating therapy at a lower dose, that is, 2 Gy. Also, G-CSF should be started in those who develop neutropenia ($<0.5 \times 10^9$ cell/L) if they are not already receiving it.
# Therapy should be continued until no longer neutropenic. Follow the current Infectious Diseases Society of America Guidelines if the patient develops neutropenic fever while receiving prophylactic therapy.

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such as interleukin-11, thrombopoietin, FLT-3 ligand, and keratinocyte growth factor have shown preclinical efficacy.[96,113]

Intermediate Management

Prophylaxis for bacterial and fungal infections should be given to those with severe neutropenia (i.e., absolute neutrophil count $\leq 0.5 \times 10^9$ cells/L) and should be continued until the absolute neutrophil count exceeds 0.5×10^9 cells/L or changed if resistance is encountered. Antibiotics should not target the beneficial anaerobes in the GI tract. Extended spectrum fluoroquinolones (e.g., levofloxacin) have activity against Gram-negative and Gram-positive bacteria, lack activity against anaerobic bacteria, and are not myelosuppressive, and thus are probably the optimal agents to use in this setting. Patients susceptible to severe life-threatening infections should receive prompt antibiotic treatment on an empirical basis if they show clinical evidence of infection such as fever. Fluconazole prophylaxis should also be initiated as it has been shown to decrease the incidence of fungal infections and mortality in patients undergoing allogeneic bone marrow transplants. In those who become significantly leukopenic or immunosuppressed, cytomegalovirus polymerase chain reaction can be monitored with leukocyte recovery. If cytomegalovirus nucleic acids are detected, the patient can be treated with either ganciclovir or valganciclovir.[117]

Selected patients without significant combined injuries who receive doses that fully ablate the marrow but may otherwise be survivable (i.e., >7 Gy but <10–12 Gy) may benefit from stem cell transplantation. Stem cell transplantation for those receiving total body doses of more than 10–12 Gy is probably of no benefit because death would result from non-bone marrow–related multiorgan dysfunction.[114] The accurate determination of whether a patient would likely improve with stem cell transplantation is difficult because the benefits of transplantation appear to be within a narrow dose window; patient selection is further compounded by the likely inhomogeneous exposure to the body. Liberal use in uncertain situations may result in death because stem cell transplantation may lead to death from GVHD. In the rare cases of patients with an identical twin or who have previously stored autologous HSCs, autologous or syngeneic stem cell transplantation may be beneficial and should be considered.

Medical Countermeasures and Treatments

In recent years, medical countermeasures against radiation have typically been classified according to the following schema

- *Radioprotectants* – given before exposure (or in the midst of ongoing exposure) as prophylaxis against radiation injury
- *Radiation mitigators* – given after exposure and prior to the onset of symptoms to reduce the biological consequences of radiation exposure
- *Therapeutics* – given after the radiation effect is manifest
- *Decorporation* – given to reduce the total body burden of an isotope following its internalization
- *Blocking Agents* – given to reduce organ uptake of an isotope following its internalization

Elucidation of the complex nature and evolution of radiation injury has dissipated hopes for a medical panacea. Antioxidants and radioprotectants such as amifostine must be present at the cellular level at the time of irradiation to offer tangible benefits in reducing acute injury, and therapeutics targeting specific signaling pathways will likely demonstrate time-sensitive windows of opportunity during which administration may provide clinical benefit and outside of which efficacy may erode fairly sharply. Modulation of cytokine activity through the use of anti-inflammatory agents or monoclonal antibodies may offer organ-specific or more general benefits but whether these compounds will improve overall outcomes remains to be demonstrated. A consensus is emerging that combinations of therapeutics will almost certainly be required to produce substantial reductions in mortality rates. Developing and confirming the efficacy of such combinations will be one of the more challenging tasks for scientists in coming years.[118] The manifestations of acute radiation syndrome reflect a molecular and physiological cascade of events unfolding over time. This may afford opportunities for intervention at multiple time points, and how medical countermeasures are sequenced may prove to be an important determinant of a regimen's overall efficacy.

Table 30.17 lists the various organ-specific syndromes associated with acute radiation exposure and the currently available countermeasures for prophylaxis, mitigation, and treatment of these syndromes. None of the drugs likely to be used in the management of patients with ARS or DEARE are U.S. FDA–approved for radiation injury. At the time of this writing, only potassium iodide (KI), Prussian Blue, Ca-DTPA and Zn-DTPA (see Decorporation Therapy for Internally Deposited Radionuclides later) are specifically FDA-approved in the United States as countermeasures for internal radionuclide contamination from radiation injury.

INTERNALLY DEPOSITED RADIONUCLIDES

Internal contamination of individuals can occur anytime radioactive materials are free to spread in an environment, with the most common routes of intake being inhalation and absorption through wounds. Despite engineering and health physics controls, activities during the various stages of the nuclear fuel cycle (i.e., mining, processing, fabrication of fuel elements, reactor operations and repair, decommissioning, fuel reprocessing, waste management) and in other industrial processes occasionally result in the accidental release of radioactive material. Unless heralded by fires and explosions, gaseous and particulate releases might not be evident until detected by air monitors. The ingestion pathway is uncommon in industrial settings, but may become critical for the general public after an accidental release of airborne or liquid radioactive material into the environment. Various documents give an overview of current thoughts on techniques pertinent to the mitigation of internal contamination.[130,131]

Following an accidental intake of radioactive material, the radiation dose, toxicity, and treatment methods are dependent on various factors such as the identity of the radionuclide and its physical and chemical characteristics (physical and biological half-life, particle size, chemical composition, solubility, tissue tropism, and so forth). For radionuclides internalized through the inhalation pathway, particle characteristics (size, chemical composition, and chemical solubility in body fluids) are important determinants of the radiation dose received. The size of aerosol particles determines the region of the respiratory tract where deposition occurs, but the ultimate fate of inhaled particles is also critically dependent on their physicochemical properties. Highly insoluble particles, for example, may remain in the lung for long periods, during which time a small fraction will be transported to the tracheobronchial lymph nodes by pulmonary macrophages. Insoluble particles may also be swallowed and therefore are often excreted primarily in the feces.

The spectrum of radiation injury caused by internal contamination with radioactive materials will necessarily reflect their biological disposition. When the disposition of such materials is nonuniform, as it will be in almost all cases of internal contamination, the clinical presentation of injury is unlikely to conform to classic descriptions of ARS. Clinicians should therefore anticipate atypical patterns of injury in patients with known internal contamination. Patients in whom the internal contamination is unsuspected will likely present significant diagnostic challenges to treating physicians, as was the case with the Russian dissident Alexander Litvinenko, whose poisoning with ^{210}Po went undetected for several weeks despite his severe illness.

General medical and health physics assessment after an inhalation event should include initial attempts to determine the maximum credible amount internalized. Nasal swabs taken within a few minutes postaccident can aid in radionuclide identification if positive and in estimating the amount of material inhaled. If there is evidence for significant intake, preparations should be considered for urine and fecal bioassay and whole-body or lung counting. There is a high false-negative rate when using nasal swabs due either to the elapsed time postevent, sampling technique, or clearance from the nasal region. Positive nasal smears bilaterally and/or a history of external contamination above the waist and contamination around the nose, can be clues to possible intake. Mansfield has offered a rough rule of thumb that the combined activity of both nasal swipes totals approximately 5% of deeper lung deposition, using the ICRP 30 lung model as a reference.[132] Experience has shown that this technique generally overestimates deep lung deposition (sometimes substantially) but is useful for initial estimates and decisions about the initiation of therapy, pending the results of bioassays.

Whole body or wound counting may be useful to identify those radionuclides that emit penetrating x-rays or gamma rays. It may also be utilized for radionuclides emitting energetic beta particles that can be detected by their bremsstrahlung. The initial problem for the health physicist and for the treating physician is to estimate the maximum credible amount internalized. This estimate directs further medical care.

In all cases involving internal contamination, it is the chemistry of the stable element in the human body that determines radionuclide biokinetics. The biological half-life (T_B) of the stable element (which is equivalent to that of the radioisotope) and the physical half-life (T_P) of the radioisotope act in concert to produce the effective half-life (T_{eff}) of an isotope, which is given by

$$1/T_{eff} = 1/T_P + 1/T_B.$$

Thus, the effective half-life is less than either the physical or biological half-lives. As an illustrative example, radioactive iodine is chemically identical to nonradioactive iodine, and the biological clearance of the radioactive and normal isotopes is indistinguishable. The toxicity of ^{131}I, however, derives from its radioactivity. The biological effects and toxicities of ^{131}I are therefore a function of both its half-life (8 days) and its concentration in the serum and thyroid. These effects and toxicities decline as a function of both the radioisotope's clearance and its radioactive decay.

TREATMENT FOR INTERNAL RADIONUCLIDE CONTAMINATION

Hospital emergency personnel triage victims of a radiation incident by using traditional medical and trauma criteria. In general, personal protective equipment appropriate for managing blood-borne/airborne pathogens (e.g., N95 respirators, gloves and suitable surgical gowns) are all that is necessary for treating patients with external contamination, internal contamination,

Table 30.17: Currently Available Medical Countermeasures for ARS and DEARE

Syndrome		*Timing*	*Treatment*	*Comment*
Hematopoietic	Neutropenia	Prophylaxis	None	
		Mitigation	CSFs (G-CSF, GM-CSF, pegylated G-CSF) to decrease duration and intensity of neutropenia	Treatment for radiation exposure >2 Gy should begin within 1–2 d;[89] CSF use has been associated with rare fatal splenic rupture[119]
			Antibiotics at time of neutropenia	Consider antibiotic prophylaxis for expected neutropenia[120]
		Therapeutic	CSFs as above	
			Supportive care: antibiotics for febrile neutropenia	
			Allogeneic stem cell transplantation	Limited utility due to severe morbidity/mortality associated with concurrent nonhematopoietic injuries sustained at marrow-lethal doses of radiation[89]
	Thrombocytopenia	Prophylaxis	None	
		Mitigation	Cytokines (oprelvekin [recombinant human interleukin-11])	Limited if any human experience with irradiated patients; label indication is for prevention/mitigation of thrombocytopenia following myelosuppressive chemotherapy in adult patients with nonmyeloid malignancies
		Therapeutic	Supportive care: platelet transfusion	
	Anemia	Prophylaxis	None	
		Mitigation	Cytokines (erythropoietin)	
		Therapeutic	Cytokines (erythropoietin)	
			Supportive care: red blood cell transfusion	
			Allogeneic stem cell transplantation	
	Lymphopenia	Prophylaxis	None	
		Mitigation	None	
		Therapeutic	Allogeneic stem cell transplantation	
GI	Nausea/vomiting	Prophylaxis	Oral and IV antiemetics: 5-HT3 receptor antagonists ± dexamethasone	
		Therapeutic	5-HT3 receptor antagonists	Preferred[121]
			Dopamine antagonists	
			Benzodiazepines	
			Corticosteroids	
	Mucosal injury	Prophylaxis	Keratinocyte growth factor (KGF)	KGF is indicated to decrease the incidence and duration of severe oral mucositis in patients with hematological malignancies receiving myelotoxic therapy requiring hematopoietic stem cell support; safety and efficacy of KGF have not been established in patients with nonhematological malignancies
		Mitigation	Cytokines (G-CSF, GM-CSF)	Mixed results in small human trials with fractionated radiotherapy[122,123]

Syndrome		*Timing*	*Treatment*	*Comment*
		Therapeutic	GI decontamination: fluoroquinolones, vancomycin, polymyxin B sulfate, antifungals	Very limited human data; animal data demonstrate reduction in bacteremia[124]
			L-Glutamine	Very limited human data[125]
			Supportive care: total parenteral nutrition, elemental diets, fluids, electrolyte repletion	
	Diarrhea	Prophylaxis	None	
		Mitigation	None	
		Therapeutic	Antidiarrheals: loperamide, diphenoxylate/atropine, tincture of opium	
	Hemorrhage	Prophylaxis	Antacids: proton pump inhibitors, H2 receptor antagonists, sucralfate, other antacids	Reduces risk of upper GI bleeding in critically ill patients; limited data in patients with ARS[126]
		Mitigation	None	
		Treatment	Supportive care: transfusions	
Cardiovascular central nervous system		Prophylaxis	None	
		Mitigation	None	
		Therapeutic	Palliative care	
Chronic organ injury		Prophylaxis	None	
		Mitigation	Pentoxifylline for early and late pulmonary toxicity	Single randomized clinical trial in patients with lung or breast cancer[127]
		Therapeutic	Pentoxifylline + α-tocopherol for radiation-induced superficial fibrosis (RIF)	Randomized clinical trial in patients with RIF after radiotherapy[128]
			Suppression of renin-angiotensin system for radiation nephropathy: Angiotensin-converting enzyme inhibitors, angiotensin II, type I receptor antagonists	Anecdotal human evidence of efficacy[129]
Combined injury – blast, thermal effects		Prophylaxis	None	Experimental models suggest that mortality from combined injuries will be significantly higher than mortality from pure radiation injury for any given dose of radiation[108]
		Mitigation	None	
		Therapeutic	Surgical interventions should be performed within 48 h or delayed 5–6 wk	

or radiation-related injury from external sources. In some cases, however, Level C or even Level B personal protective equipment is recommended (Chapter 13). In the history of radiation accidents, no healthcare provider has received an external dose of more than 0.005 Sv while providing normal patient care. Healthcare workers may perceive a large risk in treating patients with radiation injury but this is not substantiated by actual experience. It is, however, necessary to practice appropriate contamination controls to minimize doses to providers.

After immediately life-threatening injuries are stabilized, radionuclide-specific therapy may be considered. The major goal of radionuclide-specific therapy after internal contamination is decorporation (removal from the body) of the internally deposited radionuclide. Early and effective decorporation can substantially reduce the overall committed dose of radiation that the internally contaminated individual receives as a result of the radionuclide exposure. In general, treatment strategies for internal contamination fall into one of several major categories.[133]

- Reducing and/or inhibiting absorption of the isotope in the GI tract by use of Prussian Blue to bind ^{137}Cs
- Blocking uptake to the organ of interest by administering potassium iodide to block uptake of radioactive iodine by the thyroid

- Diluting the ingested radionuclide by administering fluids for internal contamination with tritium
- Altering the chemistry of the radioactive isotope by administering sodium bicarbonate to convert uranyl ions to uranium bicarbonate, a less nephrotoxic form of uranium, in the renal tubules
- Displacing the isotope from receptors by administering calcium to compete with radiothorium
- Using traditional chelation techniques by administering DTPA to enhance excretion of internalized plutonium

Early identification of the radionuclide is crucial in the medical management of the acute phase. From medical experience with industrial radiation accidents, decorporation therapy is generally recommended for intakes of 5–10 times the recommended annual limit of intake (ALI) and strongly recommended for intakes exceeding 10 ALI, when the ALI is that inhalation intake necessary to give a committed effective dose equivalent of 0.05 Sv (5 rem). It would be unusual to treat a nonpregnant adult with an intake below 1 ALI. If, however, the patient requests treatment and there are sufficient resources available, physicians may justify therapy for intakes below 1 ALI according to the radiation safety principle that exposures should be "as low as reasonably achievable" (ALARA). In an extreme event involving thousands of contaminated individuals, it is important to remember that population dose can be reduced by a factor of 2–10 or more simply by sheltering in place, depending on the quality of the shelter, whereas medical decorporation therapy can only affect dose by a factor of 2–3.[134]

Because internal contamination by radionuclides is often considered by physicians as a type of poisoning, poison control centers are occasionally contacted initially for information on reducing the body burden of the specific radioactive element. It is therefore important that toxicologists and all physicians in Poison Control Centers have access to the most current treatment modalities. Table 30.18 lists decorporating, chelating, and blocking agents available for treating or blocking internal radionuclide deposition; Table 30.19 provides dosing recommendations for these drugs.[135] These drugs and dosage recommendations are currently consistent with recommendations from the U.S. National Council on Radiation Protection. Note, however, that in the United States there are relatively few drugs actually approved by the FDA for these indications. The drugs that are approved as chelating agents or decorporation agents in the United States are noted with an asterisk in Tables 30.18 and 30.19 below. Uses of these drugs for other indications and other radionuclides must be considered "off-label." Some other countries, such as those within the European Union, have additional approved drugs.

Treating physicians should be aware that most chelating and decorporating agents are radionuclide-specific and that the value of decorporation therapy may be dependent on the context of the patient's exposure (see, for example, the U.S. FDA guidelines for use of potassium iodide).[136] Using radionuclide chelators/blockers in an effective and targeted way following a nuclear detonation, for example, would present significant challenges, and may, in fact, not be feasible or desirable. Internal exposures will vary considerably and it is likely that only a comparatively small number of people might incur doses that actually warrant treatment. It is, however, also likely that this population will have received the highest external doses from fallout and that the doses received through external exposure will be the

Table 30.18: Decorporation Therapy Recommendations for Radionuclides of Concern

Radionuclide	*Treatment*	*Preferred Treatment*
Actinium	DTPA	DTPA
Americium	DTPA	DTPA
Arsenic	BAL; Penicillamine; DMSA?	BAL
Barium	Strontium therapy†	Strontium therapy†
Berkelium	DTPA	DTPA
Bismuth	BAL?	BAL?
Cadmium	DTPA; EDTA; DMSA	DMSA
Californium	DTPA	DTPA
Calcium	Strontium therapy†	Strontium therapy†
Carbon	No treatment available	N/A
Cerium	DTPA	DTPA
Cesium	Prussian Blue	Prussian Blue
Chromium	DTPA; DMSA	DMSA
Cobalt	Pencillamine; DTPA; EDTA; DMSA; N-Acetylcysteine; Penicillamine; BAL	DTPA and EDTA
Copper	Penicillamine; Trientine	Penicillamine
Curium	DTPA	DTPA
Einsteinium	DTPA	DTPA
Europium	DTPA	DTPA
Fission products (mixed)	See text below	N/A
Fluorine	Aluminum hydroxide	Aluminum hydroxide
Gallium	Penicillamine	Penicillamine
Gold	Penicillamine; BAL	BAL
Indium	DTPA	DTPA
Iodine	KI; Propylthiouracil; Methamizole; Potassium perchlorate	KI
Iridium	DTPA; Penicillamine	Penicillamine?
Iron	Deferoxamine; Deferiprone; Deferasirox	Deferoxamine
Lanthanum	DTPA	DTPA
Lead	DMSA; BAL with EDTA	DMSA
Manganese	DTPA; EDTA	EDTA
Magnesium	EDTA	EDTA
Mercury	BAL; Penicillamine; DMSA?	BAL
Molybdenum	?	?
Neptunium	Deferoxamine	Deferoxamine
Nickel	DTPA; Imuthiol	Imuthiol
Niobium	DTPA	DTPA

Radionuclide	*Treatment*	*Preferred Treatment*
Palladium	Penicillamine; DTPA	Penicillamine
Phosphorus	Phosphorus therapy†	Phosphorus therapy†
Plutonium	DTPA	DTPA
Polonium	BAL; DMSA?; Penicillamine?	BAL
Potassium	Diuretics	Diuretics
Promethium	DTPA	DTPA
Radium	Strontium therapy†	Strontium therapy†
Rubidium	Prussian Blue	Prussian Blue
Ruthenium)	DTPA	DTPA
Scandium	DTPA, EDTA	DTPA
Silver	No treatment available	N/A
Sodium	Diuretic	Diuretic
Strontium	Strontium therapy†	Strontium therapy†
Sulfur	No treatment available	N/A
Technetium	Potassium perchlorate	Potassium Perchlorate
Thorium	DTPA	DTPA
Tritium	Force fluids	Water diuresis
Uranium	Bicarbonate	Bicarbonate
Yttrium	DTPA; EDTA	DTPA
Zirconium	DTPA	DTPA

† For strontium and phosphorus therapy, see Table 30.19.
BAL = British anti-lewisite (dimercaprol; 2,3-dimercaptopropanol)
DMSA = Dimercaptosuccinic acid (succimer)
DTPA = Diethylenetriaminepentaacetate
EDTA = Ethylenediaminetetraacetic acid
Original work by Goans.

predominant cause of morbidity and mortality for these victims. Internal contamination from inhalation or ingestion of radionuclides in fallout will therefore be at best a secondary health concern compared with the thermal, blast, prompt radiation, and combined injuries associated with the detonation. An additional consideration is that the composition of fallout will be complex, reflecting a disparate mix of radionuclides and likely including compounds for which no or only minimally effective decorporating or blocking agents exist.

THE PSYCHOLOGICAL AND BEHAVIORAL CONSEQUENCES OF RADIATION EVENTS

Incidents resulting in the release of radiation, particularly if the event represents a deliberate attack, will produce uncertainty, anxiety, and fear in many otherwise psychologically normal and healthy individuals. These feelings may manifest directly or be expressed as anger, disbelief, sadness, irritability, arousal, sleep disturbance, dissociation, or increased use of alcohol, stimulants such as caffeine and tobacco, or drugs. In general, such feelings, and the behavioral symptoms associated with them, represent normal responses to profoundly abnormal events.[137] For most persons, acute posttraumatic psychiatric and behavioral symptoms will subside with time. Individuals exposed to risks that actually threaten their lives or who sustain injuries are at the highest risk of psychiatric morbidity, which may meet the criteria for psychiatric diagnoses such as Acute Stress Disorder or Post-traumatic Stress Disorder.[138] For many persons, knowledge that one has been exposed to a toxin such as radiation can be a potent traumatic stressor.[138] Terrorist attacks are likely to produce substantial levels of persistent psychiatric illness and morbidity in the persons targeted. For example, among 267 U.S. Pentagon staff surveyed two years after the attacks of September 11, 2001, 14% had probable posttraumatic stress disorder and 7% had probable depression. Direct exposure to the September 11th terrorist attack on the Pentagon, injury during the attack, and exposure to dead bodies were associated with higher frequencies of persistent psychiatric illness and psychological distress.[139] How the additional threat posed by radiation – for example, the risk of carcinogenesis years later – would affect psychiatric well-being after a terrorist event is unclear.

In the aftermath of an event, the public will seek advice from both healthcare providers and the scientific community to determine the extent of both internal and external contamination. Those who have been exposed or anticipate possible exposure are likely to experience feelings of vulnerability, anxiety, and lack of control. Internal contamination with radionuclides may be particularly anxiety provoking because the patient essentially has little control over isotope decorporation therapy and must rely on evaluation from the medical community. In addition, if there is a lack of consensus among experts, this can increase the fear and anger of exposed individuals.

The stress of radiation exposure may also cause some victims to seek medical treatment, even when none is indicated or risk is minimal. For example, there have been many cases at industrial sites where workers have been exposed to accidental inhalation of minimal quantities of actinides. Some of these workers have requested treatment with DTPA and other medications for years after the event, even when assured that chelation therapy would provide little medical efficacy. Psychological distress after a radiological incident may also manifest as nonspecific somatic complaints (a presentation sometimes referred to as "MIPS," multiple idiopathic physical symptoms or "MUPS," multiple unexplained physical symptoms).[140]

Acute stress disorder and posttraumatic stress disorder are the disorders most commonly associated with public response to a radiation event. In addition, major depression, increased substance use, family conflict, and generalized anxiety disorder may also occur. In the acute aftermath of a radiation event, many unexposed patients will fear that they have been exposed and will misattribute signs and symptoms of autonomic arousal to radiation poisoning (after the ^{137}Cs contamination in Goiânia, Brazil, 8.3% of the first 60,000 people screened presented with signs and symptoms of autonomic arousal consistent with acute radiation sickness).[140] In the longer term, patients may present to primary care providers with multiple somatic complaints for which no etiology can be determined. Such effects can be very widespread. In 2006, for example, the United Nations Chernobyl Forum stated that the "mental health impact of Chernobyl is the largest public health problem caused by the accident to date" and concluded that the accident had had a serious impact on mental health and well-being in the general populations of the countries (Belarus, Ukraine, and Russia) most affected by the event.[1]

A well-organized and effective medical response will instill hope and confidence, reduce fear and anxiety, and support the

Table 30.19: Dose Schedules by Drug or Treatment Modality

Drug or Treatment Modality	*Dosage*
BAL	**IM:** 300 mg/vial for deep IM use, 2.5 mg/kg (or less) q 4 h × 2 d, then bid for 1 d, then qd for days 5–10
DTPA (Ca or Zn)	**IV:** 1 g in 250 mL NS or 5% glucose, given in 1–2 h, or IV push over 3–4 min
	IM: 1 g can be given with procaine to reduce pain (not U.S. FDA approved)
	Inhalation: 1g in 1:1 dilution with water or NS over 15–20 min (not U.S. FDA approved)
	Pediatrics (<12 y): 14 mg/kg as above, not to exceed 1.0 g
D-Penicillamine	**PO:** 250 mg, qd between meals & at bedtime. May increase to 4 or 5 g qd in divided doses
Deferoxamine	**IM or IV (IM is preferred):** 1 g IM or IV (2 ampules) slowly (15 mg/kg/h); repeat as indicated as 500 mg IM or IV q 4 h × 2 doses; then 500 mg IV q 12 h for 3 d
DMSA	**PO (for lead poisoning in pediatric patients):** Start dosage at 10 mg/kg or 350 mg/m^2 oral q 8 h × 5 d. Reduce frequency of administration to 10 mg/kg or 350 mg/m^2 q 12 h (two-thirds of initial daily dosage) for an additional 2 wk of therapy (course of treatment = 19 d).
EDTA (Ca)	**IV:** Ca-EDTA 1000 mg/m^2/d added to 500 mL D_5NS infused over 8–12 h.
Imuthiol	**IV:** For mild-moderate poisoning, the recommended dose is 2 g qid in divided doses. Titrate upward in dose if indicated.
PHOSPHORUS THERAPY	
Potassium phosphate, dibasic	**PO:** 250 mg phosphorus per tablet.
	Adults: 1–2 tabs po qid, with full glass of water each time, with meals and at bedtime.
	Children over 4 y: 1 tablet qid.
Potassium Iodide (KI)	**All PO**
	Adults >40 y: with thyroid exposure >500 cGy: 130 mg/d.
	Adults 18–40 y: with thyroid exposure >50 cGy: 130 mg/d.
	Pregnant or lactating women: 130 mg/d.
	Children and adolescents 3–18: with thyroid exposure >5 cGy: 65 mg/d.
	Infants 1 mo–3 y: 32.5 mg/d.
	Neonates from birth to 1 mo: 16 mg/d
Propylthiouracil (PTU)	**PO:** 50 mg tabs, 2 tid × 8 d
Prussian Blue	**PO:** Begin with 1 g tid po with 100–200 mL water; may titrate up to 4 g qid for thallium or high ^{137}Cs intake.
	Pediatrics, 2–12 y: 1 g po tid
Sodium Bicarbonate	**IV:** 2 ampules sodium bicarbonate (44.3 mEq each, 7.5%) in 1,000 mL NS, 125 mL/L, or 1 ampule of sodium bicarbonate (44.3 mEq, 7.5%) in 500 mL NS, 500 mL/h.
	PO: 2 tablets q 4 h until urine pH = 7–8, or 4 g (8 tablets) 3 tid
STRONTIUM THERAPY	
Aluminum hydroxide	**PO:** 60–100 mL, once
Aluminum phosphate gel	**PO:** 100 mL immediately after exposure once
Ammonium chloride	**PO:** 1–2 g qid for 6 d
Calcium	**PO:** Generous doses; at least 1.5–2 g daily
Calcium gluconate	**IV:** 5 ampules (500 mg calcium each) in 500 mL D5W over 4 h; continue × 6 d
Sodium Alginate	**PO:** 10 g powder in a 30 mL vial, add water and drink
Water diuresis	**PO:** >3–4 L/d

Original work by Goans.

continuity of basic community functions. Mental health professionals including psychologists and psychiatrists should be an integral part of the teams that perform initial screening and triage. When feasible, the establishment of an "Emergency Services Extended Care Center" may provide a functional mechanism for monitoring patients who remain fearful and are not reassured by negative findings on clinical laboratory studies.[140] Reinforcing individuals' self-sufficiency and providing actionable information that can be used to protect oneself and one's family can decrease distress. Distributing appropriate medical countermeasures can also provide substantial reassurance, with concomitant psychological benefits.

CASE STUDIES IN RADIATION MEDICINE

Goiânia (Large ^{137}Cs Source in the Public Domain)

On the afternoon of September 29, 1987, a physicist in the town of Goiânia, Brazil notified the National Nuclear Energy Commission of Brazil about the potential of a serious radiation accident. A 50.9-TBq (1,375-Ci) ^{137}Cs radiation therapy device had been removed by three men on or about September 13, 1987 from an abandoned radiotherapy clinic and sold to a junkyard as scrap.[141] It is believed that the source capsule was ruptured on September 18. The relatively soluble CsCl mass was divided into smaller pieces and distributed among various friends and neighbors. The accident became known 16 days later. A physicist contacted by medical authorities was able to identify the nature of the source and subsequent widespread contamination. The physicist's involvement was prompted when the wife of the junkyard owner brought a piece of the source to the attention of her physician, saying that it was responsible for illness in many of her friends.

In total, approximately 110,000 residents of Goiânia were monitored in the Olympic Stadium and 249 were found to be contaminated, either internally or externally or both. Four main foci of contamination were noted: three junkyards and the residence where the source was ruptured. Handling of the radioactive Cs generally caused internal contamination by ingestion. Four individuals died in the accident, three from external exposure and one, a 6-year-old child, from ingestion of powdered Cs. In addition, the town was extensively contaminated. During decontamination efforts, a total of 12,500 drums and 1,470 boxes were filled with contaminated debris. More recent developments from this accident have been described in a subsequent International Atomic Energy Agency publication.[142]

The Radiation Accident in Estonia (Large ^{137}Cs Source in a Private Home)

On October 21, 1994, an Estonian citizen, RiH, along with his two brothers, visited a radioactive waste facility to scavenge for scrap metal, overriding the electrical alarm system and cutting various padlocks. RiH climbed into one of the vaults to obtain salvageable metal and passed a large ^{137}Cs source to his brothers. At this time, none of the brothers realized that this metallic object was highly radioactive. During the theft, RiH injured his leg slightly when an aluminum drum fell against it. Shortly after entry into the repository, RiH began to feel ill and went home. Other occupants of the house were the man's stepson (RT), the boy's mother and the boy's great-grandmother. The Cs source was initially placed in the pocket of RiH's coat, which was hanging in the hall. Eventually, it was placed in a kitchen drawer along with various tools. Details of the radiation injury to members of the household and the resulting radiation-induced pathology are described in an International Atomic Energy Agency publication.[143]

Soon thereafter, RiH was hospitalized with severe injury to his leg. During the initial medical history, RiH claimed that he received the injury while working in the nearby forest and he was therefore treated for crush injury. On November 2, 1994, RiH died without medical authorities having any suspicion of radiation exposure as the etiology of RiH's terminal illness. Meanwhile, by November 9, 1994, the stepson RT had developed signs and symptoms that indicated that he had come in contact with the source multiple times while working on his bicycle.

Shortly thereafter the 4-month old pet dog died. The dog had slept much of the time in the kitchen near the Cs source. RT was also eventually admitted to the hospital with severe hand burns, which physicians correctly diagnosed as radiation-induced cutaneous injury. As a result of this diagnosis the police were notified, and the police in turn notified the Estonia Rescue Board, which immediately dispatched staff. A Russian medical delegation also arrived soon thereafter to provide medical and health physics consultation.

After an extensive radiation dose reconstruction, the investigators estimated that RiH received a dose of approximately 1,830 Gy to his thigh and approximately 4 Gy to the rest of his body. Clinically, RiH experienced many of the effects of the acute hematopoietic syndrome along with severe, extensive local injury to his thigh (the dose rate of the stolen source was estimated to be 2,000–3,000 Gy/hour). Twelve days following his exposure he died from neutropenic sepsis and acute renal failure. An autopsy showed acute radiation necrosis of right thigh and hip, along with hemorrhage and intestinal thinning of the intestinal wall. The cause of death was ARS with both hematopoietic and GI components, along with severe local radiation necrosis.

The investigators estimated that the stepson, RT, received 20–30 Gy to his left hand, 8–10 Gy to his right hand, and approximately 2.5 Gy to the whole body during various episodes of bicycle maintenance. Other family members received hand doses in the range 8–20 Gy and whole-body doses in the range 1–2.5 Gy. The dose estimations were based on each individual's recollection of the degree of occupancy of various locations in the house. In addition, spatial computer analysis, chromosome aberration analysis, and other specialized assays were used.

Criticality Accidents in the United States

Los Alamos Plutonium Sphere Cases

Two criticality events occurred with the same 6.2-kg delta-phase plutonium sphere at Los Alamos National Laboratory.[144] The first incident occurred on August 21, 1945, when a worker was preparing a critical assembly by stacking tungsten carbide bricks around the plutonium core as a reflector. He moved the final block over the assembly but, noting that this block would make the assembly supercritical, he withdrew it. The brick fell onto the center of the assembly, resulting in a super-prompt critical state of approximately 6×10^{15} fissions.[145] The worker sustained an average whole-body dose of approximately 5.1 Gy and a dose to the right hand of approximately 100–400 Gy. The patient died of sepsis 28 days after the accident.

The second criticality accident occurred in 1946 during an approach to criticality demonstration at which several observers were present. The operator used a screwdriver as a lever to lower a hemispherical beryllium shell reflector into place. While holding the top shell with his left thumb in an opening at the spherical pole, the screwdriver slipped and caused a critical configuration. The fission yield in this accident was estimated at 3×10^{15} fissions. The operator received an estimated acute whole-body dose of approximately 21 Gy, with a dose to the left hand 150 Gy and somewhat less to the right hand. Seven observers were exposed in the range 0.27–3.6 Gy. The operator died 9 days later.

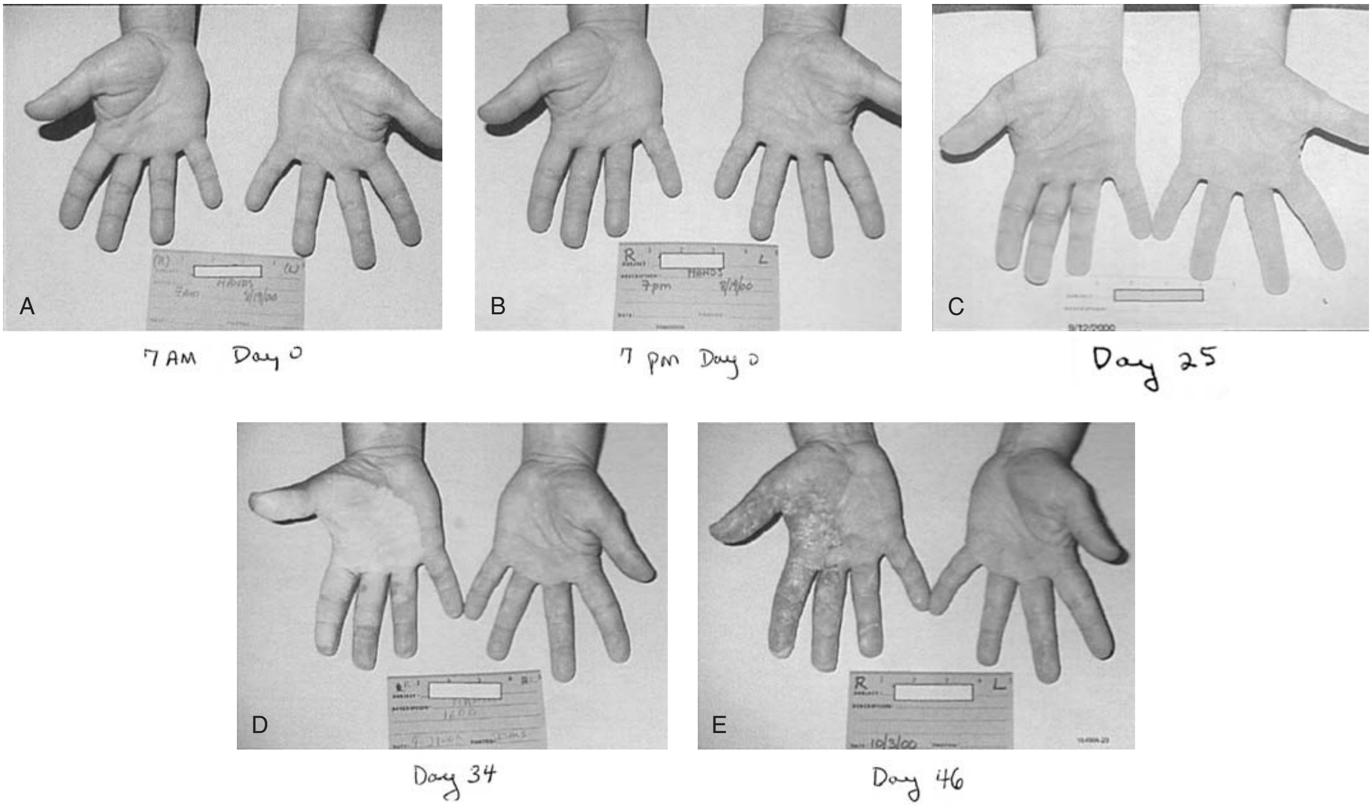

Figure 30.6. Progression of skin lesions in a patient receiving a focal high-dose exposure to the right hand. (**A**) Shortly after exposure, (**B**) approximately 12 hours postexposure, (**C**) day 25 postexposure, (**D**) day 34 postexposure, and (**E**) day 46 postexposure. Images provided by the Radiation Emergency Assistance Center/Training Site. See color plate. Used with permission from REAC/TS.

Los Alamos Liquid Criticality Event

On December 30, 1958, during purification and concentration of plutonium, unexpected plutonium-rich solids were washed from two vessels into a single large vessel that contained layered, dilute aqueous and organic solutions. The tank contained approximately 295 L of a caustic stabilized organic emulsion. The added nitric acid wash is believed to have separated the liquid phases. Accident analysis shows that the aqueous layer was initially slightly below delayed critical (approximately 203 mm thick, critical thickness 210 mm). When the stirrer was started, the central portion of the liquid system was thickened, changing system reactivity to super-prompt critical. The excursion yield was approximately 1.5×10^{17} fissions. Bubble generation was the negative feedback mechanism for terminating the first neutron spike. The system was driven permanently subcritical by mixing of the two layers. This accident resulted in the death of the operator 35 hours postaccident. The dose to the upper extremity was estimated at 120 Gy $\pm$ 50%. Two other persons received acute doses of 1.34 Gy and 0.53 Gy.

Wood River Junction Criticality Event

This liquid process accident occurred on July 24, 1964, at the United Nuclear Fuels Recovery Plant, Wood River Junction, RI. A chemical processing plant was designed to recover highly enriched Ur from scrap material left over from the production of fuel rods. Uranyl nitrate solution U(93) was poured into a carbonate reagent vessel. The critical excursion occurred when nearly all of the Ur had been transferred, resulting in approximately 1.1×10^{17} fissions. It is probable that the system oscillated, resulting in a series of excursions with total energy release equivalent to 1.3×10^{17} fissions. The acute dose to the operator was estimated to be 100 Gy. Two supervisory personnel received approximately 1 Gy and 0.6 Gy. The operator died 49 hours after the accident.

Clinical Course of the Criticality Cases

Case 1 – Los Alamos plutonium sphere (hematopoietic syndrome; cutaneous radiation injury syndrome; whole-body dose approximately 5.1 Gy, dose to right hand 100–400 Gy)

The patient was a 26-year-old man whose medical history was significant only for Wolff-Parkinson-White syndrome diagnosed 3 years prior to the incident. On admission to the hospital, his vital signs were within normal limits and his only initial complaint was numbness and tingling of both hands. The initial physical examination was also within normal limits.

Within 30 minutes postaccident, the patient's right hand had become diffusely swollen. Emesis began approximately 1.5 hours postevent, and nausea continued intermittently for the next 24 hours. The patient experienced subjective improvement but had a low-grade fever, gastric distress, and weakness during days 3–6. By day 5, the patient experienced a distinct rise in temperature with tachycardia and began to appear increasingly toxic. On day 10, he developed severe stomatitis, a paralytic ileus, and diarrhea. Clinical signs of pericarditis were noted on day 17, and the patient's mental status deteriorated. The clinical course was notable for progressive pancytopenia. Figure 30.6 demonstrates an exponential decrease of lymphocytes during the first 4 days postaccident.

Within 36 hours of the accident, blisters were noted on the volar aspect of the right third finger, and within another day extensive blistering was noted on both palmar and volar surfaces of the hand. A decision was made on day 3 to drain the blisters surgically but by the third week, the right hand had progressed to dry gangrene. Desquamation of the epidermis involved almost all of the skin of the dorsum of the forearm and hand. In addition, epilation was almost complete at the time of death.

On day 24, the patient's temperature had risen to 41.1°C. He had lost a great deal of weight, developed thoracoabdominal erythema, and had signs of sepsis. The patient became comatose and died on the same day. During the patient's clinical admission, treatment consisted of fluid support, penicillin antibiotic therapy, thiamine, and two blood transfusions.

On autopsy, severe skin necrosis was observed as well overt dry gangrene. The cardiorespiratory system was significant for pericarditis, cardiac hypertrophy, pulmonary edema, and alveolar hemorrhage. The spleen was noted to have no germinal centers and the mucosa of the large bowel and the buccal mucosa were ulcerated. The bone marrow was noted to be hypoplastic and lymph nodes also showed significant lymphocyte depletion. The testes demonstrated significant atrophy with aspermia. A solitary ulcer was noted in the large colon as well as a right renal infarct.[146]

Case 2 – Los Alamos plutonium sphere (GI syndrome; cutaneous radiation injury syndrome; acute dose approximately 21 Gy, dose to the left hand 150 Gy)

The patient was a 32-year-old man, admitted to the hospital within 1 hour of the accident. His medical history was generally unremarkable. His occupational history was significant only for several prior, generally chronic occupational exposures, none exceeding 0.005 Gy in a week. The patient complained of nausea in the hour prior to admission and vomited once in the first hour after the accident.

The general condition of the patient was good in the first 5 days postaccident. On the fifth day there was a precipitous drop in his leukocyte count, and his condition quickly declined. The patient rapidly lost weight, became mentally confused on the seventh day, became comatose, and died on the ninth day.

Medical therapy during the 9-day course was largely supportive. Penicillin (50,000 U) was given intramuscularly every 3 hours beginning on day 5 because of granulocytopenia. Blood transfusions were also given daily after the fifth day. On day 6, fever and tachycardia developed, and on day 7, the patient developed a severe paralytic ileus. The patient died on day 9 in cardiovascular shock. At the time of death, both hands showed extensive radiation damage.

On autopsy, examination of the skin was remarkable for early vesicle formation in the abdominal skin and marked epidermal damage. The cardiorespiratory system was remarkable for cardiac hemorrhage, myocardial edema, and the terminal bronchi showed features of aspiration pneumonia. The spleen exhibited no germinal centers and the mucosa of most of the GI tract showed sloughing, most pronounced in the jejunum and ileum. Widespread degenerative changes were noted in the adrenal cortex as well as hyaline degeneration in the renal tubular epithelium. Examination of the red bone marrow (myeloid tissue) showed it to be of liquid consistency.[146]

Case 3 – Los Alamos Liquid Criticality Event (Central nervous system syndrome; dose to the upper extremity 120 Gy ± 50%)

The patient was a 50-year old man with no significant medical history. The clinical course has been divided into four separate phases

- Phase 1 (20–30 min postevent): immediate physical collapse and mental incapacitation, progressing eventually into semiconsciousness
- Phase 2 (90 min): signs and symptoms of cardiovascular shock accompanied by severe abdominal pain
- Phase 3 (28 h): subjective minimal clinical improvement
- Phase 4 (2 d): rapid development of irritability and mania, progressing to coma and death

The clinical course was remarkable for continuing, profound hypotension, tachycardia, and intense dermal and conjunctival hyperemia. The patient died 35 hours after exposure.

On autopsy, examination of the bone marrow was most significant for absence of mitotic activity. The lungs showed pyknotic, degenerating cells in the pleura, degenerating lymphocytes and neutrophils in the subpleural connective tissue and many areas of focal atelectasis interspersed with foci of emphysema. All lymph nodes were markedly atrophic and lymphoid follicles in the spleen were greatly depleted.

Examination of the heart showed acute myocarditis, myocardial edema, cardiac hypertrophy, and a fibrinous pericarditis. Examination of the brain demonstrated cerebral edema, diffuse vasculitis, and cerebral hemorrhage. The GI system showed necrosis of the anterior gastric wall parietal cells, acute upper jejunal distention, mitotic suppression throughout the entire GI tract and acute jejunal and ileal enteritis.[147]

Case 4 –Wood River Junction (Central nervous system syndrome; approximately 100 Gy)

The patient was a 38-year man with no significant medical history. Following the initial criticality excursion, the patient appeared stunned, ran from the building, and immediately vomited. He also experienced instantaneous diarrhea and complained of severe abdominal cramping, headache, and thirst and he was perspiring profusely. His initial vital signs showed borderline blood pressure elevation and tachycardia. Approximately 4 hours after the accident, the patient experienced transient difficulty in speaking, hypotension, and tachycardia. A portable chest x-ray 16 hours after admission revealed hilar congestion. The physical examination showed the left hand and forearm to be edematous and also demonstrated left-sided conjunctivitis and periorbital edema (Figure 30.7). On day 2, the patient became very disoriented, hypotensive, and anuric. The patient died 49 hours after the accident in cardiovascular shock.

At autopsy, interstitial edema of the left hand, arm, and abdominal wall was noted. Examination of the heart, lungs, and abdominal cavity revealed acute pulmonary edema, bilateral hydrothorax, hydropericardium, abdominal ascites, acute pericarditis, interstitial myocarditis and inflammation of the ascending aorta. Examination of the GI tract showed severe subserosal edema of the stomach and of the transverse and descending colon. The bone marrow was noted to be aplastic, and the lymph nodes, spleen, and thymus were depleted of lymphocytes. The brain showed minimal effects, with rare foci of microglial change.

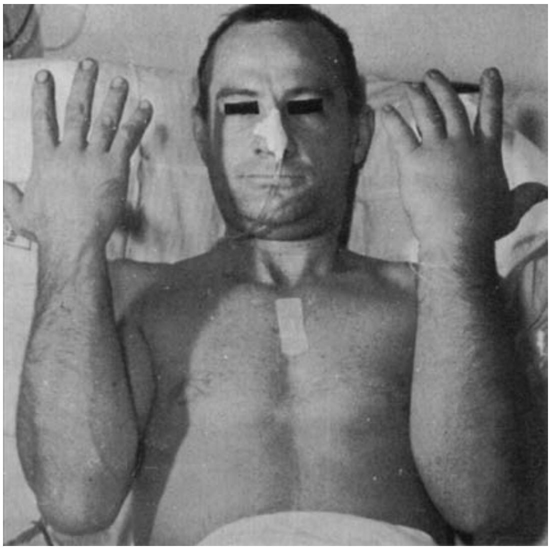

Figure 30.7. Wood River Valley patient 24 hours postaccident. Note edema in the left arm. Figure reprinted with permission of the *New England Journal of Medicine.*

The testes showed interstitial edema and overt necrosis of the spermatogonia.[148]

RECOMMENDATIONS FOR FURTHER RESEARCH

New treatments for radiation injury are emerging that may accelerate healing of acute radiation injuries and/or minimize the delayed effects of acute radiation exposure such as fibrosis, radiation nephropathy, and other complications. Current research is exploring the possibility of translating therapies that have been efficacious in the treatment of chemotherapy-induced myelosuppression, GVHD, thermal burns, ischemic injury (e.g., diabetes), and other disorders to be used for the management of radiation-induced injury.

Many of the therapies currently under consideration as potential radiation countermeasures were developed to address problems of supportive oncology. Many chemotherapeutic agents share with radiation the property of killing rapidly dividing cells and thus producing toxicity profiles (e.g., with pronounced bone marrow and GI toxicity) that mimic the effects of radiation. Drugs and therapeutics that have demonstrated efficacy in preventing, mitigating, or treating such toxic effects are obvious candidates for development as radiation countermeasures. The efficacy of CSFs such as filgrastim, pegfilgrastim, and sargramostim in shortening the duration of neutropenia after chemotherapy is well established and these products are widely used clinically for this purpose. Palifermin (also known as keratinocyte growth factor) is licensed for the mitigation of mucosal toxicity in patients receiving bone marrow transplants and has been evaluated in animal models as a radiation countermeasure. Farrell and colleagues demonstrated that keratinocyte growth factor given prior to radiation and/or chemotherapy protected mice from GI injury and mortality.[149] More recent studies with postradiation administration of keratinocyte growth factor, alone and in combination with other radiation countermeasures, have demonstrated mucosal protection that may result in improved survival in preclinical models.[150,151] Newer agents, such as the second-generation thrombopoietin receptor agonists, are being studied for the mitigation of chemotherapy-induced thrombocytopenia and other side effects of chemotherapy. None of these agents are currently licensed in the U.S. for the treatment of radiation injury. Such agents are now being studied in animal models of acute radiation exposure and it is possible that the benefits observed when they are used to reduce the toxicity of chemotherapy will translate into the radiation setting.

Others forms of injury not directly targeting rapidly dividing cell populations also appear to share common mechanistic pathways with radiation injury. Trauma, for example, appears to up-regulate many of the same proinflammatory cytokines (e.g., transforming growth factor–β and tumor necrosis factor–α) and matrix metalloproteinases as acute radiation exposure, whereas other cytokines (e.g., platelet-derived growth factor and fibroblast growth factor) might be at insufficient levels for maximal healing.[152–154] Treatments that affect cytokine levels have demonstrated significant efficacy at mitigating the acute effects of many kinds of injury in clinical studies and preclinical models, and it is reasonable to hypothesize that they may demonstrate efficacy in the treatment of radiation-induced injury and/or radiation combined injury. For example, becaplermin, a recombinant human platelet-derived growth factor, is FDA-approved for lower extremity diabetic neuropathic ulcers that extend into the subcutaneous tissue or deeper with an adequate blood supply, and it may also have efficacy in radiation-related injury.[155] The role that individual cytokines play in the healing process is complex, however, and applications or generalized class inhibition of some of the cytokines may have either beneficial or deleterious properties depending on the stage of the healing process.[156–158] Commercially available tissue-engineering products have also demonstrated efficacy in wound repair by providing a protective barrier and possibly an environment rich in cytokines for the treated wound.

The direct administration of cytokines also appears to offer great promise. Combination therapy with cytokines clearly shortens the duration of hematopoietic pancytopenia in preclinical models. Herodin et al., demonstrated that in animal models the combination of stem cell factor + Flt3-ligand + thrombopoietin + interleukin 3 (regimen name: SFT3) reduced the period of thrombocytopenia and blood transfusions required after 7 Gy of total-body irradiation. Furthermore, the addition of pegfilgrastim to the combination shortened the period of neutropenia compared with the control and SFT3 groups. Bone marrow activity recovered faster in the SFT3 groups compared with the control. Of note, no long-term mutagenic toxicity appears associated with SFT3.[159] Herodin et al., also demonstrated that postradiation administration of keratinocyte growth factor and SFT3 resulted in 75% survival at 30 days compared to the controls of less than 10% ($p < 0.01$). Thus, treatments that address multiorgan failure appear promising.[151]

Therapies that treat or mitigate both the acute and late effects of radiation exposure are being investigated. For example, angiotensin-converting enzyme inhibitors and angiotensin II receptor antagonists have been shown to decrease chemical, mechanical, and radiation acute and/or late effects in a variety of organs.[160–164] Suppressing or regulating the acute or chronic inflammatory response also appears to expedite the healing process. Although being more susceptible to infection, neutrophil-depleted mice, for example, have demonstrated more rapid wound closure, presumably as a result of the suppression of neutrophil-mediated inflammation.[165] There is emerging evidence to suggest that treatments that suppress the ongoing inflammatory response may accelerate repair while minimizing late sequelae such as fibrosis and scarring.[166]

The poisoning of Russian dissident Alexander Litvinenko in London in 2006 with ^{210}Po has underscored the lethality potentially associated with the internalization of radionuclides and thus the importance of developing new and improved methods of decorporating radionuclides. In recent years, the Radiation Countermeasures Program at the U.S. National Institutes of Allergy and Infectious Diseases, National Institutes of Health has funded research to support the development of orally available DTPA, nano-engineered sorbents, chitosan-based materials, and other novel chelating agents. Several of these projects have demonstrated improved decorporation and toxicity profiles in preclinical models and work is continuing at the time of writing. The goal is to expand the limited armamentarium of decorporating agents in coming years to include agents to treat persons internally contaminated with radionuclides (such as ^{90}Sr, ^{60}Co, and ^{210}Po) for which no licensed therapies are currently available.

Another area of concern and controversy is the exposure of large numbers of people to low doses of ionizing radiation from an atomic bomb explosion or from diagnostic procedures resulting in stochastic late effects, specifically cancer. One area of current interest is the population effect of the widespread use of CT scans. In a prominent 2007 article, Brenner and Hall suggest that 1.5–2% of all cancers in the United States may be attributable to radiation from CT studies.[167] The study is mainly based on the linear no-threshold model for cancer induction and extrapolates medical data from atomic bomb survivors. The linear no-threshold model, however, has been the subject of continuing controversy because no increased evidence of cancer has been observed at doses of less than 10 cGy in adults and infants. Some authorities have rejected the linear no-threshold model as the basis for radiation exposure risk assessment at very low doses. For example, the French Academy of Medicine "denounces utilization of the linear no-threshold (LNT) relation to estimate the effect of low doses to a few mSv."[168] A second issue involves utilizing the medical data on atomic bomb survivors for estimating the effects of diagnostic radiation. Although absolute energy exposure may be similar, the qualities of the ionizing radiation that produce such exposures are different. Diagnostic medical devices use x-rays and typically result in highly nonuniform exposures, whereas the prompt radiation associated with fission and delayed radiation from fallout results in more nearly uniform exposures to both electromagnetic (gamma rays and x-rays) and particulate (alpha particles, beta particles, and neutrons) forms of radiation. It remains to be demonstrated that the carcinogenic potential of these different kinds of exposure are identical. Uncertainty also remains as to the risk imposed by in utero exposures below 10 cGy because of the contradictory epidemiological data.[169] Regardless, the development of highly safe therapies for use in large exposed populations to minimize stochastic effects is warranted, especially at doses at which there is clear evidence for increased cancer induction, that is, more than 10–20 cGy.

Finally, for countermeasures such as those described herein to be useful, emergency management officials must have reliable mechanisms for delivering them to exposed individuals in a timely fashion. Delivery of products from centralized stockpiles may be sufficient for countermeasures that can be administered 24–48 hours after exposure but will likely be inadequate for highly time-sensitive countermeasures such as potassium iodide. The U.S. National Academy of Sciences recently reported on strategies for stockpiling and distributing potassium iodide, and other authors have proposed alternative strategies of forward deployment that could facilitate the rapid distribution of other time-sensitive countermeasures.[170,171]

CONCLUSIONS

As noted in the introduction, mass exposure to radiation does not occur frequently but such events, when they do occur, present tremendous challenges to affected communities. With the concerns of recent years about nuclear or radiological terrorism, it would also appear that the risk of deliberate mass exposures to radiation has increased. Nations, regions, and communities must maintain their primary focus on preventing the occurrence of radiological and nuclear accidents but should engage in prudent consequence management planning as well. Planning must include provision for the medical and public health response to radiation emergencies, including the management of large numbers of potentially contaminated patients, the performance of accurate biodosimetry and dose assessment, the rapid delivery and distribution of pertinent medical countermeasures, the clinical care of radiological casualties, and the extension of emergency psychological and social services to traumatized communities.

In future years, the application of novel scientific tools and techniques to the challenges of radiobiology and normal tissue injury will likely result in significant advances in the ability to diagnose, mitigate, and treat both the ARS and the delayed effects of acute radiation exposure. The application of genomic, proteomic, and metabolomic probes to irradiated tissue may result in new ways to perform rapid dose assessments and the development of a truly predictive biodosimetry. In the realm of therapeutics, a better understanding of the systems biology of radiation injury will likely lead to the rational design of targeted radiation countermeasures, an enhanced understanding of the role of growth factors, and pleiotropic cytokines in mitigating radiation injury. Improved methods, perhaps involving novel approaches to cell therapy and regenerative medicine, for promoting immune reconstitution and tissue repair after high-dose irradiation are on the horizon. After a period of comparative neglect, the future for the fields of radiobiology and normal tissue injury appears to be bright.

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31

Hazardous Material, Toxic, and Industrial Events

Hoon Chin Lim and Tareg A. Bey

OVERVIEW

Hazardous material (HazMat) incidents are increasingly prevalent due to the continuing rapid growth and globalization of the chemical industry. In a previous report, the World Health Organization (WHO) noted that 100,000 industrial chemicals exist in the workplace. This number is increasing by an estimated 1,000 per year.[1] In the United States alone, there are approximately 13,500 chemical manufacturing facilities, owned by more than 9,000 companies.[2] When it comes to transportation of HazMats, the nation has nearly 1 million daily shipments by land, sea, and air.[3] Globally, chemical production and use has also increased nearly 10-fold over the last 30 years, and this is particularly true in developing countries.[4] The presence of such large quantities of toxic chemicals and hazardous substances among populations poses a significant threat to global health and the environment.

This chapter will focus on industrial HazMat events. Hazards of a biological nature or those with radioactive properties are discussed in Chapters 29 and 30. Harm can also result from deliberate release of hazardous materials from terrorism. Chemical emergencies related to the use of entities such as nerve agents are described further in a Chapter 28. Practical advice is provided based on best available evidence and any guidance is intended to undergo local interpretation.

Acute releases of hazardous materials are common and occur on a daily basis. As an example, a total of 7,744 acute HazMat emergency events were reported in 13 U.S. states alone in a 2004 annual report by the Hazardous Substances Emergency Events Surveillance (HSEES) system maintained by the Agency for Toxic Substances and Disease Registry.[5] In England and Wales, a chemical surveillance system managed by the Environmental Health and Risk Assessment Unit of the Chemical Hazards and Poisons Division reported 1,978 chemical incidents in the years 2006 and 2007.[6] The numbers from such databases will differ depending on surveillance methodology and the sources utilized that report such events. The WHO recognizes that as far as chemical emergencies are concerned, wide-scale major industrial accidents or attacks using chemical weapons give an incomplete picture when it comes to the disease burden from chemical incidents. The majority of exposure-related deaths and illnesses are attributable to the many medium-sized and small-scale chemical incidents that take place every year around the world.[7] One has to suspect that in some countries, these are the same incidents that go unreported due to poor or nonexistent injury surveillance systems. This may lead to an underestimation of disease burden.

Most acute HazMat events affect public health within the nation of its occurrence. Occasionally, these chemical incidents become events of international public health concern. In August 2002, the WHO initiated a pilot project sponsored by the International Programme on Chemical Safety (IPCS) to determine whether a system complementary to that for communicable disease surveillance and response could be developed for chemical incidents and related illnesses. Using several informal (e.g., Internet-based resources) and formal (e.g., various networks of organizations) sources, incidents were assessed against criteria for international public health emergencies using the then proposed revised International Health Regulations (IHR). During the 17 months of the project, from August 1, 2002 to December 31, 2003, 35 chemical incidents from 26 countries met one or more of the IHR criteria. The WHO European Region accounted for 43% (15 of 35) of reports.[8] This was possibly the first global surveillance system for chemical incidents of potential international concern. It appears capable of providing early detection of important events as well as information on their magnitude and geographical distribution, thereby improving global public health preparedness.

Epidemiology of Acute Hazardous Material Events

The number of acute HazMat events is on the rise. According to HSEES, the number of events per year increased from 5,785 in 1998 to 7,105 during 2001 even after excluding states that did not participate in their reporting program for the full period.[9] It is uncommon for acute HazMat events to cause mass casualty scenarios. In 2004, 620 HSEES-reported emergency events (8% of all events) produced victims. Only one event resulted in more than 50 injured persons. In that event, 57 employees were injured due to improper mixing of a chemical that aerosolized a hydrochloride/phenol solution in a physician's clinic.[5]

An industrial chemical disaster is defined as the release or spill of a toxic chemical that results in an abrupt and serious disruption of the functioning of a society, causing widespread human, material, or environmental losses that exceed the ability of the affected society to cope using only its own resources.[10] Compared with daily small-scale HazMat emergencies, these incidents with high casualty counts are rare. One example, possibly the worst incident in history, is the 1984 Bhopal disaster in which more than 2,500 persons were killed and an additional 200,000–300,000 individuals were affected.[11] In contrast, most acute events do not result in patient injury. Furthermore, the majority of events that produce injuries result in only one or two victims.[5] Even so, these incidents call for special planning and preparedness due to the challenges of managing a chemically injured victim and the potential for HazMat incidents to harm emergency healthcare providers. Employees are most often injured (>50% of victims), followed by the general public.[9,12] Within the group of first responders, police, career firefighters, and volunteer firefighters were the most frequent victims of both fixed facility and transportation-related events.[9]

Many factors can contribute to a chemical incident. They include poor maintenance of manufacturing and storage equipment, lack of regulation and poor enforcement of existing safety standards, motor vehicle collisions, and human error as well as meteorological and geological events such as heavy rain, earthquakes, hurricanes, and floods, and terrorism.[13] As a consequence of these factors, incidents could be associated with fires, explosions, spills and leaks, and structural collapse. Industrial accidents can also be described by the initiating event, which can be one or more of the following: human error, environmental conditions, and container or equipment failure.[14] Between 1993 and 2001, most major acute chemical releases in the United States were due to equipment failure, followed by human/operator error. More than 75% of all events occurred in fixed facilities. Most events involved the release of only one substance.[9,12] Of the 7,169 transportation-related events from 1998 to 2001, 85% occurred during ground transport; 9% during rail transport, and 6% during a combination of air, pipeline, water, or other types of transport. The 10 most frequently released chemicals were ammonia (5%), sulfur dioxide (5%), sulfuric acid (2%), hydrochloric acid (2%), carbon monoxide (2%), sodium hydroxide (2%), nitric oxide (2%), mercury (2%), paint or coating not otherwise specified (2%), and ethylene glycol (1%).[9]

Bhopal Cyanide Event: Classic Example of an Industrial Disaster

On December 2–3, 1984, approximately 41 tons of highly toxic gaseous methyl isocyanate was released into the air from a Union Carbide plant in the city of Bhopal, which is located in the Indian state of Madhya Pradhesh. Additionally, other substances such as CO_2, CO, hydrogen cyanide, oxides of nitrogen, and phosgene were probably released within the gas cloud.[15] At the time of the disaster, there were inadequate industrial safety programs in place at the Bhopal Union Carbide plant (Table 31.1).[15–20] The infrastructure around the plant was deficient and included ineffective roadways and streets, water supply, and medical treatment facilities. Poor to nonexistent urban planning was prevalent for people living extremely close to the industrial plant. Additionally, people in Bhopal were destitute and had little education or training on how to respond as a community to a chemical disaster. The health infrastructure was weak in Bhopal in 1984.

Table 31.1: Factors Contributing to the 1984 Bhopal Disaster

- Multinational industrial producer of chemicals operates in a developing nation and does not adhere to accepted international safety standards
- Financial pressures supersede industrial safety regulations (violation of industrial zoning in the inner city, violation of limits for maximal production)
- No enforcement of international safety operational standards
- Lack of risk reduction in plant location
- Poor public health infrastructure in the vicinity of a major industrial operation
- Poor public utility infrastructure such as drinking water, sewer, electricity, and telephone
- Absence of an emergency response system for industrial accidents
- Lack of infrastructure and technical expertise to manage an industrial incident

Adapted after Broughton.[20]

No mass casualty emergency response system existed in the city and there was a lack of warning devices, shelter-in-place training, public education on the dangers associated with the plant, and joint planning activities by public agencies and the Union Carbide plant.[20]

No consensus exists regarding how many people died, how many were actually exposed, or the numbers who suffered long-term disabilities.[16] The literature describes different numbers of immediate and delayed fatalities as well as exposed individuals. Gupta and Broughton estimate that there were approximately 3,800–4,000 immediate deaths and more than 200,000 injuries.[17] In a report published in 2004, Sharma points out that Amnesty International estimated between 7,000 and 10,000 people lost their lives within the first 3 days of the Bhopal chemical release. Additionally, Amnesty International estimated that another 15,000–20,000 people succumbed to their exposures between the years of 1985 and 2003.[16] Eckerman suggests that approximately 500,000 people were exposed.[15] This makes the Bhopal incident the largest industrial disaster in history to date in terms of deaths and disabilities related to pulmonary, ophthalmological, neurological, reproductive, gastrointestinal, and psychiatric effects.[16]

Numerous articles were published in the aftermath, analyzing the 1984 Bhopal event.[16–20] Broughton points out that many safety measures and precautions that were normally in place in a highly industrialized country were absent in the Bhopal scenario. The Bhopal industrial disaster stands as a classic example of the consequences when pressure to expand industrialization in a developing nation leads to negligent enforcement of concurrent safety regulations.

The Bhopal disaster changed the chemical process industry permanently. Gupta emphasizes that improvements in the chemical process industry resulting from this event have saved lives and money by reducing accident damages.[17] These improvements include

- New legislation resulting in better enforcement and harsher sentencing
- Enhancement in process safety
- Development of safer industrial plants
- Monitoring by the media, nongovernmental organizations, and the public

- Chemical process industry management's willingness to invest in safety equipment, education and training

The Bhopal incident had a major effect on legislation and public political consciousness about chemical safety in the United States. It resulted in the formation of the American Institute of Chemical Engineers, the Center for Chemical Process Safety, and the Safety and Chemical Engineering program. These organizations resulted in a change in the practice and education of chemical engineers.[18]

Hazardous Wastes and the Environment

Hazardous wastes are dangerous substances intended for disposal. Their covert or deliberate release into the environment may not cause "disasters" that are immediately evident. However, being insidious and cumulative in effect, the damage they cause to the environment and subsequently public health is potentially great. Since the adoption of Agenda 21 at the United Nations Conference on Environment and Development, the attention of policy makers has been drawn to the links between health and the environment.[21] Air pollution is just one example. At the global level, air pollution is estimated to be responsible for approximately 800,000 premature deaths each year, or 1.4% of all deaths worldwide and 6.4 million years of life lost, or 0.7% of the world's total. This burden of disease is most important in developing countries, causing an estimated 39% reduction in years of life in southeast Asia (e.g., China, Malaysia, and Vietnam) and 20% in other Asian countries (e.g., India and Bangladesh).[22] Another example was the disposal of hazardous waste into Minamata Bay. This case illustrates one of the worst chemical incidents and was characterized by the chronic release of hazardous materials into the environment, poisoning a large number of victims. Between 1932 and 1968, Chisso Corporation, a company located in Kumamoto Japan, dumped an estimated 27 tons of mercury compounds into Minamata Bay. It was not until the mid-1950s that people began to notice a "strange disease." Thousands of people whose normal diet included fish from the bay unexpectedly developed a neurological syndrome characterized by ataxia, numbness, muscle weakness, and visual problems. The illness became known as "Minamata disease." The illness was ultimately diagnosed as methyl mercury poisoning. The public health impact was devastating. By 1974, 798 victims had been officially recognized as having Minamata disease, although approximately 3,000 more people were awaiting verification from the board of physicians in Kumamoto Prefecture. In 1993, almost 40 years later, victims were still being compensated for damages.[23]

Chemical Incidents and Environmental Justice

A study in the United States investigating the relationship between incidents at chemical facilities and characteristics of the surrounding communities revealed that larger facilities with higher risk for HazMat incidents are located in counties with larger African-American populations and higher levels of income disparity.[24] The relationship between chemical facility risk and the demographics of the surrounding community is complex. Higher risk facilities are more frequently found in counties with sizeable poor and/or minority populations who disproportionately bear the collateral environmental, property, and health risks.[24] In the light of such findings, environmental justice seeks to redress the inequitable distribution of this burden. The U.S. Environmental Protection Agency defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, culture, education, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.[25] Legislation such as the Emergency Planning and Community Right to Know Act (EPCRA) mandates the community be informed regarding the risks of chemical incidents that could arise from nearby facilities.[26]

STATE OF THE ART

Hazardous Materials Classification and Identification

Hazard materials are substances that pose a potential risk to life, health, the environment, or property when not properly contained because of their chemical, physical, or biological properties.[27] Different government agencies may define HazMat differently for operational reasons. Some use it loosely to describe specialized first responder teams equipped to handle on-site control and containment of hazardous chemicals. Apart from its inherent toxicity, the sheer quantity or concentration of the hazardous material in an acute release will also determine its ability to cause harm. These substances can be in solid, liquid, or gaseous form. Knowledge of a hazardous substance's physical properties (e.g., water solubility) during an acute event is useful because it will help to determine the route of victim exposure, the likelihood of secondary contamination, and the most effective method of protection and decontamination.

Chemicals may be known by their common, generic, chemical, or brand names. The Chemical Abstracts Service (CAS) of the American Chemical Society numbers chemicals to overcome the confusion regarding multiple names for a single chemical. The CAS assigns a unique CAS registry number (CAS#) to atoms, molecules, and mixtures. These numbers provide a unique identification for chemicals and a means for cross-checking chemical names. Identifying a chemical by name and CAS# is critical because one must be as specific as possible about the hazardous material in question. Trade or brand names can be misleading.[28,29] Another method for identifying hazardous substances is the globally recognized four-digit United Nations Substance Identification Number (UN SIN or UN Number), together with the United Nations Hazard Classification.

At the time of this writing, there is no universally adopted system of HazMat classification. Many different countries have their own standard for classification and communication. The presence of such inconsistent systems impacts both safety and economic interests. One positive step comes from the continuing development of a Globally Harmonized System for the Classification and Labelling of Chemicals (GHS).[30] An internationally synchronized approach to classification and labeling would provide the foundation for national programs to ensure safe use, transport, and disposal of hazardous substances. It would also provide a basis for harmonization of rules and regulations on chemicals at national and international levels, which is an important step for trade facilitation and improvement of hazard risk management. Two objectives of the GHS include 1) harmonized criteria for classifying substances and mixtures according to their health, environmental, and physical hazards, and 2) harmonized hazard communication elements, including requirements for labeling and safety data sheets. Although country participation in this program is voluntary, at least 65 countries have agreed to implementation. Many governments have either incorporated GHS into their existing regulations or established workgroups to reconcile existing legislation with the GHS. The UN released the second revised edition of the GHS in 2007.[31]

Various systems have been devised for the actual labeling of hazardous materials. Labels or placards contain information alerting people to the presence of dangerous materials by way of a pictogram or symbol. The placard may have words such as "flammable liquid" or "toxic gas," a product identifier, hazard classification number, or an emergency assistance number to call. Some identification systems are permanent and cannot be modified once attached to a container. Others can be changed with fitted slots or interchangeable placards.

In some countries, Material Safety Data Sheets (MSDSs) containing basic substance information are legally required to accompany each product supplied to an end user. MSDSs are not necessarily intended for emergency responders, but they can be used by professional staff to advise such individuals. MSDSs have existed for many years in a wide variety of formats, with a broad range of data quality and quantity. The IPCS and the European community produce International Chemical Safety Cards (ICSC) containing this information that are translated into various languages.[32,33]

The driver of a vehicle transporting hazardous materials may carry more detailed information on its contents. Within the European community, regulations require that written emergency instructions be carried in the vehicle cab. The European Chemical Industry Council has produced a series of instructions called TREMCARDS (transport emergency cards). These cards are written using internationally approved standard sentences with appropriate translations.[32,34]

First responders may also encounter other numerical codes such as the Emergency Action Codes and the Hazard Identification Number (also known as the Kemmler Code). Emergency Action Codes (commonly called Hazchem Codes) are designed to assist emergency services providers during the initial contact with a HazMat incident by instructing responders which actions they should perform. They are designed for responding to bulk product incidents. In contrast, the Hazard Identification Number, which is usually found in the United Kingdom on vehicles traveling internationally, gives advice on the nature of the hazard presented by the substance in question, as opposed to the actions required when dealing with the material.[35]

In the United States, the Department of Transportation Pipeline and Hazardous Materials Safety Administration uses the Hazard Classification System in its guidebook.[36] This system assigns a chemical to a hazard class based on its most dangerous physical characteristic, such as corrosiveness, flammability, or radioactivity. It is primarily a guide to aid first responders in 1) quickly identifying the specific or generic classification of the material(s) involved in the incident, and 2) protecting themselves and the general public during the initial response phase of the incident.

In contrast, fixed facilities in the United States use a labeling system that is different from the vehicular placarding system. The National Fire Protection Association 704 system is used at most fixed facilities.[37] This system uses a diamond-shaped sign (commonly referred to as the "fire diamond") that is divided into color-coded quadrants: blue, red, yellow, and the 6 o'clock position which is assigned no special color. Blue color indicates the degree of health hazard, red for flammability, yellow for instability, and the last quadrant reserved for special hazards. These markings assist first responders to quickly and easily identify the risks posed by the HazMat, helping to determine what specialty equipment should be used, procedures followed, or precautions taken during the first moments at the site of the release. They do not identify the substance.

First responders need to rapidly and precisely identify the chemical or the components of a HazMat mixture. They must be familiar with the local labeling systems and where to seek further information regarding the chemical. One cannot always rely on the presence of a HazMat placard. Many HazMats may not be placarded because their quantity did not exceed a certain weight limit (e.g., 450 kg). Placards may also be damaged by fire or explosions during the event. Other sources of information that may aid identification include site of the HazMat incident and the type of business, laboratory, or vehicle involved. Safety data sheets, order invoices, shipping documents, inventory sheets, and verbal information from front-line employees and management are potential sources of information.[28] The Internet provides up-to-date resources related to chemical classification and identification (Table 31.2).

Identifying a Hazardous Material Incident

To recognize a HazMat event, emergency medical services and fire department personnel responding to a motor vehicle collision or structure fire must have a high index of suspicion. They may not receive information on hazardous materials involvement prior to arriving on scene. The ability to recognize that an event has occurred is the key to responder safety. One approach is by performing a three-point incident site assessment of environment, containers, and materials (chemical and physical properties) involved.[38]

This method builds a framework that enables the responder to see the overall picture and have a manageable span of control over the data, using it to develop and implement an incident action plan. Weather patterns in the immediate area, particularly the local wind direction and speed, are important considerations as these incidents are approached from uphill and upwind. Other weather factors, such as heat and humidity, can greatly affect the behavior of a HazMat. For example, anhydrous ammonia typically moves upward, but a cloud can interact with moisture in the atmosphere and hover along the ground on a humid day.[38]

Public Health Response Cycle in an Industrial Hazardous Material Incident

Comprehensive emergency management of industrial HazMat incidents involves addressing all the elements of the public health response cycle – preparedness, mitigation, response, and recovery. The aim is to improve prevention of HazMat incidents that might affect the general population and, should an event occur, to minimize adverse effects on human health. Organizations and officials having roles include, but may not be limited to, those working in the following areas[39]

- Ministries of health, labor, industry, and transportation
- Regional and local health authorities and inspectorates
- Hospitals and other treatment facilities
- Providers of toxicological/health information, such as poison information centers and chemical emergency centers

Table 31.2: Online Resources Related to Chemical Identification and Classification

Name	*Description and Internet Address*
CHEMTREC®	Access a library of over 5 million Material Safety Data Sheets (MSDSs), has 24-h toxicology specialists, language translation services, and chemical industry experts. http://www.chemtrec.com/Chemtrec/
Chemical Abstracts Service, CAS	A division of the American Chemical Society, this group provides the most comprehensive database of disclosed research in chemistry and related sciences, including the world's largest collection of substance information, the CAS REGISTRY℠ http://www.cas.org/
MSDSOnline®	MSDSonline develops on-demand products and services to help environmental health and safety professionals around the globe to access, manage and deploy material safety data sheets (MSDS) and safety information. The database contains millions of original MSDS documents in an indexed electronic format. More than 10,000 new or updated MSDS documents are added to their database each week. http://www.msdsonline.com/
National Fire Protection Association. NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response, 2007 Edition	This standard addresses the health, flammability, instability, and related hazards that are presented by short-term, acute exposure to a material under conditions of fire, spill, or similar emergencies. http://www.nfpa.org/aboutthecodes/aboutthecodes.asp?docnum=704
Occupational Safety and Health Administration, OSHA: Chemical Sampling Information (CSI)	The Chemical Sampling Information pages present, in concise form, data on a large number of chemical substances that may be encountered in industrial hygiene investigations. It is intended as a basic reference for OSHA personnel. http://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html
Toxicology Data Network, TOXNET	Databases on toxicology, hazardous chemicals, environmental health, and toxic releases. For example IRIS (Integrated Risk Information System), which is a compilation of electronic reports on specific substances found in the environment and their potential to cause human health effects. The information in IRIS is intended for those without extensive training in toxicology, but with some knowledge of health sciences. http://toxnet.nlm.nih.gov/
U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), Emergency Response Guidebook (ERG 2008)	Developed jointly by the U.S. DOT, Transport Canada, and the Secretariat of Communications and Transportation of Mexico (SCT) for use by firefighters, police, and other emergency services personnel who may be the first to arrive at the scene of a transportation incident involving a HazMat. http://hazmat.dot.gov/pubs/erg/gydebook.htm
CAMEO (Computer-aided Management of Emergency Operations) Chemicals	CAMEO Chemicals is developed jointly by three U.S. Federal agencies: the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the Coast Guard. CAMEO Chemicals is an online version of part of the CAMEO A suite of software programs developed by NOAA and EPA. CAMEO supports a number of information management functions, such as retrieval of chemical specific information to support emergency response activities, threat zone calculation and plotting for risk assessment, organization and management of EPCRA information, and storage and computer display of area maps. http://cameochemicals.noaa.gov/

- Facilities handling, storing, or producing hazardous materials
- Occupational health centers
- Suppliers of pharmaceuticals and medical equipment

Mitigation, Prevention, and Risk Management

Measures to mitigate, prevent, and manage toxic HazMat incidents are closely interconnected and can be similar in both execution and goals. For example, global positioning system (GPS) satellite-based technology that tracks ground transportation vehicles carrying hazardous substances provides their exact locations in the event of an acute release. The system can mitigate damage by reducing response time of emergency services to the scene. It also provides surveillance and early warning of any deviation from predetermined routes, be it accidental or deliberate, as in a hijacking by terrorists. With improved situational awareness by drivers, route planning can be optimized and include consideration of hazards such as the weather. In this way, it is also assists with disaster prevention.

Plans for mitigation should incorporate an all-hazard approach, be location specific, and flexible to circumstances surrounding an event. Mitigation planning commonly includes the following areas,[40,41] which can be considered in the context of HazMat incidents.

- Business continuity plans
- Building design, for example drainage systems for decontamination run-off
- National and local regulation on land use, locating buildings outside hazard zones
- Essential building utilities

- Protection of building contents
- Mechanisms and instruments for spreading risk and/or risk transfer (insurance and safety reserves)
- Education, such as training the population and local and national institutions on the causes, impacts, and means of disaster prevention
- Surveillance
- Warning and evacuation

Table 31.3: Items to Be Considered When Undertaking a Risk Assessment in a Catchment Area[43]

- What are the use and storage arrangements for chemicals for all industrial sites?
- What are the on-site capabilities of local industrial sites?
- What are the transport arrangements for hazardous substances?
- What are the historical patterns of local chemical incidents?
- What is the population density, taking into consideration the size and position of the major population centers?
- Are all sites accessible within 20 minutes?
- What and where are the local bodies of water?
- What is the potential for deliberate release of industrial chemicals or chemical warfare agents?
- What is the overall risk?

Other areas of risk assessment include[40]

- Records of past disasters
- Specific geological, climatic, and other hazards in the local/regional area
- Drafting and updating hazard maps and vulnerability profiles with maximal participation
- Surveys of vulnerable populations
- Surveys of buildings, production activities, roads, vehicles, persons per households

Mitigation measures need not duplicate resources. For example, public warning systems for disaster evacuation are all-hazard and are not only used in chemical releases. Special considerations concerning population protection measures arise from chemicals released as vapor or gas. Shelter-in-place contingencies may be useful when there is insufficient time for evacuation following release, when remaining indoors is safer due to the presence of an outdoor chemical plume. To be effective, public awareness, education, and communication are crucial. The process of sustainable hazards mitigation requires 1) nonjudgmental debate, 2) full public participation, 3) a willingness to experiment, learn, fine-tune, and alter approaches, and 4) a consensus among stakeholders to stand behind their shared commitment to the goal.[42]

For any community, complete prevention of HazMat incidents is unrealistic. There will always be a risk of events in the presence of hazards. The approach should be that of managing and reducing risks causing disaster. Risks can be assessed by investigating the cause–effect matrix between hazards and vulnerability (hazard vulnerability assessment [HVA]). Risk management is part of disaster mitigation and prevention. The main vulnerability factors are political-institutional, economic, and sociocultural.[40] They include issues such as fragile infrastructure, absent or poorly developed safety policies, low levels of political and social organization, absence of early warning systems, and an increase in population density, especially around chemical facilities. Table 31.3 contains items to be considered when undertaking a risk assessment in a catchment area.[43]

Integrated response plans involving both specialized plant HazMat teams and local community first responders can be devised by following each stage of the chemical life cycle: 1) research and development, 2) site of manufacture, 3) storage at site of manufacture, 4) transportation, 5) storage at site of use, 6) site of use, and 7) disposal of waste products.[44] Reducing human error and equipment failure in each stage will yield the highest return. It is much more efficient to implement effective risk management strategies and avoid the costs of chemical industrial events than to respond to actual incidents. There is reluctance when approaching the topic, however, due to issues such as cost, poor awareness, resistance to reforms, and minimizing the likelihood of events.[40]

Preparedness

A systems approach to seamlessly integrate capability is needed for all-hazard incident planning. The same approach should be undertaken with special considerations to the intricacies of a HazMat incident. The 3-S Surge System (staff, stuff, and structure – see Chapter 3) is a reminder of what plans should include in order to develop optimized and sustainable capability.[45]

Planning and Systems

Healthcare authorities, local communities, and hospitals need to plan for acute chemical incidents. At any time, hospitals must safely and rapidly decontaminate, evaluate, and treat at least two chemically injured victims. This is the premise for development of further response capabilities for mass casualty incidents involving chemical or radiological weapons of mass destruction. In a study comparing 1996 and 2000 measures of preparedness among hospitals of a major U.S. metropolitan area, the hospitals were poorly prepared to manage chemical emergency incidents, including terrorism. This lack of hospital preparedness did not change significantly between 1996 and 2000, despite increased funds allocated to bioterrorism preparedness at the local level.[46]

In some countries such as the United States, extensive legislation, regulations, and standards exist mandating and assisting hospitals to plan for chemical incidents.

1) Occupational safety regulations from the Occupational Safety and Health Administration (OSHA) protect healthcare providers during a HazMat response as a worker safety issue.[47]
2) The Emergency Medical Treatment and Active Labor Act requires hospitals to provide a medical screening examination and stabilization (consistent with their capabilities) to anyone presenting to their grounds for treatment regardless of citizenship, legal status or ability to pay.[48] It does not make exceptions for contaminated patients.
3) The *Emergency Planning and Community Right-to-Know Act* is a section of the *Superfund Amendments and Reauthorization Act*, otherwise known as SARA Title III.[26] It states that facilities manufacturing or storing hazardous chemicals must report inventories and every HazMat release to public officials and emergency health agencies. The Act also requires the establishment of state emergency response commissions and local emergency planning committees.

4) Healthcare accreditation organizations such as the Joint Commission have requirements relating to HazMats.[49]

Planning for toxic incidents involves modification within the framework of existing emergency response plans and incident command systems, rather than creating entirely new protocols. Plans should be established before a HazMat incident occurs. Separate prehospital and hospital plans are needed for first responders and first receivers, respectively, to manage victims. Both plans must be integrated and harmonized.

In addition to areas addressed in general emergency management programs, specific areas to consider when planning for a hospital's HazMat response include

- Hazards and vulnerabilities identified in a HVA
- Estimated time before arrival based on location of hazard
- Casualty care areas
- Decontamination procedures and protocols
- Secondary contamination and containment of contaminated equipment and run-off water
- Safety: personal protection equipment (PPE)
- Communications at decontamination area
- Heating, ventilating, and air conditioning and in-place protection
- Medical management – antidotes
- Interfacility transfers – patients with special needs, burn patients
- Knowledge resources for hazardous materials

Local authorities that develop such plans should consider the following[50]

- Identify local facilities using hazardous substances
- Designate community and industrial coordinators
- Establish mechanisms for emergency notification
- Establish procedures for determining the occurrence of a release and an estimation of the affected population (location and numbers)
- Identify community emergency equipment facilities
- Establish evacuation plans
- Establish and schedule training programs for emergency personnel

Staff

The hospital's incident command center is responsible for optimal use of staffing resources. It should coordinate medical and auxiliary personnel, direct activities at the various treatment sites, organize equipment and supplies, and maintain contact with outside authorities.[51] Standard operating procedures indicating roles and responsibilities of personnel must be established before and event occurs.

Education and training are important aspects of planning because of specialized procedures and equipment used by prehospital providers and hospital personnel. First responders and first receivers must acquire necessary knowledge, skills, and abilities to respond safely to incidents involving hazardous materials. Because of different work environments and PPE requirements, education and training should be tailored to address their specific needs. It should be structured and standardized, locally relevant to hazards and equipment used, continually revised and updated, and delivered multiple times and across all work shifts to enhance retention.

In a study of paramedic students, retention of proper donning and doffing techniques for PPE was poor at 6 months after initial training. Critical errors were common even in individuals with previous HazMat, firefighter, and emergency medical services training.[52] It appears unrealistic to retrain hospital decontamination teams composed of staff nurses and allied health personnel every 6 months; however, annual refresher courses are achievable.

The training courses may consist of practical approaches to the management of HazMat casualties, common toxicological agents, triaging contaminated victims, computer searches for information on toxic materials, wearing PPE, and assembling a portable decontamination shower.[53] Hospitals can video record and review drills to critique and refresh the knowledge of their participating staff.

Frequently planned drills are essential for effective implementation of disaster plans. Joint training and education are important ingredients in producing a multidisciplinary team functioning optimally under stressful circumstances. Training must include 1) communication exercises, 2) small-scale (hospital and emergency service) response exercises, and 3) full-scale simulations involving industry, health professionals, emergency services, and others with responsibilities in the area, such as civil defense services and military authorities.[54] A cost-effective five-level scale for hospital preparedness in accordance with the existing threat has been suggested (Table 31.4).[51]

Stuff and Structure

HazMat medical response involves mobilization and utilization of equipment and treatment areas that are rarely encountered in the course of routine hospital work. "Structure" can mean physical infrastructure such as a fixed facility for decontamination, assembly, triage and evaluation, and patient care, all of which must be determined pre-event. Decontamination can be conducted in fixed, semifixed, or mobile facilities like tents, inflatable structures, and mass decontamination vehicles.

Some of the challenges facing hospitals on the safe treatment of HazMat exposures may be mitigated by engineering controls. Examples include[46,55]

- Controlled access points to prevent contaminated patients from entering the facility prior to decontamination
- Designing decontamination shower facilities that can accommodate placement of warm water lines
- Situating shower nozzles on the building exterior
- Collection system to control for contaminated water run-off
- Access fittings for medical gases on the building exterior that will facilitate use by emergency responders when utilizing supplied-air respirators
- Design of hospital ventilation systems that takes into account the potential need to isolate the internal hospital environment

Procurement and acquisition of PPE and decontamination items need to complement the hospital's role and HVA outcomes. Further elaboration on both topics can be found in Chapters 13 and 14. "Stuff" also includes knowledge resources that are needed for medical management of victims. A vast amount of informative resources are web based, thus underscoring the need for maintenance of Internet access during a crisis. Other resources

Table 31.4: Five-Level Scale for Hospital Preparedness According to Existing Threat[51]

*Level of Preparation**	*Action Required*
I No Threat	1. Prepare a hospital deployment plan for a chemical incident (e.g., due to a motor vehicle collision)
II Minimal Threat	1. Instruction of the hospital plan and principles of chemical agent diagnosis and treatment once a year 2. Assign specific tasks in the deployment plan to hospital personnel 3. Partial practice drill once in 3 years 4. Consider the need for medical equipment, supplies, and communication systems, and examine their maintenance once a year
III Existing Threat	1. Full practice drill once in 3–5 years, instruction every year 2. Prepare appropriate medical equipment, supplies and communication systems, and examine their maintenance every half year
IV Increased Threat	1. Organize appropriate shifts of hospital personnel to increase their availability and an emergency calling system for the staff and auxiliary personnel according to their assigned tasks 2. Full practice drill once in 1–2 years, instruction and smaller scale review drills on receiving the new threat level and as often as possible 3. Examine maintenance of equipment, protective gear, and communication systems every few months. Increase their availability by storage at or near the sites 4. Prepare arrangements for shifting of patients inside the hospital
V Maximal Threat	1. Be prepared to receive and treat chemical casualties within minutes or hours 2. Organize equipment, protective gear, and communication systems at all sites 3. Arrange patient transfer and discharge when possible 4. Maintain continuous contact with authorities outside the hospital

* Each level should also include the required actions of the previous levels

include poison information centers, ad-hoc toxicological advisory teams, in-hospital toxicologists, or textbooks.

Medical field teams deployed from hospitals to the scene of a HazMat mass casualty incident usually conduct their work in the "cold" zone. Nevertheless, they will need to carry PPE that is commensurate with the hazard's risk, in case the zone turns suddenly "warm" without the opportunity for timely evacuation. In addition to general items, an inventory of antidotes and burn care items should be considered (Figure 31.1).

Antidote stockpiling is a critical component of comprehensive medical preparedness in chemical emergencies.[56] A national program for distribution of antidotes from a central stockpile plays a fundamental role; however, demographic, geographical, and economic factors often obstruct the rapid disbursement of antidotes. Any system of antidote distribution must provide poisoned patients with empirical antidotes based on toxidromic assessment or specific antidotes based on substance identification in appropriate quantities and within the time required for treatment. Local stockpiles of antidotes are limited by factors such as infrequent use, cost, and short shelf life. A push system can be adopted to supplement local stockpiles with antidotes to common poisonings, which can be based on local HVA. This is important in the initial phase when the substance is unidentified. Larger quantities of specific items or antidotes can follow as the situation becomes clearer. Most toxins do not have specific antidotes (Table 31.5).[56] Time-sensitive antidotes such as diazepam,

Figure 31.1. Boxes of equipment on trolleys packed pre-event for rapid deployment with medical field teams located next to the exit. See color plate.

Table 31.5: Available Life-saving Antidotes for HazMat and Chemical Weapons[56]

Antidote	*Chemical*
Calcium	Hydrofluoric acid or fluoride
Hydroxocobalamin	Cyanides
Atropine	Organophosphates, carbamates, nerve agents
Amyl nitrite	Cyanides, nitriles, sulfides
Methylene blue	Methemoglobin-forming compounds
Oxygen	Simple asphyxiants, systemic asphyxiants, methemoglobin-forming compounds, carbon monoxide, cyanides, azides and hydrazoic acid, hydrogen sulfide and sulfides
Oximes	Organophosphates, nerve agents
Pyridoxine	Hydrazones

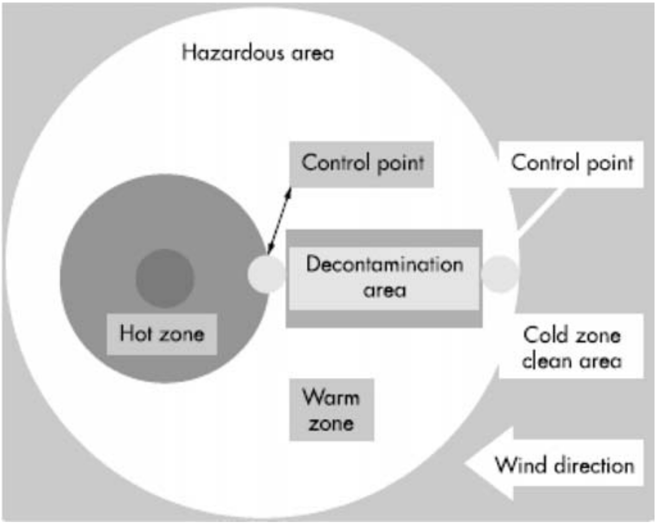


Figure 31.2. Incident site control zones.[60]

cyanide antidote kits, atropine, and pralidoxime are the most important drugs to stockpile locally for the potential treatment of mass casualties of a chemical emergency.[57,58]

Response

When responding to an acute HazMat incident, the protocols and procedures that are planned during the preparation phase are followed and executed. The command structure and responsibilities should follow the same approach as that for a major incident.[43] Early recognition that a HazMat situation exists, effective risk communication, administration of basic or advanced resuscitation measures, rapid decontamination, and timely evacuation and transport to hospitals that can provide appropriate treatment are crucial factors for improving outcomes. The response phase is usually staged in two locations: the prehospital environment and the hospital site.

Prehospital Response

First responders may immediately suspect a HazMat incident when confronted with a truck rollover and leakage of unknown substances. In the absence of such obvious clues, general indicators of possible HazMat event include[53]

- Unusual occurrence of dead or dying animals (such as dead birds)
- Unexplained casualties (multiple victims with the similar signs and symptoms such as skin, respiratory system, vision, and nervous system involvement)
- Increase in the frequency of those with the aforementioned signs and symptoms in the direction of prevailing winds
- Unusual liquid or vapor clouds (droplets, unexplained odor, or taste)
- Mass casualties without any conventional injuries

Binoculars are helpful for ascertaining visible information from a safe distance.

Once a HazMat incident has been declared, all noncontaminated, nonprotected personnel should be evacuated from the scene. The area is then cordoned off, with limited access. When full decontamination is needed, it occurs along a corridor in the "warm zone." This is the area between the contaminated area (the hot zone) and the safe area (the cold zone).[59] The cold zone is uphill and upwind from the hot zone (Figure 31.2).[60]

Information from the scene should be widely communicated as soon as possible to receiving hospitals to optimize their preparation. If available, the following data should be transmitted: number and type of casualties, chemical substance involved, estimated time of arrival of first casualties (realizing that some patients may bypass the prehospital system and self-present), time of the incident and location of the incident site, method of contamination (vapor or liquid), and potential hazards to healthcare providers.[60] The development of state-of-the-art computer-based communication and information networks designed especially for mass casualty incident management have provided the means for a more coordinated and effective response by facilitating information flow. Through these systems, first responders can activate web-based cameras to provide live streaming videos of selected incident areas (e.g., casualty clearing stations) to improve situational awareness at the hospitals.[61]

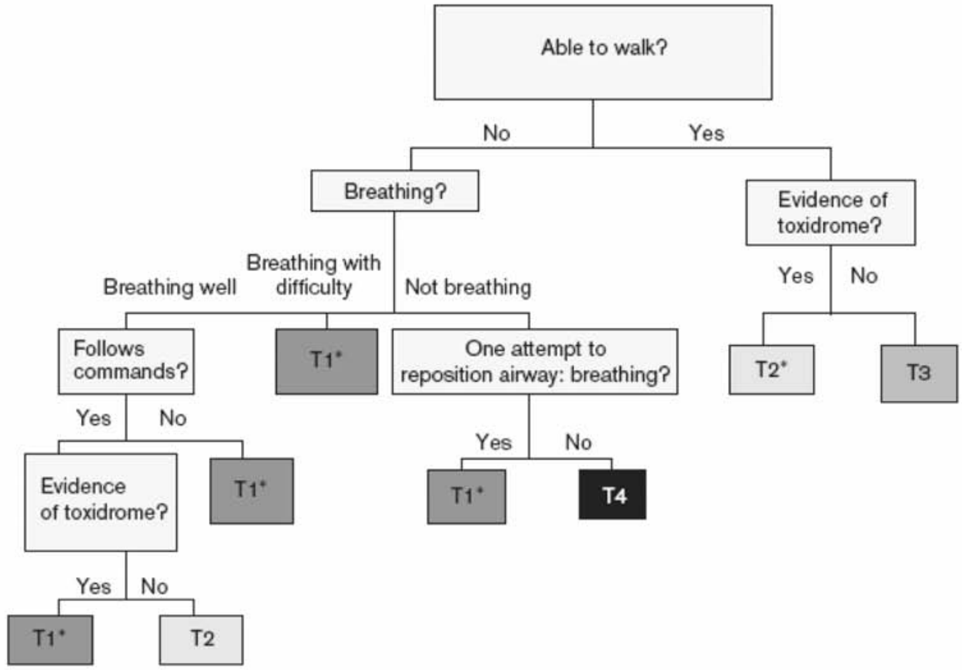
Identification of the hazardous substance is useful and potential sources of information have been discussed earlier in this chapter. Equipment exists, including chemical detection paper and the Improved Chemical Agent Monitor that allows trained personnel to detect chemicals.

Depending on the scale of the chemical incident and local emergency planning, physicians and nurses from hospitals or organized response teams may be mobilized to provide forward medical care to victims on scene. They usually perform their duties in the cold zone, where it is uncontaminated and safe. HazMat victims may, however, have acute life-threatening respiratory and cardiovascular problems that require aggressive and early definitive care. The problem is amplified should the substance have high persistence in the surroundings. To withhold care until decontamination is completed may lead to unacceptable delays in treatment. Given this situation, many emergency medical services teams are trained to work with full protective equipment and provide early, enhanced basic or advanced life support inside the contaminated hot zone.[62] Medical response personnel who enter the contaminated zone need to be adequately trained and equipped with appropriate PPE. Safety is the first and foremost consideration. Special knowledge on medical and operational aspects of managing victims in a hostile, contaminated environment is required for the best results.[63] In the situation when decontamination can be conducted quickly, limiting medical attention to opening the airway with spinal precautions, controlling hemorrhage, and terminating seizures can expedite a victim's transport to definitive care.

Triage

When decontamination facilities are saturated, two factors should help to decide patient priority – the principles of field medical triage and the severity of contamination.[59] Casualties who require immediate treatment with antidotes should receive early intervention and be reevaluated at intervals. Triage at this point will also help to identify which patients need immediate, life-saving care before and during decontamination.

Whichever triage system is used in a HazMat incident, it should be familiar to those responsible for the activity. Physiological methods such as the modified triage sieve have been described for use in the warm zone, although there is some question as to its efficacy.[43,64,65] Other triage methods have factored in aspects such as organ system involvement, area of skin



Trauma and chemical triage. *Give antidote if available and logistically feasible. Decontaminate all patients prior to transport.

Figure 31.3. Trauma and chemical triage.[66]

injury, and response to antidotes.[60] Although such criteria may improve triage precision, application of these algorithms may be restricted by their complexity in a situation in which time is limited. One chemical algorithm triage method proposed by Cone et al. considers the latency period of some hazardous chemicals like phosgene and uses "breathing" as a simple subjective assessment of patient's overall respiratory status (Figure 31.3).[66] This system will need further refinement and testing.

Decontamination and Personal Protection Equipment

Decontamination of chemically contaminated casualties should be viewed as part of the initial treatment, not as an additional process, and should occur as soon as possible.[43] It also prevents secondary contamination of personnel and equipment. Removal of outer layers of clothing may reduce contamination by up to 85%.[59]

If the exposure is from a vapor or gas, then nearly all of the contaminants will be eliminated when the victim is evacuated and the clothing is removed.[67–69] Gas or vapor releases can expose victims to toxic concentrations, but tend to dissipate quickly. Arriving victims who were only exposed to HazMats in the gaseous or vapor state, or who undergo proper decontamination at the scene, are not likely to pose a secondary contamination risk to hospital personnel. However, victims whose hair, skin, or clothing is grossly contaminated with solid or liquid material, including condensed vapor, can endanger emergency personnel by direct contact or by off-gassing of the toxic substance.[70] Nonetheless, it is unlikely that a living victim could create an "immediately dangerous to life or health" environment at a receiving hospital if contaminated clothing is quickly removed and isolated, and the victim is treated and decontaminated in an area with adequate ventilation.[71] Failure to perform these actions, however, can generate an immediately dangerous to life or health situation during treatment of a viable victim within the hospital, resulting in significant medical consequences for healthcare providers.[72]

In a mass casualty situation with limited resources, skin decontamination is not needed and removal of clothing may be sufficient if it has been confirmed that the exposure is due only to vapor or gas and no gross contamination of the hair or skin by condensation exists.[27,71,73] Special consideration should be made for highly soluble irritant gases such as ammonia. Ammonia dissolves in the moisture of mucous membranes to form ammonium hydroxide, a strong base. It produces a local toxic effect of irritation and burning on mucous membranes. If victims feel skin burning, decontamination should be conducted. All clothing should ideally be removed on scene and double bagged.

Decontamination should be conducted with consideration for privacy. Equipment for medical care including bag-mask-valve devices, oxygen tanks, airway devices, and wound care items must be prepared and mobilized to the warm zone. Further detailed discussion on decontamination and PPE can be found in their relevant chapters.

Transportation and Evacuation

Prioritizing the transportation of victims from the casualty clearing station to hospitals requires further triage. Transport vehicles should be well ventilated with the windows open if necessary. The importance of improving ventilation in the confined space of a transport vehicle was underscored by the Tokyo sarin attack in 1995, when it was observed that 9.9% of 1,364 emergency medical technicians showed acute symptoms and received medical treatment at hospitals. Most of them experienced the onset of symptoms during transportation, and it is suspected that they were exposed to the vaporized sarin from the victims' clothes in ambulances. The ventilation in ambulances and minivans was poor because the windows were shut.[74] Additionally patients were not undressed and decontaminated before transport to healthcare facilities.

Hospital-based Response

DECONTAMINATION AGAIN?

It is not easy for first receivers at healthcare facilities to accurately determine whether prehospital decontamination of casualties has been adequately conducted. Casualties can be symptomatic but "clean." Checking individually with chemical detection devices will require too much time. Some hospitals may subject these casualties to a second decontamination procedure. This method is debatable as it delays treatment. Local health authorities, experts, and first responders and receivers should discuss the options and arrive at a consensus.

Wounds should be irrigated and covered with waterproof dressing during decontamination. Following that, attention should be paid to decontamination of the eyes, nose, ears, and oral cavity as necessary. The eyes can be irrigated with the help of a Morgan lens or an improvised device using a nasal cannula placed across the nasal bridge and attached to a one liter bag of normal saline.

Medical Treatment

Initial medical attention should be focused on providing basic resuscitation measures by addressing airway (with cervical spine control), breathing, circulation, disability (nervous system), and exposure (decontamination, examination for injuries): the ABCDEs in a primary survey. The possibility of concomitant physical trauma, burns, and smoke inhalation injuries should be considered because many of these incidents involve fires and explosions. Supportive care is more important than specific antidotes. In a seizing victim, opening the airway, providing oxygenation, and aborting the seizure with a benzodiazepine will confer more benefit than any antidote.

Obtaining a concise history can be guided by using the AMPLE mnemonic, which stands for Allergies, Medications, Past medical history, Last meal, and Events leading up to the incident.[75] Any past respiratory condition is significant because inhalation is the most common route of exposure at HazMat incidents. Victims with cardiac conditions may be at greater risk in asphyxiant (e.g., carbon monoxide) or hydrocarbon (e.g., propane) poisoning due to ischemia and cardiac irritability, respectively. With regard to "Events leading up to the incident," helpful information includes: route of exposure; location of the incident; whether the incident occurred in a confined space; elapsed time since exposure; duration of exposure (entrapment); the presence of fire, explosion, or blast; and whether loss of consciousness occurred.

After the primary survey and resuscitation, HazMat patient assessment involves a secondary survey that focuses on[75]

- Identifying complications of poisoning
- Recognizing existing medical problems with potential for exacerbation
- Assessing for accompanying trauma or burns
- Recognizing HazMat toxic syndromes (toxidromes)

Toxidromes are collective sets of signs and symptoms that indicate poisoning with a specific class of agents. They help to simply the approach to treatment and have both practical and medical relevance. Table 31.6 summarizes the features and treatment of five toxidromes: irritant gases, asphyxiants, cholinergics, corrosives, and hydrocarbons and halogenated hydrocarbons.[75]

The use of PPE in the warm and hot zones limits dexterity, so antidotes are given via autoinjectors that deliver fixed incremental doses of drugs such as atropine. At the first aid post or hospital setting, a dose–response regime via intravenous route should be adopted. In patients with shock and peripheral vasoconstriction, absorption of drugs via intramuscular injection is unpredictable and erratic.

Victims with seizures should be examined for intracranial pathology, including traumatic hemorrhage. Attributing such phenomenon simply to central nervous system injury from toxins is not suggested. The common approach to differential diagnosis for clinical symptoms and signs still applies.

The toxic effect of chemicals may be seen acutely or only become apparent after a period of latency. One such example is phosgene. This agent is a gas at room temperature, is slightly soluble in water, and has an odor threshold that is five times higher than the OSHA permissive exposure level.[47] Its odor provides insufficient warning of hazardous concentration, thus prolonging exposure of victims to the chemical. This allows the chemical to enter the lower airways due to a lack of avoidance behavior by victims. It may initially cause no signs or symptoms, or symptoms may be due only to mild irritation of the airways. These symptoms (dryness and burning of the throat and cough) may cease when the patient is removed from exposure. After an asymptomatic interval of 30 minutes–8 hours, however, respiratory damage becomes evident.[76] This effects the period of observation that may be needed for victims of such exposures. There is an inverse relationship between the dose of most agents and their latent periods, i.e., a higher dose results in a shorter latency period.

While difficult to measure precisely, in mass casualty incidents, it is thought that there is often a 5:1 or larger ratio of persons who are symptomatic because they think they have been exposed to those who have actually been exposed. Those who are only psychologically affected assert an extra burden on a healthcare system that must attend to the physically and physiologically injured victims first. It is difficult to identify psychological casualties initially and decontamination will be needed before further clinical assessment can be made. Trained counselors are an important part of the management team and provide needed psychological support.

Recovery

The recovery phase involves decontamination of the facility and certification that it is safe to resume normal operations. Patients, visitors, hospital staff, and the media should be kept informed during this process. Documentation created during the incident is collected for the purposes of archiving, creation of after-action reports, and development of corrective action plans.[77] In some countries, such documents are crucial for financial reimbursement procedures.

Equipment and contaminated areas must be decontaminated. PPE such as chemical suits, gloves, and boots may require disposal. It is often difficult to ensure safe reuse due to limitations in the ability to assess the degree that chemicals have penetrated the equipment. Safe disposal of contaminated runoff water and other hazardous waste is necessary, usually with assistance from local fire, health, and environmental authorities. Disposition of the victims' contaminated personal belongings

Table 31.6: Features of Five Toxidromes (Table constructed with information from Advanced HazMat Life Support/AHLS)[75]

	Irritant gas	*Asphyxiant*	*Cholinergic*	*Corrosive*	*Hydrocarbon and Halogenated Hydrocarbon*
Common agents. Some may present with characteristics of more than one toxidrome	Ammonia, sulphur dioxide, hydrogen chloride, chlorine, phosgene	Simple: Carbon dioxide, methane, propane Systematic: Carbon monoxide, cyanides, hydrogen sulphide	Organophosphates, carbamates pesticides	Acids (sulphuric, hydrochloric, hydrofluoric acid), bases (sodium hydroxide), oxidizers (hydrogen peroxide), phosphorus	Methane, ethane, propane, butane, benzene, phenol, chloroform, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)
Industry	Chemical synthesis, bleaching, disinfectant, and dye production	Byproduct of in/complete combustion, chemical synthesis, liquefied petroleum gas (LPG), dye production, fumigant, sewer gas	Pesticide	Chemical synthesis, food production, petroleum refining, disinfectant, propellant, fireworks	Natural gas, chemical synthesis, LPG, dye production, preservatives, refrigerants
Routes of exposure	Inhalation, skin, and mucous membranes	Inhalation, skin, and mucous membranes, ingestion	Inhalation, skin, and mucous membranes, ingestion	Inhalation, skin, and mucous membranes, ingestion	Inhalation, skin, and mucous membranes, ingestion
Classification. If prolonged exposure or high concentration occurs, the lower airway can also be affected	Water solubility: High (e.g., ammonia, sulphur dioxide): upper airway affected Low (e.g., phosgene): lower airway affected	Simple: displace oxygen from surrounding atmosphere Systematic: affects oxygen transport via hemoglobin, or aerobic metabolism	Organophosphates, carbamates		Aliphatic, aromatic, halogenated Flammability
Characteristic presentation (signs and symptoms)	Upper airway: Coughing and stridor, laryngeal edema, laryngospasm, dysphonia, rhinorrhea Lower airway: Bronchospasm, noncardiogenic pulmonary edema Others: Lacrimation, conjunctival injection	Simple asphyxiant: Headache, fatigue, anxiety, giddiness, nausea, dyspnea, palpitations, altered mental status, coma, seizure, cardiac ischemia In addition, systematic asphyxiant: Cyanosis and reliable pulse oximetry readings can be due to methemoglobinemia "arterialization" of venous blood	SLUDGE mnemonic (muscarinic): salivation, lacrimation, urination, defecation, gastrointestinal cramping, emesis MTWHF mnemonic (nicotinic): mydriasis, tachycardia, weakness, hypertension, fasciculation	Coughing, dyspnea, dysphonia, stridor, laryngeal edema, nausea and vomiting, bronchospasm, noncardiogenic pulmonary edema, cyanosis, skin burns Others: Lacrimation, conjunctival injection, blindness	Present like simple asphyxiant. Sensitization of the heart to endogenous catecholamines, arrhythmias Central nervous system depression, narcosis, coma Skin irritation, defatting dermatitis and chemical burns
Main systems affected	Airway and breathing	Cardiovascular and nervous system	Nervous system	Airway, cardiovascular, nervous system White phosphorus - consider renal system	Breathing, cardiovascular and nervous system
Treatment summary	Consider latency of chemical affecting lower airway Supportive management include: oxygenation, bronchodilators, corticosteroids	Provide oxygen support Cyanide: antidotes include amyl nitrite (inhaled), sodium nitrite, sodium thiosulfate, hydroxocobalamin Hydrogen sulphate: sodium nitrite Consider hyperbaric oxygen treatment	Atropine, oximes (e.g., pralidoxime), benzodiazepine (for seizure)	Rapid decontamination, water irrigation of eyes and skin, burns management Hydrofluoric acid: local or parenteral calcium replacement	Supportive management include: oxygenation, control seizures, wound care Avoid sympathomimetics due to cardiac irritability

must also be addressed. In some cases, all such items must be retained as evidence for law enforcement investigations of a crime scene.

A separate morgue must be established to prevent cross contamination between the victims' dead bodies and those who died of other causes. The burial process will require special arrangements with environmental and public health considerations. First receivers may need further follow-up if radiological activity is present in the hazard. Behavioral health (acute and long term) services must also be provided for staff and patients.

RECOMMENDATIONS FOR FURTHER RESEARCH

Develop Surveillance and Early Warning Systems

The development of surveillance and early warning systems is based on a transition from a culture of reaction to one of being proactive, preventive, and prepared. As part of the revised IHR 2005, the WHO has been developing a system to rapidly identify, verify, and alert nations to the occurrence of incidents of (potential) international public health concern, including those involving environmental health hazards. This system is a technical collaboration among existing institutions and networks including the Global Outbreak Alert and Response Network, the Global Public Health Information Network, and the WHO/IPCS Global Chemical Incident Alert and Response System.

The WHO/IPCS Global Chemical Incident Alert and Response System consist of two components.

- ChemiNet: This network pools human and technical resources for detecting, verifying, and responding to chemical incidents of international public health concern.
- ChemiTeam: WHO/IPCS staff who, on a daily basis, identify and assess chemical events of (potential) international concern and determine appropriate response.

Strengthen Both Regional and Global Public Health Responses

Public health responses must be integrated globally as well as locally. Chemicals released into the environment can spread beyond the local vicinity and, in some cases, cross national borders. Therefore, it is also necessary to coordinate international preparedness and response. Some international agreements already exist, such as the United Nations Economic Commission for Europe's Convention on the Transboundary Effects of Industrial Accidents.[7,78] The aim of the Convention is to help its parties prevent, prepare, and respond to industrial accidents that can have international impacts. The Convention also encourages its parties to assist each other in the event of such an accident, to cooperate on research and development, and to share information and technology.

Environmental Justice

Developing nations struggle with the lack of technical capacities and regulatory infrastructure to ensure safe chemical management. In some countries with good technical capacity, the rapid pace of industrialization is outstripping the implementation of effective control measures. Increasing urbanization in such countries is exposing growing numbers of people to the risk of chemical incidents as they settle in proximity to hazardous installations. This particularly affects the poorer segments of society who have little choice about where to live.[7]

Table 31.7: Future Disaster Research Goals and Objectives for Industrial and HazMat Incidents

- Epidemiological research and improved data collection before, during, and after disasters
- Strengthening of the research agenda for technology, meteorology, engineering, and the environment. Alignment and synthesis of these activities with the medical and public health research agenda
- Development of best practices for public warning
- Urban and city planning research focusing on the locations of industrial and HazMat facilities and transportation corridors
- Support for infrastructure research and high-technology modeling for preparedness, mitigation, response, and recovery for industrial and HazMat disasters
- Strengthening of the toxicology and occupational medicine research agenda
- Continuous HVA to improve surge capacity based on the latest data for the facility, staff, and current equipment
- Funding for dedicated research staff with existing protocols deployed to incidents as a part of disaster management teams
- Technology research for prevention and monitoring of industrial accidents. Examples: video cameras, surveillance satellites and aerial reconnaissance, and fixed and mobile monitoring units similar to "black boxes" in airplanes. Enhanced medical and technological monitoring of staff and environment
- After events, implementation of improved, harmonized, and synchronized data collection on long-term effects of industrial incidents
- Economic research examining the risk/benefit ratio for operation of industrial and HazMat facilities and transports
- Sociological research to study behavioral and psychological patterns during disasters
- Educational goals and objectives research agenda
- Investigate strategies to optimize collaboration among different specialties such as chemists, meteorologists, physicians, and managers

Future Research in Hazardous Material, Toxic, and Industrial Events

The performance of disaster research is often difficult. For economical and ethical reasons, it is not possible to "create disasters" for scientific study purposes. As such, investigators must usually wait for actual events to occur, and so the ability to conduct meaningful research is often limited. Nonetheless, opportunities do exist (see Table 31.7).

Fundamentally, research in disaster medicine should have a strong public health and epidemiological approach and should be outcomes oriented. At the same time, disaster research should be fiscally responsible and based on the best scientific evidence. Newer technologies such as computer-based programs and teaching methods such as simulations have greatly expanded the possibilities for facilitating problem-based research and finding solutions in disaster management.

One of the biggest challenges in disaster medicine is accurate data collection before, during, and after an actual event. One of the obstacles to collecting accurate data is the lack of dedicated research staff. When managing disasters, most personnel are usually engaged in disaster response activities and not available for independent academic research. Additionally, disaster research for complex events such as industrial incidents must be multidisciplinary and use an all-hazard approach. One possibility to increase data collection during and after industrial accidents is the use of newer monitoring technology such as closed-circuit video cameras, aerial and satellite observation, and "black boxes" on fixed structures that collect data and monitor all events similar to those used on aircraft. A high-quality HVA and subsequently designed disaster management plan can only be based on accurate and sufficient data from previous experiences and events. Safety and security protocols for industrial facilities and HazMats should be based on the best scientific evidence and less on financial interests.

Decision makers and disaster managers who are responsible for development and implementation of protocols face a special challenge. They are caught in a conflict between the scientific data depicting the correct approaches and the financial realities of what they can afford. Many of the existing disaster protocols and much of the equipment have not been scientifically tested under the actual conditions for which they were designed. Often theoretical models, policies, and equipment are simply transferred from one disaster scenario to another. In general, there should be more funding from unbiased sources to support independent and sound scientific research. There should be more collaboration among academic institutions with respect to the collection of research data in a central repository to prevent duplication. A well-developed research agenda will provide the evidence-based science to guide community risk management and enforcement of high safety standards in the chemical industry.

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Section B: ENVIRONMENTAL EVENTS

32

Floods

Mark E. Keim

> Water, water everywhere, and all the boards did shrink;
> Water, water everywhere, nor any drop to drink.
> – Rime of the Ancient Mariner by Samuel Coleridge

OVERVIEW

Definition and Classification

Floods are defined as "the overflow of areas that are not normally submerged with water or stream that has broken its normal confines or has accumulated due to lack of drainage."[1]

Engineers studying past floods use statistics to estimate the chance that floods of various sizes will occur. For example, a flood found to occur on the average of 10 times in 100 years would be called the 10% chance flood or the 10-year flood. A flood that only occurs on the average of once every 100 years would have a 1% chance of occurring in any particular year and would be called the 100-year flood or 1% chance flood.[2]

Floods are classified according to cause (high rainfall, tidal extremes, or structural failure) and nature (e.g., regularity, speed of onset, velocity and depth of water, and spatial and temporal scale). This chapter will discuss impacts according to health outcomes. The influence of flood characteristics on health impacts is discussed where appropriate.

Causes of Floods

Floods may be caused by natural processes that are either fluvial (an abundance of rainfall or melting snow) or coastal (hurricane-related storm surge, coastal inundations, or seismically induced tsunami) in origin.

Human alterations in the environment may also cause flooding by alteration of watershed due to deforestation, overgrazing and the failure of dams, embankments and levees,[3] channeling of streams, and urbanization of wetlands (which act as a natural flood control by storing water during heavy rains, slowing runoff into streams, and reducing flood peaks). Human alterations in the environment affecting global climate change are also predicted to increase the frequency of flooding hazards worldwide.[4]

Human behaviors can exacerbate flooding severity and impact. Even after prior flooding, human settlement frequently occurs in flood prone areas, thereby increasing a community's vulnerability to the affects of flooding. Lack of awareness of the dangers posed by fast-moving floodwaters has led to maladaptive behaviors by people encountering floodwaters. Paradoxically engineering flood controls such as levee and dam construction may contribute to greater human losses and physical damages after a flood disaster (e.g., levee failure).[5]

Nature of Floods

Fluvial Floods

For the purpose of this discussion fluvial (or riverine) flooding will be characterized as either a seasonal flood or a flash flood.

Seasonal floods are typified by a gradual rise to flood stage that may extend across large areas over a long duration. Because seasonal floods are usually caused by a relatively gradual accumulation, warning times are generally sufficient to allow safe evacuation of nearby communities. Flash floods are characterized by a short-duration, high-volume stream flow and usually occur within 6 hours of a rain event, after a dam or levee fails, or after the sudden release of water from an ice or debris jam. Once the flash flood has occurred, it is often accompanied by an extremely short warning and response time with potential for great loss of life.[6]

Coastal Floods

Storm surge, produced by the high winds and vacuum effect of low-pressure cyclonic storm systems, can produce dramatically high seas that result in coastal flooding. Storm surge–related drownings account for 90% of worldwide deaths

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related to cyclonic storms.[3] Coastal inundations may also occur due to rogue surface waves and cyclonic eddies imparted by weather systems. Seismic events such as earthquakes, landslides, and volcanic eruptions may generate a tsunami pressure wave at sea. Once the tsunami is generated, a series of extremely low frequency, long-wavelength (~300 km) waves are propagated in an expanding radius from the area of displacement. These waves differ from short-wavelength surface waves (those caused by wind) or storm surges (those caused by cyclones), in that tsunami waves are propagated throughout the entire depth of the ocean. For this reason, tsunamis represent a tremendous amount of potential energy and can travel the speed of a jet airliner. As the tsunami enters shallow water near coastlines, the enormous kinetic energy previously spread throughout the large volume of deep ocean water becomes concentrated to a much smaller volume of water, resulting in a tremendous destructive potential as it inundates the land.[7] This remarkable difference in potential energy imparted over a very large distance by a tsunami compared with other types of floods is unique in character and public health impact. This discussion will therefore focus on floods other than tsunamis, which are the focus of Chapter 36.

Scope of the Problem

Flooding is the most common type of disaster worldwide, accounting for 42% of all disasters during the decade from 1996 to 2005.[8] During this same time, floods affected 1.3 billion people, with more than 90,000 killed. Flooding caused more damage than any other disaster during this time, comprising one-third of all disaster-related costs. Floods have tremendous economic impact worldwide in both high- and low-income nations.[8]

According to the U.S. National Oceanographic and Atmospheric Administration, "In most years, flooding causes more deaths and damage than any other hydro-meteorological phenomena. In many years it is common for three-quarters of all federally declared disaster declarations to be due, at least in part, to flooding."[9]

Parts or all of more than 20,000 communities in the United States are subject to a substantial risk of flooding. Approximately 7% of the nation's land area (an area almost as big as the entire state of Texas) is subject to severe flooding.[2,10] In the United States, floods cause as much as 90% of the damage from all disasters (excluding droughts).[11]

Direct economic losses from the 1993 great midwestern U.S. floods surpassed $10 billion.[12] Flood damage as a result of the 1998 floods in central Texas was estimated at approximately $900 million, including the costs of damage to 12,000 homes, 700 businesses, and public property.[13] In the late summer of 2005, flooding brought on by Hurricane Katrina caused more than $200 billion in losses, constituting the costliest disaster in U.S. history.[10] Trends toward increasing population density near coasts and in floodplains point to a likely probability of future catastrophic flood disasters. The current trend of climate change is projected to have an impact on the frequency and severity of floods worldwide.[4,14] Munich Re, the world's largest reinsurance company and a member of the United Nations Environment Programme's Finance Initiative, has been compiling annual records on catastrophes and their costs since the 1970s. In 2002, Munich Re reported that rain intensities reached unique values worldwide. The report estimated that during 2002, 42% of worldwide fatalities, 66% of the economic losses and 64% of insured losses were due to floods.[14]

Table 32.1: Relative Degree of Public Health Impact that May Be Expected After a Flood

Impact	*Degree*
Drowning mortality	High-income nations – Few Low-income nations – Can exceed 100,000/event
Epidemics	Can occur in low-income nations
Need for trauma care	Rare
Loss of clean water	Can be widespread
Loss of shelter	Can be widespread
Loss of personal and household goods	Can be widespread
Permanent population migration	Rare
Loss of routine hygiene	Can be widespread
Loss of sanitation	Can be widespread
Disruption of solid waste management	Can be widespread
Public concern for safety	High
Increased pests and vectors	Can be widespread
Loss and/or damage of healthcare system	Can be widespread
Worsening of existing chronic illnesses	Can be widespread
Toxic exposures	Possible
Food insecurity	Can occur in low-income nations and remote islands

THE PUBLIC HEALTH IMPACTS OF FLOOD DISASTERS

Public health impacts of flooding include damage to homes and consequent displacement of occupants, infectious disease exacerbated by crowded living conditions and compromised personal hygiene, contamination of water sources, disruption of sewage service and solid waste collection, increased vector populations, injuries sustained during clean-up, stress-related mental health and substance abuse problems, and death.[15]

Loss of Safe Water and Adequate Sanitation

During the 1993 great midwestern U.S. flood, 9% of the population in the state of Iowa suffered a complete loss of the public water system. Twenty-nine counties in Iowa (representing 37% of the population) reported flood damage to water systems, and 31 counties (with 35% of the population) reported flood damage to sewer systems.[16]

Food Insecurity: Crop Losses and Disruption of Food Distribution

Generalized food shortages severe enough to cause nutritional problems usually do not occur after disasters but may arise among low-income nations in two ways. Food stock destruction within the disaster area may reduce the absolute amount of food available, or disruption of distribution systems may curtail access to food, even if there is no absolute shortage. Flooding and sea surges can damage household food stocks and crops, disrupt distribution, and cause major local shortages. Food distribution, at least in the short term, is often a major and urgent need, but large-scale importation/donation of food is not usually necessary.[17] One notable exception occurs when remote low-lying islands are flooded by seawater to an extent that island aquifer becomes brackish and agricultural land becomes salt contaminated so that it can no longer support gardens for the next several years. Such an inundation event occurred in the U.S.-associated Pacific island nation of the Federated States of Micronesia during March 2007 and resulted in a loss of food security sufficient enough to warrant a declaration of disaster by the U.S. Federal Emergency Management Agency.[18]

Loss of Shelter and Population Displacement

Floods displace literally millions of people. Displacement is a key risk factor for morbidity and mortality among disaster-affected populations. During and after displacement, vulnerable populations undergo additional risks for morbidity and mortality.

Misdirected or misguided settlement solutions may increase and prolong the risk of morbidity and mortality among displaced populations by providing shelter below internationally accepted standards for space, nutrition, food, clean water, safety and security, sanitation, hygiene, and access to medical care.[19]

Individual household shelter solutions can be short or long term, subject to the level of assistance provided, landuse rights or ownership, the availability of essential services and social infrastructure, and the opportunities for upgrading and expanding the dwellings. Existing shelter and settlement solutions should be prioritized. Where it is sustainable, members of affected households should be allowed to return to the site of the original dwellings. Affected household members who cannot return to the site of the original dwellings should be able to settle independently within a host community or with host families, whenever possible. Research has indicated that providing increased social support can significantly lower illness burdens after disasters.[19] Household members should be accommodated in temporary camps or mass shelters only as a last resort.

TOXIC CHEMICAL EXPOSURES

The mobilization of chemicals either from storage (e.g., underground fuel tanks, pipelines, hazardous landfill sites, and wastewater lagoons) or by remobilization of chemicals already in the environment (e.g., pesticides, dioxin in river/canal sediment, runoff from roads and bridges, overloaded sewers, and acid mine drainage) has occurred during floods.[20] These chemical hazards are more likely to mobilize when industrial and agricultural areas are submerged underwater.[3] One 2004 review identified epidemiological evidence for flood-related adverse health affects following chemical exposures to carbon monoxide, pesticides, agricultural chemicals, dioxin, volatile organic carbons, heavy metals, cyanide, acid waste water, sulfides, and cadmium.[20]

According to records kept by the local fire department, 1,200 homes in Grand Forks, North Dakota affected by the 1997 Red River flood reported problems with fuel oil spills ranging from 190 to 985 liters. Experts from the U.S. Environmental Protection Agency conducted a study of 34 homes approximately 1 year after the flood occurred. Six homes (17.6%) still had measurable hydrocarbon vapors that were considered a serious health problem. The homeowners were advised to move or undergo major structural work to replace contaminated structures.[21]

TOXIC MOLD EXPOSURES

In 2004, the U.S. Institute of Medicine reviewed the literature regarding health outcomes related to damp indoor spaces. The findings of this report indicate that indoor environmental conditions and personal practices may provide mold exposures that potentially expose residents and remediation workers to the risk of negative health effects.[22]

Investigators identified mold as a potential public health problem arising from the 1993 floods in the midwestern U.S.[3] Visible mold growth was found in 46% of homes inspected after flooding caused by Hurricane Katrina.[22] Predominant fungi indoors and outdoors were *Aspergillus* and *Penicillium* species. Although interpreting the significance of measures of airborne mold toxins is complex, indoor air levels were markedly elevated and usual indoor/outdoor ratios for mold were reversed, that is, indoor levels of mold toxin were higher than outdoor.[22,23]

Among the residents interviewed, two thirds quickly identified particulate respirators as appropriate and necessary respiratory protection for cleaning of mold. Of those who had cleaned up mold, two thirds did not always use appropriate respirators. Among persons who self-identified as remediation workers, 95% thought mold causes illness and 85% correctly identified particulate filter respirators as the appropriate protection for cleaning up mold; however, 49% of remediation workers had not been fit tested for respirators and 35% of the same group reported that they did not always use respirators.[22] These findings suggest that a significant proportion of disaster-affected residents and remediation workers may be exposed to potentially hazardous levels of mold contamination by virtue of a lack of understanding or lack of access to personal protection or a lack of compliance when those measures were recognized and made available.[22]

DISRUPTION OF HEALTHCARE SERVICES

Flooding may directly damage healthcare facilities or it may hinder public access to these facilities by closing transportation routes. During the great midwestern U.S. floods in 1993, five of the 99 counties representing 14% of Iowa's population reported closures of primary care physician offices.[16]

Floods have a substantial impact on the operation of most emergency medical services systems. The primary effect often results from disruption of usual transport routes due to water. Data concerning air transport in flooding collected during Hurricane Floyd demonstrated a nearly 650% increase in helicopter utilization for emergency medical services transports in the affected areas of the U.S.[4] In most flood-related disasters in the U.S. approximately 0.02%–2% of flood survivors require emergency medical attention.[24]

The Midwest floods of 1993 presented multiple challenges to the six metropolitan medical centers in Des Moines, Iowa when these hospitals lost all public utilities. Healthcare leaders cancelled elective admissions and diverted nonemergency clinical services to alternate facilities. They identified and implemented ancillary resources to maintain essential operations. Modifications were made for alternative methods of infection control, sterilization, housekeeping, and food preparation. Planners implemented extraordinary measures to maintain adequate amounts of water for laundry, fire protection, cooling, instrument sterilization, renal dialysis, physical therapy, and dietary services.[25]

DISRUPTION OF PUBLIC SERVICES

During the great midwestern U.S. floods in 1993, eight counties in Iowa (24% of the state population) reported interruption in public health services (e.g., supplemental food programs and various clinics such as those for vaccinations and treatment of sexually transmitted diseases). Ten counties (15% of the population) reported at least one nonoperational public sewer system.[16]

Power outages are a common impact of flood disasters. Power outages not related to flooding have been associated with outbreaks of diarrheal illness.[26] The disruption of public access to refrigeration may have the potential to impact food safety as well as drug safety. Life sustaining medications such as insulin also require properly controlled refrigeration to remain efficacious.

FLOOD-RELATED MORBIDITY AND MORTALITY

Flood-related Mortality

Floods continue to be the number one nonterrorist-related disaster in the United States in terms of lives lost and property damage.[27] Over a 25-year period prior to Hurricane Katrina, floods killed approximately 140 Americans and cost $6 billion in property damage each year. In the United States, the most common cause of flood-related deaths is drowning.[10]

"The number of deaths associated with flooding is closely related to the life-threatening characteristics of the flood (rapidly rising water, deep flood waters, objects carried by the rapidly flowing water) and by the behavior of the victims."[28] The most readily identifiable flood deaths are those that occur acutely from drowning or trauma, such as can occur after being hit by objects in fast flowing waters. The number of such deaths is determined by the characteristics of a flood, including its speed of onset, depth, and the extent of flooded area. Information on risk factors for flood-related death remains limited, but men appear more at risk than women. In high-income countries most deaths are due to drowning and, particularly in the U.S., are vehicle related.[4,29] The most likely group to drown in their own homes are the elderly.[29]

Flash floods are the number one cause of flooding deaths.[3] Flash flooding is the leading cause of weather-related mortality in U.S.[16] In general, high mortality rates are frequently observed in flash flood incidents, examples of which occurred in Puerto Rico in 1992,[30] Missouri in 1993, and Georgia in 1994, and Texas in 2001 when heavy water runoff inundated communities with great immediacy and intensity.[5,15,30] The majority of flood-related drownings occur when a vehicle is driven into hazardous floodwaters.[4,13]

The power of water, especially moving water, is astounding. For example, "Two feet of water will carry away most automobiles. The lateral force of a foot of water moving at 10 mph is about 500 pounds on the average car. And every foot of water displaces about 1,500 pounds of car weight. So two feet of water moving at 10 mph will float virtually every car."[31]

During the 1998 floods in central Texas, 24 of the 29 deaths directly related to the storm were caused by drowning. Of those 24 drownings, 22 (92%) with known circumstances occurred because the vehicle was driven into high water. These deaths occurred in 16 separate incidents, some with multiple fatalities. Of the 16 water-crossing incidents, 11 (69%) occurred at locations known to reporting authorities to have a history of flooding; 10 (63%) involved trucks and/or sport-utility vehicles.[13]

Prior to the implementation of early warning, evacuation, and shelter systems, drowning from hurricane storm surge accounted for an estimated 90% of cyclone-attributable mortality in both high-income and low-income nations.[3] Approximately 8,000 people died as a result of flooding in 1900 after a large hurricane hit Galveston, Texas. In 1928, 1,836 people died as a result of another hurricane storm surge around Lake Okeechobee in Florida. Most of these deaths were believed to be caused by the large storm surge associated with powerful hurricanes.

Storm surge drowning deaths have decreased markedly in high-income nations due to improvements in population protection measures.[32] One notable exception is that more than 1,300 deaths were attributed to Hurricane Katrina, most of which occurred as result of flash flooding caused by catastrophic levee failures, making 2005 the third deadliest year in U.S. history for flood deaths to that date.[33]

Flood-related Morbidity

POVERTY AND FLOOD-RELATED MORBIDITY

Poverty is a key risk factor for human vulnerability to flood disasters. The correlation between poverty and morbidity is seen clearly during flood disasters. Low-income populations within a given society often dwell in locations at higher risk for flooding and have fewer resources available for response and recovery. Rarely, if at all, are any resources available to prepare for or mitigate flood disasters. High-income populations within a society possess a much higher level of resilience and availability of resources and can better afford more cost-effective risk reduction measures. Diseases normally endemic to a given population are typically exacerbated as a result of flood disasters. As a result, low-income nations have a higher incidence of flood-related outbreaks of infectious diseases, such as leptospirosis, typhoid, malaria, and cholera. High-income nations tend to suffer few flood-related outbreaks, but instead have a higher proportion of flood-related noncommunicable diseases, such as injuries, mental illness, cardiovascular disease, and chronic obstructive pulmonary disease.

Causes of flood-related morbidity reported in high-income nations during the first 6 weeks after the disaster are frequently equally divided between injuries and illnesses. Injuries commonly include sprains/strains, lacerations, and abrasions. Many of these injuries occur during the clean-up phase rather than immediately during the flooding. The causes of flood-related illnesses in high-income nations are often equally divided between communicable and noncommunicable diseases.[16,32]

COMMUNICABLE DISEASES AND FLOOD-RELATED MORBIDITY

The relationship between disasters and communicable diseases is frequently misconstrued. The risk for epidemics is often presumed to be very high in the disaster aftermath. The risk for outbreaks after disasters is often greatly exaggerated by both health officials and the media.[17] The risk of infectious diseases after flood-related disasters is often specific to the event itself and is dependent on a number of factors. The risk factors for outbreak after disasters are primarily associated with displacement of highly vulnerable populations. Specific risks to these populations are determined by proximity of safe drinking water and functioning latrines, nutritional status of the displaced population, level of immunity to vaccine-preventable diseases, and access to healthcare services.[17,26,34] Historically, the large-scale, long-term displacement of populations as a result of flood disasters is uncommon. This likely contributes to the low overall risk for outbreaks.[34] In high-income countries with adequate public health infrastructure, postimpact surveillance has only occasionally detected increases in life-threatening infectious diseases after disasters and these increases have been relatively small.[3,4,34] In comparison, in low-income nations, disaster recovery workers have reported larger outbreaks of infectious diseases including cholera and typhoid, acute respiratory infections, and leptospirosis.[23] Despite frequent public concern to the contrary, nonendemic diseases do not spontaneously emerge after flood disasters. Floods exacerbate diseases that are endemic to the affected populations.

DIARRHEAL ILLNESS

In flood conditions there is potential for increased fecal–oral transmission of disease, especially in areas where the population does not have access to clean water and sanitation. Outbreaks of diarrhea occur in both high-income and low-income nations and are associated with locally endemic pathogens. The risk of diarrheal illness appears to be less for high-income countries compared with low-income countries. Diarrheal illness in high-incomes countries most commonly manifests as a self-limiting gastroenteritis without a specifically identified pathogen. Flood-related outbreaks of life-threatening diarrheal diseases (such as paratyphoid and cholera) have been reported in very low-income nations.

Flood-related Diarrheal Illness in High-income Nations

In 1983, an outbreak of diarrheal illness was reported in Utah possibly associated with contaminated water supply that resulted from flooding during the spring snow melt. Five routine bacteriological samples from the source revealed coliform counts to be elevated above acceptable limits.[35] A similar period of heavy water runoff associated with unseasonably warm weather and ash fall from the Mount St. Helens volcano eruption in 1980 was also linked to an outbreak of diarrhea due to *Giardia lamblia*.[35]

After flooding caused by tropical storm Allison in Houston, Texas during June 2001, 54 (12.9%) surveyed households reported at least one person with illness that occurred after the onset of flooding. Persons living in flooded homes were significantly more likely than those living in nonflooded homes to report illness; the only specific illnesses significantly associated with residing in a flooded home were diarrhea/stomach conditions.[15] In 2002, in a village near Barcelona, Spain an outbreak of shigellosis affected more than 10% of the population. The outbreak was linked to consumption of drinking water that may have been contaminated after heavy rain caused floods.[36] After Hurricane Katrina in 2006, clusters of diarrheal disease were reported in evacuation centers in four states; gastroenteritis was the most common acute disease complaint among evacuees in Memphis, Tennessee.[23] Approximately 6,500 of an estimated 24,000 evacuees in Houston shelters visited Reliant Park medical clinic, and 1,169 (18%) persons reported symptoms of acute gastroenteritis. In stool samples from 44 patients tested, norovirus was confirmed in 22 (50%) specimens; no other enteropathogen was identified.[37]

Two cases of toxigenic *Vibrio cholerae* O1 infection were reported in Louisiana after Hurricanes Katrina and Rita.[38–40] There was, however, no epidemic and no evidence to suggest that there was an increased risk of cholera among residents of the gulf coast after these hurricanes.[23]

Flood-related Diarrheal Illness in Low-income Nations

Surveillance data showed an apparent increase of mortality as a result of diarrhea during the 1988 floods in Khartoum, Sudan,[41] but a similar rise was also apparent in the same period of the preceding year.[42] Routine surveillance data and hospital admission records showed diarrhea to be the most frequent cause of death following severe flooding in 1988 in Bangladesh, but again, the effect of the flood was not separately quantified from seasonal influences.[29] Two devastating monsoon-related floods in Bangladesh in 2004 resulted in very large outbreaks of diarrheal disease reaching epidemic proportions throughout the capital city of Dhaka. Healthcare workers evaluated more than 17,000 patients in one hospital during one of these flood periods. Cholera was the most common cause of admission, and enterotoxigenic *Escherichia coli* was also an important cause of acute watery diarrhea, particularly in children younger than 2 years of age.[23] In a large study conducted in Indonesia in 1992 and 1993, flooding was identified as a significant risk factor for diarrheal illnesses caused by paratyphoid fever.[26]

RESPIRATORY INFECTIONS

Whenever there is a lack of clean water among displaced populations, there is often a concomitant difficulty in maintaining adequate hygiene. This lack of hygiene can lead not only to diarrheal illness, but also to acute respiratory infections. Reported incidence of acute respiratory infections increased fourfold in Nicaragua in the 30 days after Hurricane Mitch in 1998.[26]

Flooding may also result in episodes of near-drowning and pulmonary aspiration of floodwater. Direct inoculation of the pulmonary system with marine and soil debris may cause serious acute respiratory infections and systemic infections. Flood-related aspiration pneumonia is often polymicrobial.[23]

VECTOR-BORNE DISEASES

The relation between flooding and vector-borne disease is complex. The predicted impact of severe weather or floods on vector-borne illnesses is less certain than that of enteric infections. Severe weather can either increase or decrease the transmission of vector-borne illness.[23,29] Such variance probably mirrors the complexity of a given situation, and partly reflects the prevalence of vector-borne diseases in the region before the disaster, the identity and ecology of the local vectors (some vectors prefer clean water, others prefer organically rich water, some prefer fresh water, and others prefer water containing low amounts of salt), and the impact of control programs or other interventions that minimize vector–human contact (for example, the use of larvicidal or insecticidal agents, access of survivors to nets or window screens, and access of survivors to shelters versus sleeping outdoors).[23]

ARTHROPOD-BORNE DISEASES

Flood-related Arthropod-borne Disease in High-income Nations

Floods are often followed by a proliferation of mosquitoes. In the U.S. such disasters are rarely followed by outbreaks of arboviral disease. This is attributable mostly to the relatively low prevalence of vector-borne diseases in the region before the disaster.[23,43] Heavy rains and flooding have been associated with outbreaks of St. Louis encephalitis in Florida, believed to be associated with the feeding activities of the responsible mosquito vector.[23] In comparison, despite the proliferation of large populations of mosquitoes known to amplify transmission of arboviruses that cause St. Louis encephalitis and western equine encephalitis after the great midwestern flood of 1993, surveillance data indicated minimal risk for arboviral disease above background levels in the disaster area. During the 1993 floods, 45 counties (53% of the population) in Iowa reported vector problems. Mosquito vectors were found to exist in extremely high levels. Serum conversions were not detected in sentinel chicken flocks nor were there any reported human cases of illness as result of mosquito vectors.[16] As a result, contingency plans for large-scale mosquito adulticiding were not implemented, resulting in an estimated cost savings of more than $10 million. Despite the presumed low risk for mosquito-borne arboviral disease after flood-related disasters in high-income countries, surveillance programs are useful to assist with determining prevalence in large vector populations and prevent unnecessary expenditures associated with the application of insecticides implemented during prophylactic mosquito control.[43]

Flood-related Arthropod-borne Disease in Low-income Nations

Malaria outbreaks in the wake of flooding have been reported in several very low-income nations with warm climates.[26] Increased numbers of cases of drug-resistant malaria were noted after floods in Sudan[44] and an outbreak of more than 75,000 cases of *Plasmodium falciparum* occurred in Haiti after Hurricane Flora in 1963.[26] A four–fivefold increase in malaria incidence also occurred after a flood disaster in 2000 in Mozambique.[26] After the 2004 Indian Ocean tsunami, no appreciable increase in the number of malaria cases was reported in Indonesia.[45]

Dengue transmission is influenced by meteorological conditions; however, transmission has not been directly attributable to flooding. In Brazil, Indonesia, and Venezuela, rain, temperature, and relative humidity have been associated with patterns of dengue infection.[23] Monsoon rains and floods have been associated with outbreaks of dengue fever in India. In Thailand, dengue was a common cause of fever in children after heavy rain–associated flooding.[23]

Rodent-borne Diseases

Diseases transmitted by rodents may also increase during heavy rainfall and flooding because of altered contact patterns. Humans usually acquire leptospirosis after exposure to fresh water contaminated with the urine of infected animals, such as rats.

There have been reports of flood-associated outbreaks of leptospirosis from a wide range of countries including Argentina, Brazil, Cuba, India, Korea, Mexico, Nicaragua, Philippines, Portugal, Russia, Taiwan and the U.S. (Hawaii and Puerto Rico).[23,26,29,46]

DERMATOLOGICAL CONDITIONS

Exposure of intact skin to floodwaters does not pose a serious health risk.[35]

The risk of possible estuary-associated syndrome due to *Pfiesteria piscicida* is actually thought to decrease during periods of coastal flooding.[4] Dermatological conditions, usually in the form of nonspecific rashes, are a commonly reported complaint during flood and other disasters.[3,17] Among hurricane evacuees from the New Orleans area, a cluster of infections with methicillin-resistant *Staphylococcus aureus* was reported in approximately 30 pediatric and adult patients at an evacuee facility in Dallas, Texas. Three of the methicillin-resistant *S. aureus* infections were confirmed by culture.[40]

WOUND INFECTIONS

Wound infections are common after disasters. The destruction of the regional health infrastructure, the inability to wash wounds with clean water, and the inability to treat individuals with topical or systemic antimicrobial agents can all lead to severe wound infections, even if the initial trauma was relatively minor. In 2005, after Hurricane Katrina, 24 cases of *Vibrio* sp. bacterial wound infections were noted among individuals in the affected area. Most patients had associated comorbidities that probably increased their risk of *Vibrio* wound infection, and many had been wading in floodwaters.[23,40]

There is no evidence indicating that the risk of tetanus is increased in flood-related lacerations; therefore standard immunization practices should be used.[4] In comparison, the incidence of tetanus in the disaster setting has been associated with wounds that are highly contaminated with soil as a result of high-energy traumatic inoculation occurring in low-income nations where patients are less likely to have had primary vaccinations and access to postexposure tetanus prophylaxis. Clusters of tetanus cases were reported after the Indian Ocean tsunami as well as the Pakistan earthquake in 2005. These exposures were sustained during the initial trauma on the day of the event and not associated with exposure to floodwater or contaminated water sources. No subsequent cases were reported 2 weeks after the tsunami, indicating an association with the initial traumatic injury on the day of the event and not from wound exposure to flood waters afterward.[45]

INJURIES

During a flood disaster, injuries are more likely to occur as residents attempt to travel or evacuate through flooded areas and in the aftermath of a flood disaster when residents and workers return to dwellings to clean up damage and debris. Hypothermia with or without submersion injury is seen in some flood casualties. Conductive heat loss due to immersion in any water less than 16°C –21°C may lead to hypothermia. Wet clothing and water immersion tend to conduct away core body heat even when the ambient air temperature is considerably warm, if it is less than the body temperature. Convective heat losses increase in windy conditions. Electrocutions have occurred as a result of downed power lines, electrical wiring, and improper handling of wet appliances. Injuries from fires and explosions from gas leaks also occur. Musculoskeletal and soft tissue injuries are frequent conditions associated with floods. Lacerations and punctures are common sequelae during postflood clean up and recovery activities.[3,4]

Although it is a recurrent public concern that animals such as snakes may be forced to seek refuge from rising floodwaters in areas that may be inhabited by humans, public health surveillance after floods has not indicated that wild animal bites have been a major problem.[3,4] In contrast to wild animals, after Hurricane Floyd there were increases in reports of domesticated dog bites.[32]

In the U.S. state of Missouri after the Midwest floods of 1993, injuries were reported through the routine surveillance system. During a 6-week period, a total of 524 flood-related conditions were reported, and of these 250 (48%) were injuries. These injuries were categorized as sprains/strains (34%), lacerations (24%), abrasions (11%), and other injuries (11%).[6] Epidemiologists reported similar data from Iowa during the same year.[16]

MENTAL HEALTH EFFECTS

The long-term effects of flooding on psychological health may be even more significant than for any other illness or injury.[47–49] For many people, the emotional trauma continues long after the water has receded.

Factors that appear to make people more vulnerable to the development of psychological problems include the following

- Objective and subjective characteristics of the disaster – proximity of the victim to the disaster site; the duration of the disaster; the degree of physical injury; the witnessing of death or injury[47]
- Characteristics of the postdisaster response and recovery environment – community cohesion; secondary victimization; disruption of social support systems;[47] lack of home-ownership and duration of displacement from home[19]
- Characteristics of the individual or group – history of psychological problems; elderly; unemployed; single parent; children separated from their families.[47]

In one study of the health effects of flooding in 30 locations of the United Kingdom, psychological effects were much more commonly reported after flooding than physical ones. Women also appeared to suffer markedly more frequently than men at the worst time of flooding.[19] A number of psychological effects reported by flood victims have been quite strongly associated with reporting physical effects, particularly immediate effects.[19]

Increased morbidity and mortality following a flood may also result from heightened psychological stress.[48] Bennett studied 316 flood respondents and 450 nonflood controls for morbidity and mortality for the year after the Bristol floods in England in 1968. He found higher mortality among residents of the flooded sections, especially the elderly.[49] Psychiatric examinations of 224 children 2 years after the 1972 flood in Buffalo Creek, West Virginia showed that 80% of the children were severely emotionally impaired by their experiences during the flood.[49] Five years after the flood caused by tropical storm Agnes in Pennsylvania, perceived health problems were reported more commonly by flood-affected respondents than nonaffected controls.[49]

Anxiety and Depression

There is considerable evidence for the impacts of anxiety and depression among flood-affected populations. Most studies are from high- or middle-income countries, including Australia, Poland, the United Kingdom, and the United States, but there is also a study from Bangladesh.[29] A few studies have examined flood-related mental health impacts on children. One 1993 study found postflood changes in behavior among children 2–9 years old.[29]

Posttraumatic Stress Disorder

Studies in Europe and North America have revealed post-flood psychiatric disorders among flood-affected populations that meet the criteria for posttraumatic stress disorder.[29] One longitudinal study found 15%–20% of people affected by a disaster had symptoms of posttraumatic stress disorder.[48] Other studies after the 1997 floods in Poland also suggest long-term negative effects on the well-being of children aged 11–14 and 11–20 years with increases in posttraumatic stress disorder, depression, and dissatisfaction with life. Six months after Hurricane Floyd similar findings were reported for disaster-affected children aged 9–12 compared with controls.[29]

Table 32.2: Top 10 Medical Conditions Based on Limited Needs Assessments among Persons in Hurricane Katrina Evacuation Centers between September 10 and 12, 2005

Condition	*Incidence per 1,000 Residents*
Hypertension/cardiovascular	108.2
Diabetes	65.3
New psychiatric condition	59.0
Pre-event psychiatric condition	50.0
Rash	27.6
Asthma/Chronic obstructive pulmonary disease	27.5
Flulike illness or pneumonia	26.3
Toxic exposure	16.0
Other infection	15.6
Diarrhea	12.8

Data from Centers for Disease Control and Prevention. Available at: www.cdc.gov/od/katrina/09–19-05.htm.

Suicides

Evidence is limited regarding flood-related suicides. One study in a high-income nation indicated that suicide rates increased by 13.8% above the predisaster rates.[4]

EXACERBATION OF CHRONIC ILLNESS

Conditions related to exacerbations of chronic disease may comprise a majority of patient complaints among flood-affected populations in high-income nations, especially in shelter settings. Table 32.2 provides an example of typical patient complaints after flood displacement in a high-income nation.

The development of hypertension by male flood victims was reportedly greater than by male non-flood victims in the 5 years after flooding caused by Hurricane Agnes in Pennsylvania.[49] Benin also reported a marked increase in hypertension in Russia after the 1964 flood and in Moldavia after two successive floods in 1969.[49]

CARBON MONOXIDE POISONING

Carbon monoxide poisonings occur, usually in association with loss of electrical power, when flood-affected populations improperly use carbon monoxide–emitting fuel sources within poorly ventilated, enclosed spaces. This happens when people place generators indoors, in garages, or outdoors but near windows. Other carbon monoxide–emitting sources include indoor burning of charcoal for cooking and heating and using leaf blowers indoors for flood clean up. After the 2004 hurricanes in Florida, 157 persons were treated from 51 exposure incidents, with six reported deaths. Of the 167 cases of carbon monoxide poisonings associated with Hurricane Katrina in 2005, 48.5% were treated and released without undergoing hyperbaric oxygen

Table 32.3: Four Main Strategies and Associated Tools for Floodplain Management[2]

Strategy	*Tools*
Modifying vulnerability	Regulations
	Development and redevelopment policies
	Disaster preparedness
	Flood forecasting, warning, and evacuation plans
	Flood proofing and elevation
Modifying hazard	Dams and reservoirs
	Dikes, levees, and flood walls
	Channel alterations
	High-flow diversions
	Storm water management
	Shoreline protection
	Land treatment measures
Modifying impact	Information and education
	Flood insurance
	Tax adjustments
	Flood emergency measures
	Disaster assistance
	Postflood recovery
Restoring and preserving the natural and cultural resources of floodplains	Regulations
	Development and redevelopment policies
	Information and education
	Tax adjustments

therapy, 43.7% were released after undergoing hyperbaric oxygen therapy, and 7.8% were hospitalized (most for just 1 day). Among these patients, 80% complained of headache, 51.5% nausea, 51% dizziness, 31.5% vomiting, and 16.4% dyspnea, and 14.5% experienced loss of consciousness. The mean carboxyhemoglobin level was 19.8%, with a range of 0.2%–45.1%.[11]

CURRENT STATE OF THE ART

Sustainable Development and Disaster Risk Management

A widely used international definition of sustainable development is "development which meets the needs of the present without compromising the ability of future generations to meet their own needs."[50] The concept of sustainable development was first codified decades ago during the Declaration of the United Nations Conference on the Human Environment at Stockholm in June 1972. Principle 1 of this declaration stated, "Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generations."[50]

Over time the overall approach to emergencies and disasters among nations has shifted from ad hoc postimpact activities to a more systematic and comprehensive process of risk management that emphasizes the importance of preimpact risk reduction activities including prevention, mitigation, and preparedness.

Building on these core principles of both sustainable development and disaster risk management, the 2002 World Summit on Sustainable Development plan of implementation stated, "An integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century."[51] Sustainable disaster risk management is a comprehensive approach to reduce disaster impact on a society over time without transference of additional risk and associated costs to future generations.

Toward Sustainable Flood Risk Management

The risk from disaster occurs when vulnerable populations are exposed to a hazard such as flooding and there are insufficient resources to match the immediate needs. This can lead to morbidity and mortality.

Risk assessment is used to quantify environmental health risk. For flooding events, the risk equation has been applied to estimations of the likelihood of disaster impact as follows:

$$\text{p(flood hazard)} \times \text{p(vulnerability or "susceptibility")} - \text{p(absorbing capacity or "resilience")} = \text{p(disaster impact)}.$$

The probability of the hazard occurring is based on models that apply historical data from past floods in the same specific location being analyzed for risk.

The term "floodplain management" embodies the effort to manage the waters and lands subject to flooding to

- Reduce all losses due to flooding
- Protect and enhance the natural values (inherent social, economic, ecological, and cultural) of floodplains

It includes actions by all levels of government and the private sector ranging from constructing massive dams to the zoning decisions of small communities. It involves concerns with wetlands, water quality, location of new developments, and a host of other considerations. Planning and carrying out a comprehensive floodplain management program usually requires the cooperative participation of all levels of government and the private sector. The four main strategies of floodplain management relate to modifying the likelihood of the hazard ever occurring, the vulnerability (or susceptibility) to the hazard, and increasing the resilience or capacity of the society to absorb the impact of the hazard without mismatch of needs and resources. See Table 32.3.

The newly emerging paradigm of sustainable flood management is derived from the concept of sustainable development. A "seismic shift" has been described as taking place in managing flood risk. Many countries' well-established reliance on structural defenses is being questioned and cheaper and more sustainable alternatives are being sought.[52]

In the past, due to emphasis on structural defense, alleviation was prioritized above complimentary strategies such as promoting avoidance, raising awareness, and providing assistance. For many decades this paradigm of flood defense has been successful in protecting urban dwellers from riverine inundation and enabling farmers to cultivate or raise livestock right up to the edge of the river or seashore. This strategy, initially questioned because of the threat posed by climate change, is being increasingly abandoned.[52] More cost-effective strategies for disaster risk reduction through flood prevention, preparedness, and mitigation are now gaining wider application.

The Scotland Water Environment and Water Services Act of 2003 states that public officials have a duty "to promote sustainable flood management and act in a way best calculated to contribute to the achievement of sustainable development." In practice this means that officials must seek to balance social, economic and environmental needs within a framework that incorporates intergenerational equity.[52] Intergenerational equity is a concept based on the fundamental principle of sustainable development that calls for a meeting of present population needs without compromising the ability of future generations to meet their own needs. Present development should not add a burden of disaster risk for future generations to pay through expensive and inefficient response and recovery measures. It is the responsibility of each generation to avoid public policies and developmental practices that increase the future risk of disaster.

Sustainable flood risk management also seeks to reduce risk at all stages of the disaster cycle giving preference to more cost-effective disaster risk reduction activities such as prevention, preparedness, and mitigation.

Lessening Public Health Vulnerability to Flood Disasters

Until recently, vulnerability has mostly been measured in terms of flood damage to infrastructure and commerce. The current state of the art is seeking to further define and measure human vulnerability in terms of indicators for health, socioeconomic status, and quality of life. By focusing on vulnerability and the ability of individuals and communities to recover (resilience), sustainable flood management places individuals at risk in the center stage and places the responsibilities for enhancing social equity and promoting community cohesiveness on appropriate authorities. This is coupled with a heightened sense of individual responsibility. Fundamental to sustainable flood management is a change in attitude in which a willingness to take on greater personal responsibility for mitigating flood losses steadily replaces undue reliance on state intervention when losses occur.[52]

Flood risk assessments commonly focus on protecting property and are the basis for financial decision-making. Environments are often protected irrespective of the cost. The health and social impacts suffered by people affected by floods remain mostly ill considered. In this respect, a better understanding of the social effects of individuals involved in floods is needed. Disruption of people and communities cannot be measured in monetary costs. Floods can cause health impacts that are enduring, including the stress and trauma created months or years afterward. The psychological effects of flooding can continue for months or even years after the event and are often more pronounced than the physical health effects.[53] Tapsell et al., have proposed a Social Flood Vulnerability Index (SFVI), which measures the impact that floods could have on the communities potentially affected. The SFVI is a composite-added index derived from a review of the existing literature and hundreds of interviews of disaster victims. It is based on three social characteristics and four financial deprivation indicators. It recognizes that age and financial status of the affected populations are the most important variables, followed by the prior population health status. The seven indicators used for derivation of the SFVI are

- Unemployment
- Overcrowding
- Nonownership of a car
- Nonownership of a home
- Long-term illness
- Single parent family
- Elderly

Strengthening Public Health Resilience to Flood Disasters

A 2002 Institute of Medicine report claimed that U.S. governmental public health agencies have long suffered "grave underfunding and political neglect." After Hurricane Katrina, a 2005 editorial also criticized the less than adequate support for a resilient public health system that protects human life when disasters occur.[54] Populations that possess a high capacity for access to public health and medical services are more resilient and less vulnerable to flood-related morbidity or mortality. There is growing concern regarding the longer-term impacts of climate change on human health, including flooding.[4,14,19] The sustainable development of cost-effective public health and medical systems serves to strengthen population resilience to flood disasters. Methods that seek to reduce population vulnerability also serve to increase resilience of the public health against flood-related morbidity and mortality.

Preventing the Public Health Impact of Flood Disasters

Since 1926, flood damage has increased in both the U.K. and the U.S. despite local efforts and federal encouragement to mitigate flood hazards and to regulate development in flood prone areas.[52–55] Although flood-related mortality during the past half-century has declined among high-income nations (mostly because of improved warning systems), economic losses have continued to rise due to increased urbanization and coastal development.[56] Many people lack the ability to prevent flood hazards from occurring, leaving the public health and medical sectors to play an important role in mitigating and preventing the public health impact of disasters.

The majority of disaster-related mortality is directly attributable to drowning. Therefore, population protection measures such as evacuation are aimed at preventing drowning by warning populations and moving them away from the flood hazard. The incidence of flash floods in the United States is increasing; however, the mortality from these floods is decreasing. This decrease in mortality parallels advances in the U.S. National Weather System advanced warning system. Warning has been identified to be a substantial factor in decreasing mortality from flash floods by more than 50%.[4]

Health communication is a valuable tool in educating the public before and after flood impact regarding protective behaviors that help to prevent drowning (i.e., cautions regarding driving vehicles in flooded areas). Other injuries and illness may also be prevented through public awareness and education that promotes safe and healthy activities during flood response and recovery efforts. Injuries such as electrocutions, burns, and carbon monoxide poisonings are typical examples of flood-related morbidity that are preventable through public awareness and health education campaigns. Chronic psychological and medical illnesses can also be prevented through activities that adequately manage stress in the disaster-affected population.

The appropriate use of personal protective equipment (Chapter 13) among disaster-affected populations and recovery workers can help to prevent secondary disaster-related morbidity due to toxic exposures from chemicals or mold. Measures to increase awareness of the appropriate respiratory protection among the public are warranted to lessen potential exposures to mold hazards. This information can be provided via public service announcements on radio and television and by educational sessions for employees of home improvement stores and other commercial entities that sell respirators. To decrease the probability of flood-related illness, flood victims and relief workers should practice proper hand hygiene (wash their hands with soap and water) before preparing or eating food, after toilet use, and after participating in flood clean up or after handling potentially contaminated articles.[57]

Chemical risk assessments can be used to identify and characterize industrial and agricultural hazardous material sites located in flood prone locations to prevent toxic exposures and associated adverse health effects.

Public policy may guide landuse and zoning regulations that prevent population displacement. These efforts subsequently lessen the potential future need for expensive shelter and settlement options that must also include access to basic necessities for space, food, water, sanitation, hygiene, security, and medical care. Lessening population displacement markedly decreases the risk for morbidity and the excess demand for services as a result of flooding.

Well-established disease surveillance systems are necessary to monitor health effects among the flood-affected population and direct cost-effective public health interventions that may prevent secondary morbidity and mortality. Clinical and laboratory surveillance should be integrated to rapidly detect disease and guide therapy.

Early implementation of environmental health capacity related to toxicology, water, sanitation, waste management, and vector control can prevent disease due to toxic, vector-borne, food-borne, and water-related illnesses.

Flood disaster risk assessments should be used to guide both local and national decisions regarding location/relocation of critical public health and healthcare facilities outside of floodplains whenever possible, so that secondary disasters (i.e., public health and medical facility evacuations) do not occur at healthcare facilities.

Public health programs that offer primary prevention of chronic disease (as compared with merely managing existing illness) also serve to lessen the vulnerability of the disaster-affected population to flood-related morbidity and mortality. In this sense, building and maintaining a baseline robust public health infrastructure also serves to reduce the public health impact of floods. Population reliance on food sources and distribution systems that are not vulnerable to flooding may prevent any significant public health impact attributable to malnutrition. Reliable and economical access to drugs and medical care also helps to prevent adverse health effects. This is best accomplished through a well-developed and equitable healthcare system.

Mitigating the Public Health Impact of Flood Disasters

The public health impact of floods reflects secondary effects of the disaster such as population displacement and disruption of existing health services. To minimize these secondary effects, public health and healthcare relief efforts must be coordinated within the general emergency management cycle before, during, and after the impact phase and throughout recovery. Strategies should seek early reinstatement of normal routine activities of daily living among disaster-affected populations to mitigate ongoing adverse psychological and other health effects.

Mitigation is defined as the reduction of harmful effects of a disaster by limiting the disasters impact on human health and economic infrastructure. In the past, mitigation measures have been used in the traditional fields of engineering and urban planning. Flood-related mitigation activities lessen deaths and injuries by ensuring structural safety through enforcing adequate building codes, promulgating legislation to relocate structures away from flood prone areas, planning appropriate land use, and managing coasts and floodplains.[3] Critical public health and medical assets can be identified before flood impact and engineering measures can be taken to mitigate loss of critical health infrastructure and assets during flooding. Key buildings may be designed or strengthened in ways that lessen the risk of flood damage.

Shelter and settlement solutions for displaced populations must adequately address basic human needs related to space, water, sanitation, hygiene, nutrition, and security to mitigate the public health impact of floods. Settlement solutions that do not promote hastening resettlement and minimizing population displacement may contribute to the long-standing psychological impact of the disaster and its subsequent association with chronic health effects. Therefore, public health workers should be involved in decisions regarding the rapid reinstatement of healthy homes and healthy communities that would have a direct impact on the health of flood-affected populations.

Preparing for the Public Health Impact of Floods

The public health impact of flood disasters is predictable for both high- and low-income nations. It is therefore possible to prepare emergency response and recovery activities that will lower the risk of flood-related morbidity and mortality.

"Public health emergency preparedness is the capability of the public health and health care systems, communities, and individuals, to prevent, protect against, quickly respond to, and recover from health emergencies, particularly those whose scale, timing, or unpredictability threatens to overwhelm routine capabilities."[58]

An emergency management program has the goal of strengthening the "overall capacity and capability of a country to manage all types of emergencies and bring about an orderly transition from relief through recovery and back to sustained development."[59]

Eleven "Es" of emergency preparedness have been described

- Evaluation and forecasting of hazard
- Early warning
- Evacuation
- Emergency operations planning
- Education and awareness
- Exercises and drills

- e-Health and electronic media
- Epidemiology
- Equipment and supplies
- Enforcement of landuse regulations and zoning codes
- Economic incentive

In recent years, accurate weather forecasts linked to timely warning systems for hazardous flooding have effectively mitigated the affects of floods on the health and well-being of communities. Emergency operations planning for response and transition planning for recovery are core elements of public health preparedness. Once plans are developed, both the public and response communities must be made aware and trained to implement protective behavior. Exercises test the validity of emergency plans and the effectiveness of education and training. Epidemiological investigations identify the adverse health effects of flood disasters. Surveillance activities monitor health trends, allowing for early warning and intervention. The availability of equipment and supplies (i.e., personal protective equipment, boats and helicopters, power generators, water pumps, and water purification units) offers the affected community enhanced absorptive capacity and resilience. Enforcement of landuse regulations and zoning codes also helps to break the response cycle by lessening or eliminating the risk of population exposure to flooding.

Despite the increased level of preparedness, flood-related deaths, diseases, and injuries continue to occur in affected communities.[3] The development of robust emergency operations plans[17,60] and the design of effective messages to prompt desired behavior are key elements for saving lives.

Responding to the Public Health Impact of Floods

Community Needs Assessment

Immediately after the flood impact phase, responder teams conduct rapid needs assessments to identify gaps between health and medical needs of a flood affected community and available resources. A needs assessment typically consists of administering a standardized questionnaire that assesses health and medical and pharmaceutical needs; the status of public health services; and access to basic services such as water, sanitation and hygiene, food, shelter, sewage, and electricity.

Disease Risk Assessment

Responding effectively to the needs of the disaster-affected population requires an accurate disease risk assessment that includes both acute and chronic disease, including injuries as well as illnesses. A systematic and comprehensive postflood evaluation should identify: 1) diseases that are common and endemic to the affected area; 2) living conditions of the affected population; 3) availability of safe water and adequate sanitation facilities; 4) underlying nutritional status and immunization coverage among the affected population; and 5) degree of access to healthcare and to effective clinical care.[26] Risk assessments can also characterize flood-related toxic exposures.

Fatality Management

The public is often concerned about the danger of disease transmission from decaying corpses. Responsible health authorities should be aware that health hazards such as epidemics associated with unburied bodies are minimal, particularly if death resulted from trauma or drowning. It is far more likely that survivors will be a source of disease outbreaks.[17] Mass graves are not necessary when considered solely to prevent the spread of disease caused by mass fatalities. Normal funeral ceremonies and practices should be respected and maintained whenever possible (Chapter 21).

Clinical Diagnosis and Management of Flood-related Morbidity

Health caregivers should anticipate flood-related adverse health effects and be prepared to detect and intervene effectively when they occur. Clinicians should maintain a high index of suspicion for illness and injuries commonly associated with floods. Flood-related injuries frequently include soft tissue lacerations, contusions, and abrasions. Endemic infectious diseases as well as chronic diseases may worsen. Mental illness and toxic exposures, for example carbon monoxide and mold, are known to increase after floods but may manifest with nonspecific symptoms such as malaise, anxiety, headaches, and nausea.

Studies of flood disasters have shown that outbreaks of vaccine-preventable diseases rarely result.[35] Despite the fact that these epidemics have not been reported to occur following flood disasters in the United States, public demand for emergency mass immunization, especially against typhoid fever, hepatitis, and tetanus, is common. Assuring the safety of water and food supplies is of paramount importance in preventing enteric disease transmission when water and sewage systems have been compromised. Active surveillance data should be used to justify consideration of an immunization campaign. Basic rules of hygiene and sanitation are far more important than immunizations in preventing infectious disease that floodwaters could potentially spread.[57] Mass immunization in the absence of a documented outbreak is usually counterproductive during flood disasters and diverts limited human resources and materials from other more effective and urgent measures.[3,17,35] Mass vaccination would be justified only when the recommended sanitary measures do not have a preventive effect and if there is evidence of the progressive increase in the number of cases of illness with the risk of an epidemic.[17]

Mass Care and Shelter of Flood-displaced Populations

Public health officials should be involved in decisions regarding the mass care and settlement of displaced populations to ensure a safe and healthy environment. Public health workers assist in performing food safety and water quality inspections, and assessment of sanitation and hygiene during mass evacuation and in shelters.

Environmental Health Services for Flood-affected Populations

The demands for environmental health services and consultation are high during flood disasters. The following are common considerations[6]

- Purification of drinking and cooking water
- Disinfection of wells
- Food safety
- Sanitation and personal hygiene
- Mosquito control

Surveillance for Flood-related Morbidity and Mortality

Although communicable disease outbreaks worldwide are rare after flooding, some potential does exist for disease transmission; therefore, flood-affected communities should be under close surveillance.[57] Mortality surveillance is performed to determine the nature and circumstances surrounding flood-related deaths so that appropriate preventive actions can be taken to reduce further mortality. Morbidity surveillance is conducted to determine: 1) any increases in diseases that are endemic to the area; 2) any cases of infectious disease that must be contained or controlled; and 3) any cases of injuries that may require public advisories. Flood-specific surveillance systems are often used to determine any increases in vector populations such as mosquitoes. In addition, public health officials should conduct laboratory-based surveillance of drinking water sources such as public and private wells.[3]

Chemical Emergency Response

The role of public health in the investigation of a flooding event that results in a chemical release should include the following activities[20]

- Hazard identification
- Risk communication
- Liaison with other relevant responder agencies
- Technical advice including aspects of toxicology, decontamination, antidotes, and personal protective equipment
- Registry and follow-up of exposed casualties
- Emergency plan development for flooding in other high-risk areas

The Role of Social Support in Improving Behavioral and Physical Health Outcomes

A complex set of social and other factors define flood victims' susceptibility to health and stress effects. There is some evidence that effective community and professional agency management of the flooding aftermath can mitigate deleterious mental health outcomes, which in turn are strongly associated with physical health effects.[19] Research from the United States has indicated that providing increased social support can significantly lower illness burdens after disasters.[61]

Recovering from the Public Health Impact of Floods

Long-term recovery from the public health impact of flood disasters can take years. Additional financial, health, and emotional costs may continue long after basic utilities and shelters have been reinstated. The disaster recovery phase may also offer a window of opportunity for improving risk reduction strategies, such as preparedness and mitigation efforts. Recovery strategies that promote future reduction of risk should be prioritized. Permanent migrations of populations are rare after disaster floods. Disease surveillance systems are necessary to identify the long-term adverse health effects of flood disasters. Public health and medical services must recover to normal levels to detect and help patients to manage the long-term risks of flood-associated illness, such as mental illness and cardiovascular disease.

RECOMMENDATIONS FOR FURTHER RESEARCH

Flooding is one of the most widespread disaster hazards, posing multiple risks to human health. Despite this, there has been only limited systematic research on the health outcomes of flooding.[19] There is surprisingly limited evidence about the health effects of floods, particularly in relation to morbidity. There are virtually no studies available on the effectiveness of public health measures, other than flood warning systems. A wide range of health risks have been well documented, although there remains scientific uncertainty regarding the strength of association and public health burden for specific health effects.[29] Overall, there are few data on the long-term health impact of flooding.[48]

Although some studies conducted during and after floods have provided important information on factors contributing to the risk of morbidity and mortality, unresolved inconsistencies remain nearly 20 years after being posed as research recommendations.

Research recommendations originally offered by Jean French and Kenneth Holt in 1989 include[49]

- Factors influencing actions people take in the face of flash flood warning and evacuation notices should be studied further
- Study should be done to assess the circumstances under which there is sufficient time to permit evacuation by car or when it is safer to abandon vehicles and escape to higher ground on foot
- A cohort of flood victims should be followed over time to determine whether they are at higher risk than a comparable group of nonflood victims of having adverse physical and mental health effects
- Systematic study should be undertaken taken to determine whether an increase in certain biological agents results from disrupted water supplies and sewage systems after floods and whether this is related to geographical location
- Systematic studies should be undertaken to examine the release of chemical agents during flooding and the potential for contamination of human pathways from such events
- A reporting system should be established to more accurately assess the number of deaths and injuries associated with each flood and the circumstances surrounding each flood death and injury

There is a need for standardized criteria for estimating flood damage and public health impact. Perception of flood damage is influenced by historical experience. For example, in low-vulnerability U.S. states, floods causing more than $1 million of damage are notable events and are likely to be reported. Conversely, in high-vulnerability states, damage of $5 million or more occurs frequently, so smaller damages might seem unremarkable and be underreported.[55]

The effectiveness of detection and warning systems should be evaluated and researchers should make recommendations for appropriate standards for such systems in ensuring greater warning sensitivity.[3] More research into the behavioral outcomes of health risk communication is important. This is especially significant to help prevent the continued cases of drowning related to vehicle use, as well as other preventable morbidity and mortality such as mold-related exposures and carbon monoxide intoxication.

In 2005, Ahern and colleagues identified the following knowledge gaps with respect to managing the public health impact of flood disasters[29]

- Mental health impact of flooding, especially the long-term impacts, and their principal causes
- Nature and magnitude of mortality risk in the period after flooding

- Quantification of the risk of infectious and vector-borne diseases following floods
- Effectiveness of warning systems and public health measures in reducing flood-related health burdens
- Defining health-related costs of flooding in terms of how they influence decisions about specific interventions
- Quantification of the degree to which climate and landuse change will contribute to flood risk and associated health burdens in different settings

The World Health Organization also recognizes that the mental health consequences of floods "have not been fully addressed by those in the field of disaster preparedness or service delivery," although it is generally accepted that disasters, such as earthquakes, floods, and hurricanes, "take a heavy toll on the mental health of the people involved, most of whom live in developing countries, where capacity to take care of these problems is extremely limited." Areas of particular concern relate to anxiety and depression, posttraumatic stress disorder, and suicide.[29] In summary, much work remains to be done to define evidence-based approaches to decrease morbidity and mortality from floods, a disaster with one of the greatest overall public health impacts.

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Cyclones/Hurricanes/Typhoons

Kelly R. Klein and Frank Fuh-Yuan Shih

OVERVIEW

Introduction

In the history of all ancient civilizations, there are fantastic tales in which a country or kingdom is saved by *divine* intervention. For example, when the Mongols sought to conquer Japan and complete their control of all Asia, a divine wind known as the Kamikaze saved the Japanese people from Kublai Khan by sinking the invasion fleet. This powerful storm, which saved Japan, is known today as a tropical cyclone.

Storms such as these have caused deaths in the hundreds of thousands and billions of dollars in property loss in the past 100 years on coastlines around the world. The risk seems to be increasing as more and more people decide to live in vulnerable coastal areas. As discussed in the 1999 Hangzhou Declaration in China, more than half the world's population lives in coastal areas with several of the fastest growing cities, Jakarta, Shanghai, and Miami, all projected to have 20–30 million in population by the year 2025. In the U.S., it is estimated that by 2010, 60% of the population will live on a coast.[1] With the projected increase in number and intensity of tropical cyclones, this becomes a significant threat. The focus of this chapter is on the impact of tropical cyclones on human societies. This includes public health; the mortality and morbidity resulting from these events; intervention measures such as evacuation; medical preparedness for the affected population; and mitigation, prevention, and response strategies for the medical community drawn from a global perspective.

Tropical Cyclones

Tropical cyclones, often referred to as hurricanes, cyclones, and typhoons, are given different names depending on their particular geographical locations (see Table 33.1). All are capable of producing large-scale devastation.[2] In the northern hemisphere, from the International Date Line to the Greenwich meridian, they are known as hurricanes. In the Pacific, north of the equator and west of the International Date Line, they are known as typhoons. In the Indian Ocean, they are known as cyclones. The tropical cyclone, among the most destructive of weather systems, is defined meteorologically as a storm system characterized by a low-pressure center with surrounding thunderstorms that produce strong winds and flooding rain.[3] These storms are capable of producing up to 20 billion tons of rainwater per day. A fully developed hurricane contains the equivalent energy of 2 million Hiroshima-sized atomic bombs.[4,5]

These massive and deadly storms originate over tropical or subtropical oceans and derive their storm energy from these warm waters. They begin as fragile meteorological entities that require several factors to ensure their formation.

1 Warm oceanic waters that are at least 26.5°C
2 An atmosphere that cools rapidly with moist layers at mid-troposphere elevations to enhance thunderstorm formations
3 The Coriolis effect to rotate the winds and the near-surface disturbance to create a vortex with minimal vertical wind shear

Cyclonic systems, which may last over open waters for more than 2 weeks, rotate counterclockwise in the northern hemisphere and clockwise in the southern hemisphere with general storm movement of east to west. As the storm develops, it progresses through successive meteorological stages: tropical wave, tropical disturbance, tropical depression, tropical storm, and cyclone (see Table 33.2). Storms strengthen over water by the energy released from differences between water and upper

Table 33.1: Classification of Cyclones Based on Geographical Location

Hurricane: the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean east of 160E
Typhoon: the Northwest Pacific Ocean west of the dateline
Severe tropical cyclone: the Southwest Pacific Ocean west of 160E or Southeast Indian Ocean east of 90E
Severe cyclonic storm: the North Indian Ocean
Tropical cyclone: the Southwest Indian Ocean

Table 33.2: Storm Progression

Storm Type	*Wind Speeds*	*Duration*	*Metrological Features*
Tropical/Easterly wave	variable	24 h	Low pressure moving westward through the trade wind easterlies. Associated with extensive cloudiness and showers
Tropical disturbance	variable	>24 h	Area of organized convection. Often the first developmental stage of any subsequent tropical depression, storm, or cyclone
Tropical depression	<38 mph (16 m/s)		Having 1 or more closed isobars (line drawn on the weather map of equal barometric pressures)
Tropical storm	>39 mph (17 m/s)		No classic developed eye; rain bands form outward from the center; given a name and it is tracked
Cyclone	>74 mph (33m/s)		

atmospheric temperatures and are further defined by degrees of barometric pressure, precipitation counts, and the radius of their cloud mass. A well-developed storm has a highly organized warm center of low barometric pressure and definite cyclonic or circular surface wind movement. Due to reduction of temperature disparity, they weaken upon landfall. Occasionally there are two mature-stage tropical cyclones that directly interact with each other in a phenomenon known as the Fujiwhara effect. If conditions are right, the Fujiwhara effect occurs when two cyclones come within 300–700 nautical miles of each other and begin to rotate around each other (Figures 33.1 and 33.2).

When a tropical cyclone develops, it is graded on a 1–5 rating scale based on wind speed, using the Saffir–Simpson scale and/or the Australian Tropical Cyclone Intensity scale (Table 33.3). These scales are used to estimate potential property damage and the degree of flooding expected along the coast after the tropical cyclone has made landfall. It is important to remember that although the intensity of the winds is predictive of damage, the speed with which a storm moves through an area also has significant impact. Tropical cyclones cause loss of life and property damage primarily due to their strong winds, flooding from the inundating rains, and storm surges. In addition, secondary events are often induced by these cyclones, creating or exacerbating new or existing hazards. Such problems include tornadoes, landslides, mudslides, and increased flooding due to levee breaches (see Chapter 32).

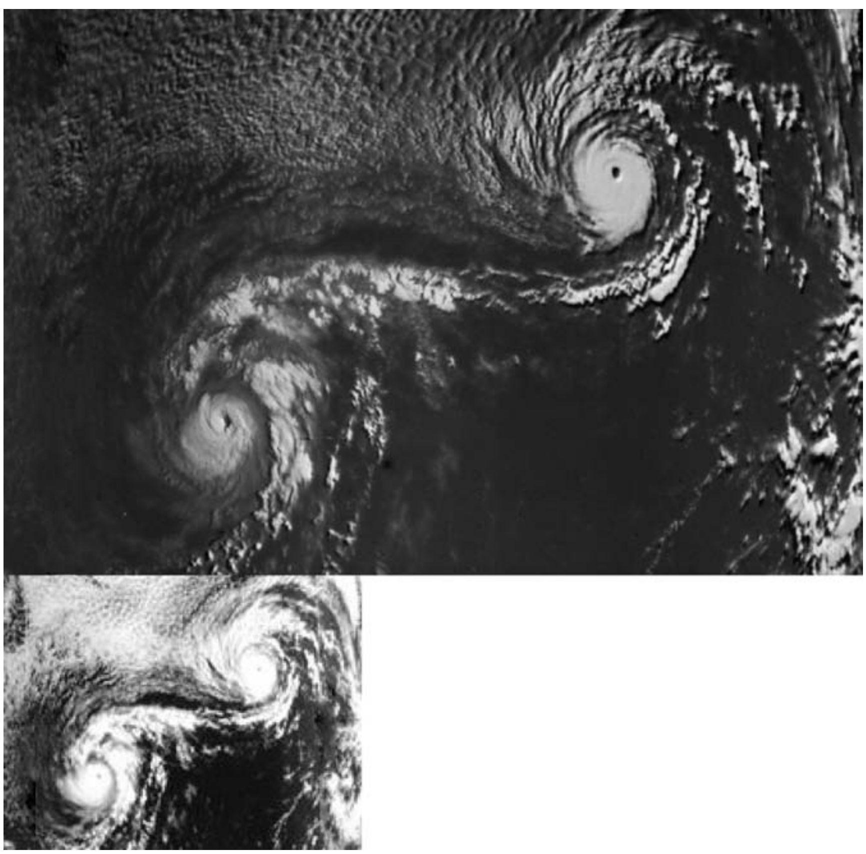

Figure 33.1. Fujiwhara effect: Typhoons Ione and Kirsten, August 24, 1974. *Image ID:* wea00481, NOAA's National Weather Service (NWS) Collection *Source:* NOAA Photo Library. See color plate.

Table 33.3: Saffir–Simpson Hurricane Scale

Category	*MPH (km/h)*	*Storm Surge Feet (Meters)*	*Damage Caused*
Tropical depression	0–38 (0–62)	0 (0)	None
Tropical storm	39–73 (63–117)	0–3 (0–0.9)	None
1 Minimal	74–95 (119–153)	4–5 (1.2–1.5)	Minimal to buildings structures; primarily to unanchored mobile homes, shrubbery and trees; some coastal road flooding and minor pier damage
2 Moderate	96–110 (154–177)	6–8 (1.8–2.4)	Some roofing material, door and window damage; considerable damage to vegetation, mobile homes and piers; small craft in unprotected anchorages break moorings
3 Extensive	111–130 (178–209)	9–12 (2.7–3.7)	Structural damage to small residences and utility buildings with a minor amount of curtain wall failures; mobile homes are destroyed; flooding near the coast destroys smaller structures with larger structures damaged by floating debris
4 Extreme	131–55 (210–249)	13–18 (4–5.5)	More extensive curtain wall failures with some complete roof structure failure on small residences; major beach erosions; major damage to lower floors of structures near the shore
5 Catastrophic	156> (>250)	>18 (>5.5)	Complete roof failure on many residences and industrial buildings; some complete building failures with small utility buildings blown over or away; major damage to lower floors of all structures located less than 15 ft (3 m) above sea level

One of the most devastating metrological manifestations of the tropical cyclone is its storm surge. Here, water accumulates along the coast as the storm approaches, pushed forward by the wind and speed of the storm. Depending on the slope of the continental shelf, the storm surge can be quite massive and destructive. Its effects are exacerbated by topographical changes due to deforestation, topsoil erosion, and increased coastal construction. Without natural barriers to block the water and wind, the cyclone's effects are carried much farther inland, increasing secondary effects from landslides and building collapses.

The severe effects of storm surge are augmented by the local tide and the storm's extremely low barometric pressures. This barometric impact causes the water surface to rise 1 cm for every millibar reduction of air pressure; hence, the more intense the storm (lower barometric pressure), the greater the storm surge.[6] The Galveston hurricane that killed 8,000 people in the year 1900 is an example of the effects of storm surge. It produced a 5-m storm surge that flooded the island of Galveston, Texas, which has a maximum height of only 3 m. In 2005, during Hurricane Katrina, a recorded surge wave averaging 2 meters traveled as far inland as 19 km. During that same hurricane, a documented storm surge of 8.5 m was recorded in the city of Pass Christian, Mississippi.[7]

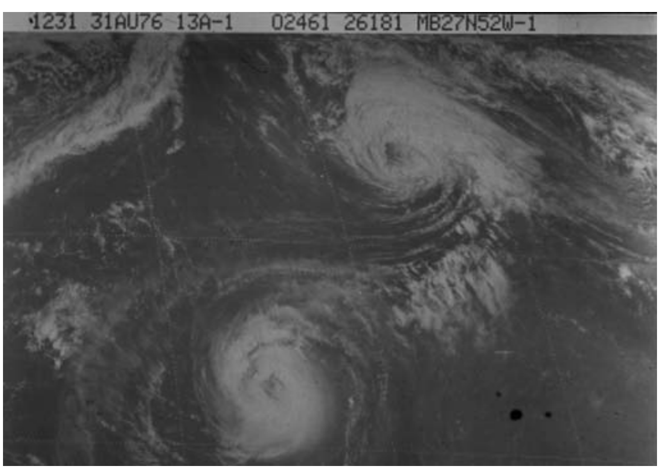

Figure 33.2. Fujiwhara effect: Hurricanes Emmy and Frances, August 31, 1976. *Image ID:* wea00489, NOAA's National Weather Service (NWS) Collection. *Source:* NOAA Photo Library. See color plate.

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Consequences for Public Health

Recent large cyclonic storms such as Hurricanes Katrina and Rita in the U.S. and Typhoon Nari that caused devastation in Taiwan reaffirmed the need to meet the complex challenge of public health planning, especially for those with special needs. Burkle and Rupp stated that disasters "keep governments and planners honest by defining public health and exposing its vulnerabilities."[8] Noji noted that a variety of public health emergencies share a common thread by "adversely impacting the public health system and its protective infrastructure (e.g., water, sanitation, shelter, food, and basic health)." Poverty and social inequality, environmental degradation from inappropriate land use, and rapid population growth all contribute to the public health effects of a tropical cyclone's landfall.[9] Following a disaster, levels of resilience to both chronic stress and any subsequent catastrophic shock are typically lowered for individuals and groups. An increased risk of susceptibility exists to diseases, both physical and mental. Depending on its magnitude, the greatest potential for loss of life does not come from the actual event, but instead comes from everyday health risks such as reduced access to potable water, break down of sanitation systems, lack of medical care for chronic medical and psychiatric conditions, and exposure to entomological vectors. These conditions create

Table 33.4: Impact of Cyclones and Storm Surges on the Community

Categories of Impact	*Components Involved*	*Indicators of Impact*
Physical	Inadequate physical protection; poor-quality housing and infrastructure; disruptions of communication, roads, utilities, public works infrastructure	Trauma-related death tolls; damage/loss physical properties such as infrastructure, homes, industry, animal, and crops; disruption of normal life, migration to safe places, lack of electricity, potable water, food sources, waste build-up
Economic	Loss of livelihood and income opportunities; loss of assets and savings; need for recurrent aid, lower socioeconomic stratification	Low income, poverty, unemployment, landlessness, unequal land distribution, lack of relief and rehabilitation, and forced movement of lower-income populations
Agricultural	Land degradation; intrusion of salt water for irrigation increasing seasonal, unplanted fields	Low productivity, frequent crop loss, outbreak of migration among the owners of small farms and farm laborers; lack of money for purchasing seed
Social	Disintegration of social organization, increased incidence of female-headed households and resource-poor communities; poor education services	Social/ethnic crisis; social marginalization, violence and crime; apathetic attitude; identity crisis; plight of people for safety and survival
Environmental	Land and environmental degradation; deforestation, loss of biodiversity and marine resources, increase in salinity, intrusion of salt water, lowering of water table, dams	Deforestation; loss of soil fertility; limiting of biodiversity; increase refugees, migrants, and homelessness; rising disaster-related deaths
Public Health	Disruptions of healthcare and utility services, inadequate sanitation, lack of qualified physician and clinical services	Increase mortality and morbidity; poor health and malnutrition; disease epidemics; exacerbation of chronic diseases, increased PTSD

long-term effects, depending on the socioeconomic stratification of the area involved, with lower baseline status most often associated with poor outcomes.[9–11]

The public is generally aware that tropical cyclones are capable of causing devastating damage, severely crippling if not destroying society and its infrastructure. Yet, it is expected by the effected community that established public health and healthcare systems will continue to provide services not only in the days leading up to the storm but during and after the event as well.[12] Because of these demands, it is imperative that the medical and public heath care community be prepared to not only manage injuries created by the storm, but also to provide continued care for patients with chronic medical conditions and those with special medical needs (see Chapter 8). Typically, these include victims with hypertension, diabetes, renal failure needing dialysis, mental illness, and physical disabilities. This is in addition to ensuring safe public drinking water; appropriate sewage disposal; control of disease vectors such as mosquitoes and rats; food distribution; and protection of food supplies from contamination (Table 33.4).

Evacuations

Ideally, no one would be physically present to suffer death or injury during the landfall of a devastating tropical cyclone. In fact, due to their well-defined paths of travel and the use of modern meteorological tracking systems, 70% of hurricanes will be forecasted 24 hours in advance of their approach to land based on their speed and direction during the previous 24–36 hours.[13] Computer-based models, such as those that use the Sea, Lake and Overland Surges from Hurricanes (SLOSH) software, can assist emergency planners in predicting storm surge heights. Based on these predictions, people in vulnerable areas are often asked to evacuate voluntarily while local officials assist by changing traffic flow patterns. Often, the contra flow technique is used, in which both lanes of a roadway are used for outgoing traffic. Researchers have observed that, depending on local and personal experiences, citizens will engage in two opposing types of behavior prior to an evacuation order. They will either spontaneously self-evacuate or, despite storm warnings and subsequent evacuation orders, refuse to comply and remain in their homes sheltered in the same way they have done in previous years during storms.[14]

Evacuation is a very complex undertaking requiring the coordination of a multitude of factors, not the least of which is maintaining basic public health services for evacuees. In addition to the logistics, cost is an issue. This includes not only the expenses related to the evacuation itself, but also of lost revenue to displaced individuals and to local industry. Therefore, the decision to evacuate an area has significant ramifications.

Hospitals also face the threat of hurricane-induced evacuations. From the years 1971–1999 in the U.S., hurricanes prompted over 38 hospital evacuations.[15] Mathematical modeling of hospital evacuations predicts that, depending on resources available, it could take between 30 and 60 hours to evacuate 50 patients.[16] Evidence from hospital evacuations after Hurricane Rita suggests the actual time frame may be somewhat shorter, with seven hospitals evacuating in an average of 29 hours.[17]

Many countries other than the U.S. do not undergo mass evacuations in the face of a storm. For example, in Taiwan, a community that is frequently subjected to tropical cyclones, most of the buildings are wind resistant, and only people who live in flood plains, mudslide prone areas, or who are physically disabled or dependent are considered for evacuation.[18]

The decision to evacuate is based on available resources and an estimate of the resulting economic impact as well as the potential loss of life. Because storm landfall predictions can lead to expensive preparations and subsequent disruptive population movements, individuals involved in making such decisions must consider the potential negative impacts of an evacuation on commercial, healthcare, and other public health activities. Making

Table 33.5: Time Considerations for Phases of Population Evacuation

Evacuation Phase	*Time Needed*
Mobilizing community evacuation resources	Hours
Communicating appropriate protective action instructions to the public	Hours
Individual mobilization of resources to leave the area at risk	Hours to days
Completing the physical evacuation of people occupying the affected area	Days

the decision to evacuate is a challenge for administrators and community leaders and involves determining who should be evacuated, when the evacuation should start, and the logistics for the evacuation, that is, mass transportation, traffic patterns, and provision of control/security. There are four major event scenarios for which evacuation decisions may affect credibility of the policy makers and economic losses.[19]

- Evacuation with direct damage to the area or structure evacuated: no lives lost due to the damage nor credibility lost but large economic costs through loss of revenue and expenses incurred
- Evacuation with *no* damage to the area: no lives lost due to the storm but a loss of credibility with large economic costs through loss of revenue and expenses incurred
- No evacuation with damage to structures and the area: even if no lives lost due to the damage there is a loss of credibility and a large economic cost due to repair and loss of revenue
- No evacuation with no damage to the area in the absence of a direct impact: no lives lost, no credibility lost, and no economic effects

The time required to accomplish an evacuation once the physical movement of people is underway depends on the characteristics of the area and on the availability of public transportation and large highways. Research indicates that, once a decision to evacuate is made, up to 2 hours may elapse before most people in the affected area hear, absorb, and decide to respond to the instructions (Table 33.5).[20] It is intuitive to think that a larger population warrants a longer evacuation time, but warning and evacuation times do not necessarily increase with population size and density. This is true, in part, because the infrastructure capacity (e.g., street system, public transportation resources) necessary for moving people out of the area is generally more extensive in regions with greater population.[21] In areas where there is public reluctance to evacuate or the evacuation routes are limited, repeated warnings may be necessary. Characteristics of a good evacuation plan include

- Identification of available resources such as community faith-based organizations and voluntary medical and fire assets
- Knowledge of vulnerable populations, which would include those who are elderly, ventilator dependent, and have language barriers
- Awareness of hazardous sites in the area: flood zones, refineries, and hazardous material sites
- Knowledge about main transportation assets: highways, trains, buses, and airports
- Shelter locations and staging areas for evacuation

Mortality

In violent tropical cyclones, almost all primary weather-related deaths are attributed to the storm surge. Examples include the cyclones that impacted Bangladesh in 1970 and 1991, the Indian coastal states of Andhra Pradesh in 1977 and Orissa in 1999, the Indian state of Gujarat along its coast facing the Arabian Sea in 1998, and the state of Mississippi in 2005 (Hurricane Katrina). Other immediate deaths result from tornadoes, flying debris, and collapsing structures.[14,22–23] In Taiwan and many other Asian/Pacific basin countries, mortality numbers due to storm surge and mudslides remain quite high despite warnings. This has been attributed to deforestation, which allows for mudslides and debris to flow through farming communities during the torrential rainstorms that accompany tropical cyclones (Figure 33.3). Many countries prone to damage from storm surge have installed early warning systems, which if used in conjunction with timely evacuations and storm-resistant sheltering, can achieve a decrease in mortality rates. Prediction and warning systems have been credited with protecting lives in the Mississippi counties of Mobile and Baldwin. Here, computer models predicted a large storm surge 2 days in advance of the hurricane's arrival, allowing for evacuation and adequate preparation.[24] In the countries of Bangladesh and Cuba, storm-related mortality rates are lower despite the lack of sophisticated electronic warning systems. This is due to the use of trained volunteers who implement a well-known and easily recognizable flag and siren signal system. Conversely, simply having the technology will not guarantee a decrease in mortality. This was seen in Haiti during tropical storm Jeanne in 2004. The area had a good electronic warning system, but due to a coup earlier that year, there were no emergency managers available to utilize the system and more than 1,000 people died.[25]

Morbidity

During a tropical cyclone disaster, there are phase-specific morbidity patterns. Understanding these patterns may help with medical and emergency planning. In the pre-landfall phase, injuries result from storm preparation and evacuation activities. Typical problems include car crashes and falls from ladders. When the tropical cyclone makes landfall, injuries occur from nonreinforced structural collapses, wind-borne debris, falling trees, drowning, and downed power lines. In the immediate postimpact phase, traumatic injuries result from electrocution by downed power lines, falling objects and trees, and severe lacerations from chain saws as people clear debris from houses and roadways. As a result of power outages, burn injuries and carbon monoxide poisoning may occur from cooking, lighting equipment, or improperly ventilated gas-powered generators.[22] It is during the postimpact phase that a surge occurs in the demand for healthcare by patients with chronic medical conditions. Interventions such as dialysis and refills of medications for hypertension, diabetes, psychiatric illnesses, and chronic pain are required. During the recovery phase of the disaster, acute care

Figure 33.3. Area of mudslide resulting from deforestation. Personal photo, Hawaii, 2007. See color plate.

needs transition to chronic care. Within weeks, the increased need for generalists, pediatricians, obstetricians, nephrologists, psychiatrists, and cancer specialists replaces the need for surgeons and emergency medicine providers.

The provision of mental health services for victims and rescuers is an important component of any disaster recovery process (see Chapter 7). Therefore, the recovery plan should include provisions for the involvement of psychiatrists and mental health workers. Patients will require continued treatment of their addictions, depression, and schizophrenia. In addition, services are needed for victims suffering from acute stress syndromes and posttraumatic stress disorder (PTSD).[26]

Many people initially experience fear and distress at the time of a tropical cyclone's impact, but the majority of them quickly return to normal. Some people may experience persistent distress that affects functional capability, and a subset of these people will progress to PTSD. In the U.S., surveillance systems detected increases in rates of psychological disorders after hurricanes. Disorders occurring after the storms that victims had never previously experienced included PTSD, major depression, and anxiety. Risk factors attributable to adverse mental health outcomes included: 1) the severity of an individual's exposure to a family member's injury or death; 2) experiencing extensive property loss or displacement; 3) belonging to a vulnerable group such as women, children, the elderly, and the poor; and 4) existing psychopathology. Social support, self-efficacy, and positive coping strategies can ease the severity of mental health consequences. Early intervention allows mental health professionals to triage people with an increased risk for more severe mental illness.[27]

Infectious and Environmental Diseases

The likelihood of infectious outbreaks in a community following a tropical cyclone *may* increase for a multitude of causes: disruption of public health services and healthcare infrastructure, damage to water and sanitation networks, population displacement, and crowded conditions in temporary shelters. Fecal–oral routes of infection are often the cause and result in outbreaks of diseases such as cholera, hepatitis, shigella, and other diarrheal illnesses. In crowded shelters, outbreaks of measles and meningitis have been reported, but not in epidemic proportions.

In regions of the globe where infectious disease vectors such as mosquitoes or fleas exist, outbreaks of diseases such as typhoid fever, encephalitis, or plague may occur under certain conditions and when these vectors are already present in the ecosystem. For example, following flood inundations in tropical areas, ecological conditions are frequently optimal for mosquito reproduction. In 1963, following Hurricane Flora, 75,000 cases of *Plasmodium falciparum*, a potentially deadly form of malaria, were recorded in Haiti. This is much higher than the number of infections normally observed.[28] Despite a popular disaster myth, if a disease pathogen is not normally present in the affected area, then that particular disease cannot occur in that region despite ideal environmental conditions.[29]

Special Needs Populations

Philosophers have said that a true measure of a society's greatness is how it protects those least able to care for themselves. Large cyclonic storms in modern times, such as Hurricanes Katrina and Rita in the U.S. and Typhoon Nari in western Pacific, underscore the necessity to meet the complex challenges of public health and disaster planning for those individuals with special needs by making sure that emergency management plans address this population (see Chapter 8). Studies in the U.S. indicate that up to 19% of the general population is disabled. Often, people with special needs have difficulty receiving and understanding public emergency broadcasts (for example, due to language barriers or physical limitations). They also have difficulty taking protective actions such as moving to a "special needs" shelter or complying with evacuation orders. In addition to persons with physical disabilities, other individuals that belong to the special needs population would include

- People without access to transportation or who lack financial resources

- People who do not speak English or communicate differently (the hearing impaired)
- Migrant workers, homeless persons, visitors, and tourists
- People who are in confined facilities (e.g., schools, hospitals, nursing homes, and prisons)
- Children

The special needs population is an important but challenging one to include in the disaster planning process. It is clear they will require much in the way of resources during a tropical cyclone disaster. It is essential that emergency managers anticipate the needs of this population and create appropriate plans. These written plans should be practiced and revised through exercises and drills to ensure assistance will be available to the special needs population.

Hospital Mitigation, Preparedness, Response, and Recovery

Preimpact Phase

Pre-event planning for a devastating tropical cyclone is essential for continued hospital operations during and after the disaster, and it starts years before it is needed. As previously stated, the public expects that hospitals and the healthcare system will continue treating current patients and also providing care to those seeking emergency medical attention regardless of what disaster has just occurred.[12] This means that hospitals, clinics, and medical personnel must be prepared and have planned in advance to deal with the large number of issues associated with a tropical cyclone: loss of electricity, failure to deliver fuel or food, emergency generator failure, tainted municipal drinking water supplies, hospital flooding, and personnel shortages. In addition, planning should include how to feed the hospital's patients, their families, staff, and the staff's families.[30]

Prior to the topical cyclone season, it is imperative that emergency management programs are created to address the needs of the hospital and the community it serves. After plans to support these comprehensive programs have been developed, they must be practiced and modified before the need to use them arises. They should incorporate a list of volunteers that includes medical personnel, environmental workers, and social workers along with their current contact information. Plans should also include an up-to-date list of hospital assets such as ventilators and autoclaves and possible hospital hazards such as liquid oxygen tanks. Additional plan components should address 1) morgue capabilities and contingency plans for managing the deceased when the morgue is full or power to cool the area is lost, 2) provision of staff emergency information kits, and 3) memoranda of understanding (MOU) with other hospitals, vendors, and emergency medical services for services. In addition, plans should include what pharmaceuticals, if any, to give patients when they are discharged. Issues include whether the hospital gives a week's supply of essential medications or just discharges patients with a prescription and a list of possibly open pharmacies (Table 33.6).

An often-overlooked point in hospital disaster planning is addressing the needs of vulnerable community members such as the elderly, the infirmed, and those who are ventilator or oxygen dependent. These individuals will frequently use the hospital for shelter and basic care when surrounding infrastructure fails and floodwaters rise. In this situation, social workers are incredibly important. They can compile a list of 24-hour pharmacies, oxygen companies that will deliver canisters, and shelters the can accept patients when they are discharged postevent. Social workers often have this information readily available as they manage these issues on a daily basis.

Impact Phase and Immediately Thereafter

Typically, hospitals experience a lull in emergency department visits around the time the tropical cyclone makes landfall and in the storm's immediate aftermath. Once this respite is over, there is generally a rapid increase in visits to the hospital, mostly for emergency trauma care. In planning for this phase of the disaster, managers should be aware that most patients will not require advanced life support. In fact, medical data from three tropical cyclones affecting Taiwan indicate that only one fifth of the patients needed an ambulance for transportation to the hospital and that 90% of the patients seen for emergency care did not require hospitalization. The most common injuries recorded were soft tissue injures followed by head injuries and orthopedic problems such as sprains and fractures.[18]

From a staffing perspective, the hospital will need environmental crews to assist with cleanup and engineers to assess buildings for signs of damage. Other staff required to support medical care needs include nurses to staff floor beds; operating room staff to care for trauma victims as well as nondisaster related surgical cases such as appendicitis; intensive care unit personnel; and extra emergency department staff to assist with storm-related injuries.

Postimpact Phase

This phase can last days to years depending on the magnitude of the tropical cyclone and the devastation that it has brought to the area. Hospital effects can vary from minor flooding damage to permanent closure, as was seen in New Orleans after Hurricane Katrina. The functional status of hospitals will influence what actions are necessary to return a community to baseline health and medical status. In many countries, disaster response teams exist that respond quickly and offer assistance provided by medical professionals including surgeons, pediatricians, midwives, and emergency medicine providers. The assignment of such teams to the disaster area is temporary, deployments lasting a few weeks but generally not for months.

If there is widespread devastation, establishing alternate care sites may be an option. This would help hospitals manage the initial onslaught of victims requesting emergency medical care and allow institutions to more effectively distribute the patient load. "Surge" facilities, staffed by community providers or government assets delivering healthcare to patients with nonacute to moderately acute medical needs, should be available for at least a week after the cyclone makes landfall.[31] Conversely, if the hospital has sustained only minor damage, then the need for a surge facility would be reduced. Planning for this phase is challenging because it is difficult to anticipate how events will unfold after each tropical cyclone. An example is the impact of Hurricane Katrina on the city of New Orleans. There would not have been the devastation that occurred if the levees had not broken and flooded parts of the city.

In this recovery phase, hospitals must be ready to support the community. If there has been a drop in municipal water pressure, water sources must be tested before hospital administrators permit use for drinking and equipment sterilization.[30] In the weeks following a devastating tropical cyclone, trauma

Table 33.6: Personal and Hospital Needs

Personal	Hospital Considerations	
A week's supply of prescription medication	Infrastructure	Generators that are biannually tested
An extra pair of glasses or contact lenses plus lens solution		Generators in a location that will not flood
A week's supply of potable water (2.5–3 L/d - climate dependent)		Fuel tanks for generators in a location that will not flood and taint the fuel
Full tank of fuel for generators and vehicles		Fuel tanks located for easy access to refueling
Clothing appropriate to weather conditions		Fuel tanks filled pre-event
Flashlight		Potable water stored
Family evacuation plan with understood rendezvous points		Morgue on the generator circuit
		MOU with fuel vendors to ensure resupply
		MOU with emergency generator companies to provide support in case of generator failure
		Sandbags and lumber for windows and doors
		MOU for liquid oxygen supplier
	Operations	Plan for emergency staffing and postevent cleanup staff
		List of essential jobs to include housekeeping, nursing, social work, laboratory technicians, respiratory therapy, cafeteria support staff, and cooks
		Accurate contact list for all personnel
		MOU with food vendors
		MOU with other hospitals in case of evacuation
		MOU with transportation vendors
		MOU with ventilator companies
		Downtime areas for staff and their families
		Pharmacy supplies for staff and families
		Pharmacy: essential medications for discharged patients
		Evacuation plans
		Operating room supplies, e.g., autoclaves, sterile instruments
		Intensive care operations supplies

and acute care needs gradually evolve to chronic illnesses and psychological needs. Patients with renal failure will need routine dialysis, patients with cancer will require continued chemotherapy or radiation treatments, people will exhaust their supplies of medications and need refills, patients with chronic conditions will suffer acute manifestations, and victims with depression and other debilitating psychological illnesses will present to hospitals requesting assistance. Staffing will be stretched thin and many people might not return to work as their personal life issues will take precedent. Others might move out of the area entirely and seek new employment elsewhere. Within a few weeks to months after the event, the emergency assistance personnel originally dispatched to the disaster zone from outside the area will return to their communities. Those living in the devastated areas must begin rebuilding their community. There are no easy answers or simple templates to support this reconstruction effort. Hard work and communication within the community and with the local and regional governments will facilitate movement towards the goal of return to normalcy.

Pharmaceutical Needs

Part of disaster planning is deciding which medical supplies should be stockpiled for a tropical cyclone and its aftermath. Many of the lists and recommendations available are based on hearsay and personal experiences. There is a paucity of evidence-based literature available for use by hospitals, clinics or disaster medical teams. Published studies that examined the needs of patients following multiple hurricanes found that wounds, musculoskeletal pain, medication refills, upper respiratory infections, rashes, and abdominal complaints were the most common conditions in people seeking emergency medical care.[32] Analysis of Hurricane Andrew medical treatment data gathered by the U.S. Centers for Disease Control and Prevention demonstrated that 16% of households were unable to obtain prescription drugs for chronic and acute conditions between 3 and 10 days after the hurricane hit Florida and Louisiana.[33]

Based on this observational literature, there seems to be a need for the following medications in the immediate aftermath of a cyclone: tetanus toxoid, oral and parental antibiotics, hypoglycemics, cardiac medications, respiratory agents, antiepileptics, analgesics, gastrointestinal drugs, and psychotropics.[34] Medications needed after an event can be modeled after an average community hospital's normal emergency department pharmacy usage because chronic diseases will still require treatment.[35] From this information, medications could be stockpiled for both emergency treatment and for medication refills until normal pharmacy services are restored or outside assistance is available.

For catastrophic disasters, which result in a total collapse of a region's medical infrastructure, the World Health Organization, the High Commissioner for Refugees, UNICEF (United Nations Children's Fund, formerly United Nations International Children's Emergency Fund), the United Nations Population Fund, Médecins Sans Frontières, the International Committee of the Red Cross, and the International Federation of Red Cross and Red Crescent Societies designed the New Emergency Health Kit. It was created to meet the primary health needs of a displaced population of 100,000 people for three months. The kit includes medicines, disposable items, sterilizable instruments, and basic sterilization equipment. The primary unit is intended for use by basic health workers; the supplementary unit is designed for physicians and advanced practitioners and is used to augment the Basic Unit if there are advanced providers available.[36]

RECOMMENDATIONS FOR FURTHER RESEARCH

Tropical cyclones will have a disproportionally greater impact on areas that are socioeconomically depressed; the worse the poverty, the more devastating will be the disruption to infrastructure, public health, and medical care in that region. In developing countries or poverty stricken areas of wealthy nations, tropical cyclone mortality continues to be significant, with the majority of deaths occurring from storm surge. In situations where the local and regional infrastructure has been severely damaged, morbidity is more evenly distributed throughout the population, causing devastating and long-term consequences to the affected region. Governments and nongovernmental agencies throughout the world have been working diligently to improve mitigation and preparedness efforts in areas prone to these devastating storms. These regions seem to be increasing in numbers and they are experiencing increasingly severe storms. There have been successes in decreasing mortality in many developing and wealthy nations by using early warning systems, improving building codes so structures are better able to withstand tropical cyclone winds, creating storm-safe shelters, and implementing early evacuation in areas at risk from flooding, landslides, and deadly storm surges. These projects work well as long as the government remains stable and provides philosophic and economic support to these mitigation projects.

Further studies are needed regarding hospital design and construction techniques to minimize flooding of critical areas and generator failures like those seen in the Houston floods in 2001 following tropical storm Allison. Hospitals must examine where critical patient care areas are located within their facilities, develop designs that permit expeditious and safe evacuations, and eliminate elements that could make evacuation difficult should it become necessary. Additionally, better studies are needed to create appropriate recommendations for healthcare response teams. Multidisciplinary study groups should investigate alternative methods of population evacuation such as the use of boats, buses and trains where feasible.

The process of mitigation, preparation, response, and recovery from the effects of a tropical cyclone is a very complex and expensive process for public health and hospitals. These entities are expected to remain open and functioning regardless of the disaster's intensity. Plans should address infrastructure, staffing, psychological, and community needs. Further research is needed in these areas to ensure these entities remain functional and can provide appropriate services after a cyclone.

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34

Tornadoes

Arthur G. Wallace Jr.

OVERVIEW

Tornadoes occur worldwide, with the greatest incidence in North America.[1] Australia ranks second in incidence to the United States while countries such as Italy, New Zealand, and the United Kingdom rival this incidence if it is expressed as tornadoes per area rather than in absolute numbers. Tornadoes sometimes occur with very little or no advanced warning, causing considerable structural damage, traumatic injury, and death. Although meteorologists are capable of advanced forecasting of weather conditions that favor tornado development, the exact touchdown location and ground track of a tornado is not yet predictable. Even with advanced warning, there are still the challenges of notifying the population at risk and communicating the correct response to minimize injury or death.

Historical data reveal similar patterns of injury and death in all tornado disasters.[1] Community healthcare systems face significant challenges in attempting to manage the influx of tornado casualties. The sudden surge in patient volume, added to the routine daily challenge of providing medical care in hospitals functioning near 100% capacity, can overwhelm an already stressed healthcare system.

The track of destruction and injury produced by tornadoes is relatively small in proportion to the exposed population. The occurrence of a "worse-case scenario," the impact of a large tornado on a densely populated event located at a fairgrounds or sports arena, could produce significant casualty numbers. Fort Worth, Texas had such a near miss when a sudden massive hailstorm caught 10,000 spectators in an open area.[2] A sudden onset storm with little advance warning over a populated location could create a mass casualty event that exceeds the capabilities of any medical response system. This chapter will review risk factors for injury and death, injury patterns, and mass casualty scenarios by using modeling and real event reports.

STATE OF THE ART

Terms

Understanding that many terms necessary for discussing tornadoes are somewhat technical and not universally understood, it is prudent to define and explain some of these expressions so their meaning is clear. In addition, as current weather broadcasts and warnings are becoming widely available via television and wireless services, there are certain terms that should be familiar to emergency system managers, planners, and responders.

Super cell – A thunderstorm with a persistent rotating updraft. Super cells are rare, but are responsible for a remarkably high percentage of severe weather events – especially tornadoes, extremely large hail, and damaging straight-line winds.[3]

Mesocyclone – A storm-scale region of rotation, typically approximately 2–6 miles (3.3–10 km) in diameter and often found in the right rear flank of a super cell.[3]

Hook (or Hook Echo) – A radar reflective pattern characterized by a hook-shaped extension of a thunderstorm echo, usually in the right-rear part of the storm (relative to its direction of motion). A hook often is associated with a mesocyclone and indicates favorable conditions for tornado development.[3]

Fujita Scale

Dr. T. Theodore Fujita developed a tornado rating scale that has been in use for the past 30 years (Table 34.1).[4] Essentially, the scale rates tornadoes on wind speed and the most intense damage created in the path of the storm based on direct observation. By Dr. Fujita's own admission, this scale is somewhat arbitrary and subject to observational bias. Furthermore, no objective measurements exist comparing wind speed and damage relationships.[5] Beginning in February 2007, the United States began using the enhanced Fujita scale (EF Scale) to rate tornadoes (Table 34.2).[6] This new scale takes into account 28 different indicators evaluating the impact of a storm on buildings constructed of gradually stronger material and applies weighted values to the degree of structural damage. This method of rating a tornado is performed after the storm has passed and represents a set of wind estimates (not measurements) based on an assessment of structural damage. Although it is not a contemporaneous reading, the estimated wind speed is used in analysis of the predicted morbidity and mortality as they relate to storm strength. A significant tornado is considered one rated at F2 or greater.[7] Some researchers use the F2 rating and aforementioned criteria as indicators for

Table 34.1: Fujita Tornado Damage Scale*

Scale	*Wind Estimate (mph)*	*Typical Damage*
F0	<73	**Light damage.** Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; signboards damaged.
F1	73–112	**Moderate damage.** Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113–157	**Considerable damage.** Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158–206	**Severe damage.** Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207–260	**Devastating damage.** Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261–318	**Incredible damage.** Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (109 yards); trees debarked; incredible phenomena will occur.

* Developed in 1971 by T. Theodore Fujita.[4]

Table 34.2: Enhanced Fujita Scale 2006[6]

Damage f scale	Little Damage	Minor Damage	Roof Gone	Walls Collapse	Blown Down	Blown Away
	f0	**f1**	**f2**	**f3**	**f4**	**f5**

17 m/s 32 50 70 92 116 142

Windspeed F scale | **F0** | **F1** | **F2** | **F3** | **F4** | **F5** |

40 mph 73 113 158 207 261 319

To convert f scale into F scale, add the appropriate number

Weak Outbuilding	**–3**	**f3**	**f4**	**f5**	**f5**	**f5**	**f5**
Strong Outbuilding	**–2**	**f2**	**f3**	**f4**	**f5**	**f5**	**f5**
Weak Framehouse	**–1**	**f1**	**f2**	**f3**	**f4**	**f5**	**f5**
Strong Framehouse	**0**	**F0**	**F1**	**F2**	**F3**	**F4**	**F5**
Brick Structure	**+1**	**–**	**f0**	**f1**	**f2**	**f3**	**f4**
Concrete Building	**+2**	**–**	**–**	**f0**	**f1**	**f2**	**f3**

The Fujita tornado scale (F scale) pegged to damage-causing windspeeds. The extent of damage expressed by the damage scale (f scale) varies with both windspeed and the strength of structures.

Figure 34.1. Funnel cloud in Ardmore, Oklahoma, 1985.[9] See color plate.

examining mortality data.[5] Tom Grazulis, an accomplished meteorologist and tornado researcher, considers any tornado that results in death as a significant tornado.[8] If future development of tornado analysis could generate a product that described tornado strength over a storm track in real time, it would be a significant response-planning asset for emergency planners.

Tornado Epidemiology

Tornadoes are generated when warm moist air from the Gulf of Mexico, moving as a warm front, collides with a cold front traveling down from the Northwest. This creates an unstable environment where moist warm air rises rapidly through colder dry air. As the warm air rises with increasing intensity, thunderstorms are formed. The increase in energy potential within these storms sometimes results in the development of super cells. As super cells continue to grow, a rotation of wind begins within the storm, creating a mesocyclone. As the mesocyclone spins, clouds descend toward the earth forming a funnel-shaped structure with a visible rotation (Figure 34.1).[9] The rotating funnel cloud is officially called a tornado when it makes contact with the ground (Figure 34.2).[10]

The United States has an average of 1,000 tornadoes each year. Ten percent of these tornadoes are rated at F2 or greater. Violent tornadoes, rated F4 or F5, only occur 2% of the time but account for 67% of tornado-associated deaths.[5]

The annual occurrence of tornadoes appears to be increasing (Figure 34.3).[11] The increasing incidence of tornadoes may simply reflect advances in detection rather than a true increase in events. In addition, more frequent observation of storms that have gone unreported in the earlier years might explain this change. Perhaps more important than the number of storms is where they occur. Population density in relation to storm occurrence may be more predictive of potential disaster-creating events.[12] With a population shift toward the southeast coastline and a subsequent population reduction in parts of the Great Plains, there may be a shifting of tornado hazard areas.[12] A geographical area known as "Tornado Alley" that is infamous for 25% of significant tornadoes had only 9% of major killer storms from 1980–2000.[5]

Significant tornadoes, when rated by storm strength, occur most frequently in high-prevalence areas; however, when tornado significance is rated by associated deaths, both killer tornadoes (one to seven fatalities) and major killer tornadoes (eight or more fatalities) have consistently occurred more frequently outside of the high-prevalence "Tornado Alley" area over the 54 years between 1950 and 2004 (Figure 34.4).[13] In Figure 34.4, note that the "Tornado Alley" area lies just to the left of the significant tornado regions. Reviewing National Climate Data Center records for injury and death related to F2 or higher tornadoes from 2001 through September 2006 revealed only 32% of reported injuries and 35% of deaths were in high-occurrence areas (Figure 34.5).[14,15] Possible explanations include increased population awareness and response to tornado warnings in high-occurrence areas compared with less awareness and less protective response behavior in low-occurrence locations.[5] Along with a direct storm strike in a high-population area, another potential catastrophic event would be multiple storms similar to the "Super Outbreak" event in 1974. Over a 2-day period, 148 tornadoes affected 13 states causing 330 deaths and 5,484 injuries (Figure 34.6).[7]

Risk of Injury and Death

Although a tornado is inherently dangerous, it only becomes a serious risk if it threatens a populated area with damage and injury. The vulnerability of the affected population defines the risk of the storm. Many variables characterize a given population's vulnerability. Advanced warning and the subsequent protective actions taken by individuals affect health outcomes during the preimpact and impact phase of the storm. Tornado warnings issued by the National Weather Service provide, on average, 11 minutes advanced notice. This would require an action plan to seek appropriate shelter immediately.

Risk of injury or death has been associated with storm strength, victim age, type of material used for dwelling construction, shelter location, income level, and time of day.[16] Elderly persons may have reduced physical response capability, impaired sensory function, or reduced access to appropriate shelter. Prefabricated and frame houses may not provide protection, evidenced by the fact that a significant number of deaths and injuries occur in individuals sheltering within these structures. Seeking shelter in a basement has been associated with injury and death if the house is shifted off the foundation or the basement walls collapse on victims.[17–20] Storms after dark may not be visible or may occur when victims are asleep and unaware or unable to hear a warning siren. People with lower incomes may reside in dwellings that cannot withstand high wind stress or in areas of a community without public warning sirens. Locations at

Figure 34.2. Tornado in Mayfield, Oklahoma, 1977.[10] See color plate.

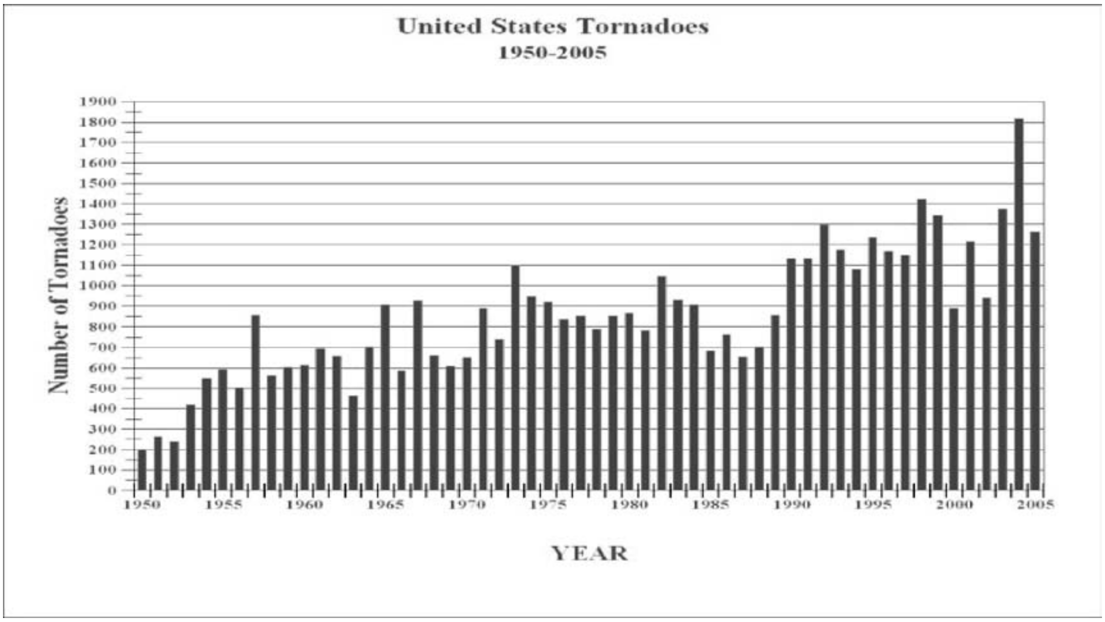

Figure 34.3. Incidence of tornadoes in the U.S.[11]

significant risk included schools, churches, and restaurants where multiple potential victims are present at the time of a direct tornado strike.

Most tornado deaths occur at the time of impact. The most common mechanisms of death result from rapid movement of victims through the air, accelerated by storm winds, who then strike a stationary object. The reverse is also true; wind-driven projectiles can strike people or collapsing structures can crush them.[21] Traumatic injuries to the head, thorax, and abdominal organs are the most common causes of immediate mortality in tornado victims.[21] According to National Climatic Data Center data from 2001–September 2006, overall mortality rates range from 5% to 10% of all those injured. Hospital mortality rates are significantly lower. The overall mortality trend from 1940 to 2005 is shown in Figure 34.7.[22]

At first glance, it appears one could make the assumption that the emergency medical system is performing adequately and no further critical review is necessary. The overall tornado mortality is decreasing and is accompanied by an even smaller hospital mortality rate. The low overall mortality rate may not, however, adequately reflect trauma system performance. This rate becomes deceptively diluted because it is analyzed as a percentage of total injuries, regardless of how minor the wounds are. By considering even minor wounds in the calculation, this inflates the size of the denominator and makes the mortality rate appear smaller. Perhaps a better marker is the critical mortality rate.[23] This has been explored in the trauma literature and examines mortality rates only in the victims with significant injuries, defined as an Injury Severity Score greater than 15. It does not include those with minor injuries. Using the critical mortality rate, a more accurate assessment of system performance is possible. One such measurement is time to surgical consultation, as a delay in surgical referral has been associated with preventable trauma deaths estimated to range from 2% to 50%.[25] Another situation that can generate an increased critical mortality rate is when a tornado strike produces large numbers of patients who seek medical treatment simultaneously. Other factors that can influence this rate are reviewed below.

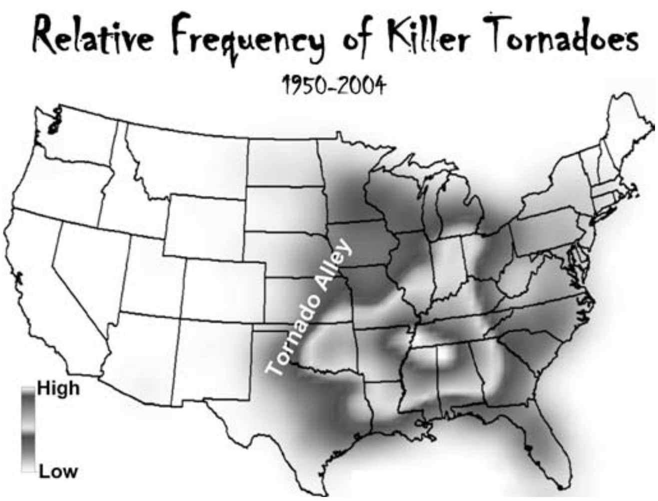

Figure 34.4. Relative frequency of killer tornado events around "Tornado Alley."[13]

Injury Patterns

Injury patterns can be categorized by the time at which they occur in relation to the storm. This approach may affect treatment strategies. Preimpact injuries can include traffic collisions as people flee ahead of the storm, and falls that occur while running down stairs into basements or storm shelters. Impact phase injuries result from victims being thrown against objects by strong storm winds or being struck by wind blown projectiles. The latter phenomenon can predispose to wound contamination by organisms that become airborne in high-wind events. Wound infection resulting in septicemia has been responsible for some hospital mortality.[26] Recommendations have been made that wounds occurring during this phase should be considered for delayed primary closure. For unclear reasons, this approach is often avoided in clinical practice.[21,27] Postimpact injuries include puncture wounds and lacerations associated with debris

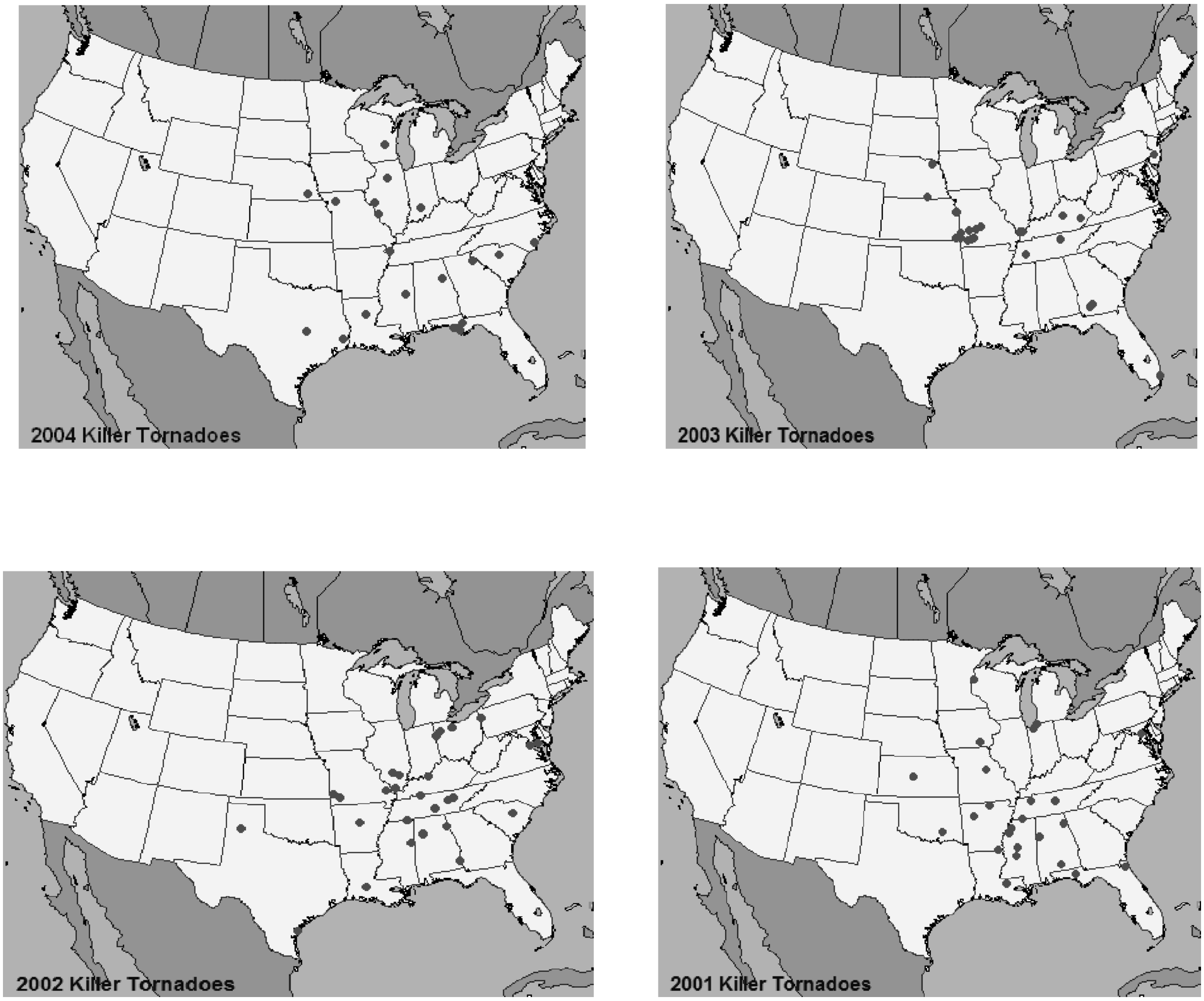

Figure 34.5. 2001–2004 Killer tornadoes.[15]

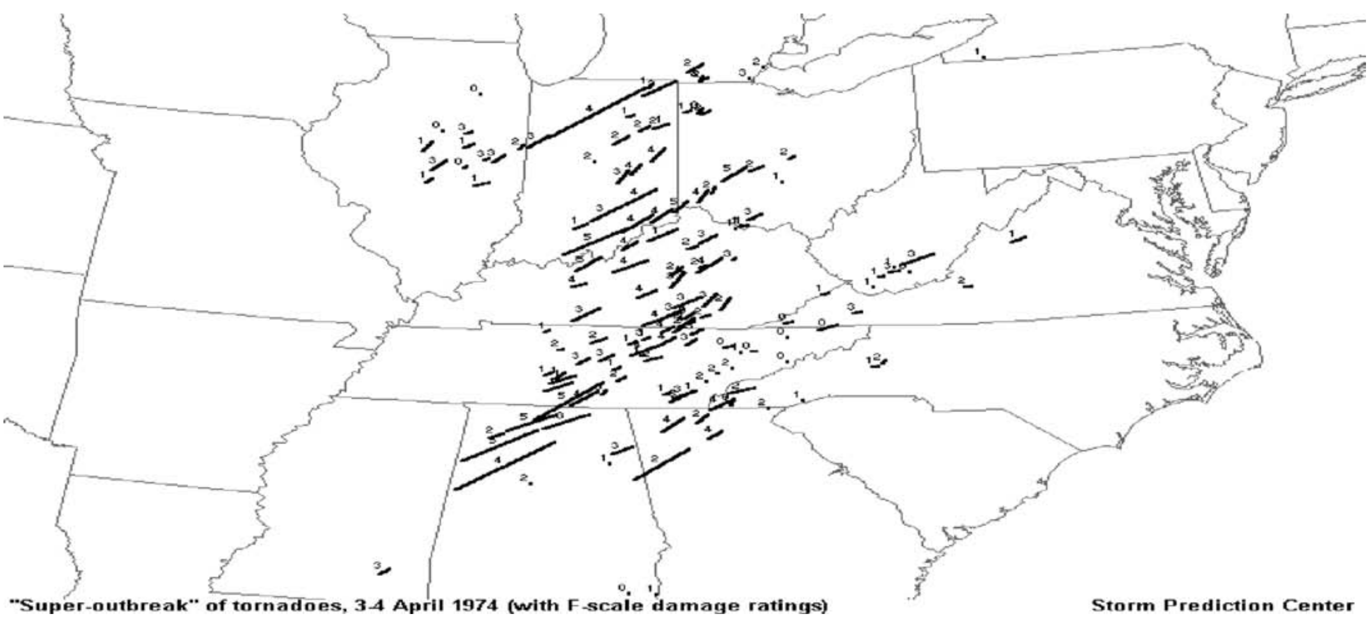

Figure 34.6. Super outbreak April 3–4, 1974.

Table 34.3: Mechanisms of Blast Injury*

Category	*Characteristics*	*Types of Injuries*
Secondary	Results from flying debris and bomb fragments	– Penetrating ballistic (fragmentation) or blunt injuries – Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind	– Fracture and traumatic amputation – Closed and open brain injury
Quaternary	– All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms – Includes exacerbation or complications of existing conditions	– Burns (flash, partial, and full thickness) – Crush injuries – Closed and open brain injuries – Asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes – Angina – Hyperglycemia, hypertension

Notes
1. The Primary Category is not included in the chart as it does not apply to tornadoes.
2. Any body part may be affected by the secondary, tertiary, or quaternary mechanisms.
COPD, chronic obstructive pulmonary disease.
* Department of Health and Human Services.[24]

removal and electrocution while individuals are working around downed power lines erroneously thought to be inactive.

Approximately 50% of injuries seen in hospital emergency care areas are soft tissue wounds and include lacerations, contusions, and punctures.[21] Fractures occur in 30% of victims and are the most common cause for hospital admission.[21] Head injuries including extra- and intracranial trauma, accounts for 7% of injuries.[21]

Injury patterns caused by tornadoes can be contrasted and compared to injuries from blasts or explosions. With the exception of primary blast injury, the other categories are similar in terms of mechanisms of injury and event-associated complications. Treatment options for blast injuries are discussed in more detail in Chapter 26. Table 34.3 outlines blast categories; tornado injuries are similar.[24] One difference between blast and tornado injury patterns may be the body part affected, because

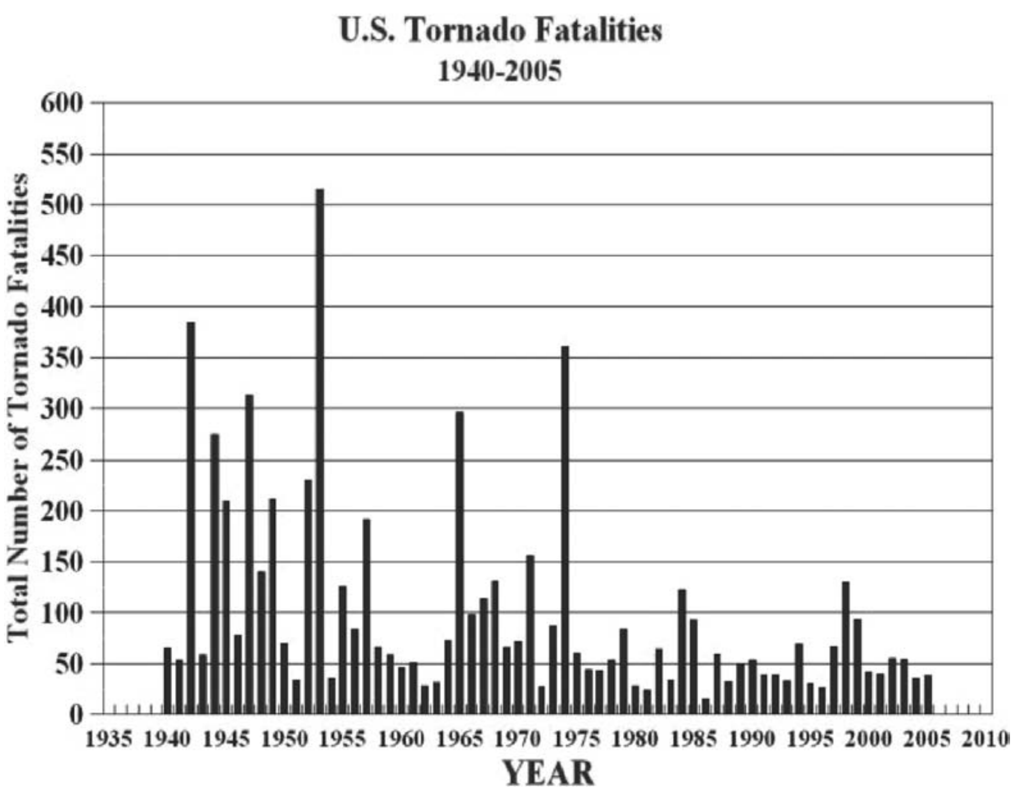

Figure 34.7. U.S. tornado fatality rates.[22]

blasts typically occur without warning, while tornado victims may become aware of the approaching threat at the last moment and take a protective posture that could influence the injury pattern.

Immediate Medical Considerations

Prehospital Impact

Tornadoes have both seasonal and geographical variability.[1] Awareness by the local population at high risk provides a starting point to begin understanding what vulnerabilities exist. Because tornadoes usually strike with little advanced warning; the medical system response will consist of whatever the local capabilities are at that time. State and federal assistance, if needed, may not be readily available in the early phase of the response. If the closest medical center is in a rural or suburban area, established transfer or referral arrangements with a trauma center should be in place for those victims requiring such services. If there are multiple medical facilities in the response area, a coordinating center should assist with victim distribution to avoid overloading any particular facility. This approach was effective in the April 8, 1998 F5 tornado response in the U.S. state of Alabama.[28] These coordinating centers take the form of medical emergency response centers in association with metropolitan medical response systems and become activated during events requiring a coordinated response.

A strategy to deal with the initial victim surge is the "First-Wave" protocol reviewed by Auf der Heide.[29] This is a casualty distribution plan in which hospitals are identified by capability to treat victims of a given severity category (immediate, delayed, minor) and includes how many patients in each category they can accommodate. Initial emergency medical services (EMS) transports could then attempt even distribution of the victims to appropriate medical centers, avoiding overloading one facility as much as possible. The impact of an incident management system on resource distribution and casualty convergence cannot be overemphasized. It is often not just a paucity of resources, but their maldistribution that adversely impacts the delivery of medical care. An effective incident management system can substantially improve utilization of existing resources.

Triage

Overtriage is assigning a patient or victim to a higher level of urgency than is actually necessary. Undertriage is underestimating the true nature of the victim's condition and assigning an inappropriately lower acuity status. Acceptable rates exist for over- and undertriage. Triage officers try to minimize underestimating a patient's medical condition, but they also realize that overtriage may create an additional burden to the system. During routine medical operations, overtriage happens daily and is usually acceptable because it is a temporary situation and has no negative impact on outcomes. Although unproven, in a disaster or mass casualty situation, overtriage could theoretically reduce ability to rapidly identify and prioritize victims that require immediate treatment. If the majority of victims are transported either to the closest facility or to a tertiary referral center, those centers will become overburdened to the point that system efficiency deteriorates. Arrival of victims from a mass casualty event usually occurs in a distinct pattern. The first wave is characterized by those that self-refer and transport themselves to a hospital, usually the closest one. As the first victims arrive, the triage team may begin assigning emergency beds, ordering radiographic and laboratory studies, and requesting consultations from specialty services. (This first wave references ambulatory victims, as opposed to the "First-Wave" protocol mentioned previously referring to EMS-transported victims.)

Table 34.4: Recommendations for Hospital Workers in Preparation for and Response to an Imminent Tornado Event

1. Protect yourself, staff, and current patients (inside hallways away from windows and glass)
2. Consider a safe alternative triage and treatment site
3. Assess trauma team availability, regional referral support, and local community support agencies
4. Appropriately scrutinize triage decisions on early ambulatory arrivals, anticipating that later arrivals by ambulance may be more critical
5. Inspect wounds for foreign bodies and contamination
6. Provide tetanus prophylaxis if indicated
7. Limit laboratory investigations to those critical to manage patients from the acute event

The second wave of patients usually arrives approximately an hour after the event begins. These victims are usually transported by EMS and may be the more seriously injured than the self-presenting patients that arrived earlier. It has been postulated that the consumption of medical resources by victims with less severe conditions that arrive in the first wave via self-transport may negatively impact the care of those more seriously ill that arrive later via the EMS system. In addition, it has been hypothesized that overtriage may have a direct linear relationship to critical mortality rate.[30] No studies published to date have proven either of these assertions. In fact, the data demonstrate, at best, an association of higher mortality with overtriage. Data also support the opposite interpretation that severe events with high mortality rates induce overtriage behavior in responders. An analysis of the London subway bombing in July 2005 reported significant overtriage but no increase in critical mortality.[31] Resolution of this controversy must await further studies.

The hospital's ability to increase its surge capacity to care for this patient population may be affected by the rate of victim entry into the trauma care area, rather than by the number of available beds or level of emergency department staffing.[23] Results of modeling using an actual event reenacted at a trauma facility examined casualty load and its impact on surge capacity. Using the optimal level of care, defined as the resources committed to a single trauma patient on a normal working day, alterations in care levels were noted to occur with increasing numbers of critical victims.[32]

Hospital Impact

In the situation in which a tornado strike at or near a hospital is imminent, personnel must respond quickly. Although no evidence-based recommendations exist, the actions listed in Table 34.4 are reasonable and prudent. These will help protect personnel and prepare the hospital for incoming casualties.

Admission rates of tornado victims are typically less than 25%.[21] Estimating the overall number of victims a facility can manage would depend on the resources available, knowing that serious injuries occur 10%–15% of the time.[23] For example, if three trauma teams were available, 30 victims could theoretically be processed without compromising the level of care for those needing urgent intervention.

Recommendations for Further Research

Special Medical Needs Populations

Tornado damage to a retirement center or nursing home may force evacuation of the residents. If arrangements for relocation are delayed, even without acute injuries from the tornado event, this population of individuals with special medical needs may be referred to the emergency response system and be transported to local medical facilities. In addition, special medical needs populations may not be permitted in general community shelters. Alternatives are needed to improve the management of these displaced individuals (see Chapter 8). Research is necessary to develop best practices that guide strategies for designation and management of off-site facilities that can rapidly be converted to temporary shelters for this group of victims.

Rapidly Establishing Alternate Care Sites

If a medical facility is threatened or damaged by a storm, a number of issues arise. Top concerns include protection of inpatients should the decision be made to shelter in place, evacuation of patients to another facility, and establishing an alternate care site for victim reception. Furthermore, if a densely populated area is struck by a significant tornado generating an exceedingly high number of injured victims, local healthcare facilities could be overwhelmed. In these scenarios establishment of an alternate triage and treatment area may serve as one remedy to system overload. Research examining this issue would be useful.

Triage Concepts

Earlier discussion reviewed issues related to the triage process. Questions remain regarding the effectiveness of triage methodology and its impact on patient outcomes, including whether overtriage adversely affects critical mortality rates and surge capacity. From past accounts, it appears that less severely injured tornado victims arrive early, are frequently ambulatory, and usually not transported by EMS. The majority of injuries sustained by this group will not be life threatening. Those requiring admission, typically less than 25% of all victims, arrive later and are usually transported by EMS. Could triage accuracy and speed improve if those arriving physiologically intact and ambulatory were assigned to a delayed care category? The reliability of the motor component in the Glasgow Coma Scale for predicting increased risk of morbidity and mortality from trauma has been demonstrated in previous studies.[33] Military and civilian programs have used this concept in field triage strategies. Such algorithms as Simple Triage And Rapid Treatment (START) [34] and the triage concept taught in the Advanced Disaster Life Support course direct victims to specific acuity categories based, in part, on their response to verbal commands.[35] Using such methods that are easily taught and applied could be helpful in improving triage accuracy and the assignment of only appropriate high-risk victims into the treatment areas first. Although not without potential error, comparison of outcomes within these current methods when applied to tornado victims would be helpful.

Injury Classification

Currently there is no standardized classification scheme for tornado injuries. Soft tissue injury, muscle strain, orthopedic injury, trunk, and head injuries are all broad categories mentioned. Using a system similar to that for blast injury categorization may help to corroborate other reviews of tornado injury patterns. Timing of injury occurrence as pre-event, intraevent, or postevent may be important predictors of wound contamination and infectious complications. Investigation of such issues may help define whether primary or delayed wound closure is appropriate.

Standards of Care

Typical daily trauma care utilizes significant resources and personnel for individual patients. In a mass casualty event, the system may need to operate in a population-based mode. A great deal of controversy currently exists regarding how this should be achieved, including debate on altering care. Further investigation is needed on how standard of care issues are addressed, including development of templates that can recommend a time stratification strategy for medical care based on available resources, referral sources, injury patterns, and patient volume.

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35

Earthquakes

Carl H. Schultz and Solisis Deynes

OVERVIEW

Disasters have posed a significant threat to human lives and property throughout history. Such events include hurricanes, floods, tornadoes, tsunamis, and earthquakes, among others. During the past 40 years, disasters have caused more than 3 million deaths worldwide, including more than 1 million deaths from seismic events.[1–3] Earthquakes are considered one of the most destructive disasters. An average of 16 earthquakes leading to death occur throughout the world each year with many more leading to injury and property damage.[2] The Hanshin-Awaji earthquake in Japan produced at least 100 billion USD in damage and killed more than 6,000 people.[6] The 1994 Northridge earthquake in California caused an estimated 20–30 billion USD in damages, and preliminary damage estimates for Hawaii's 2006 temblor reached 100 million USD.[4,5] These events occurred in nations that have sophisticated, modern seismic building codes. Outcomes can be even more destructive in less developed countries (Table 35.1).

Society's continued vulnerability to the devastating effects of earthquakes is due to several factors. Earthquakes are within the category of sudden-impact disasters that strike quickly and without warning, making mitigation and evacuation efforts difficult. The quantity of property damage, loss of life, disruption of economic activity, and interference in the provision of important services associated with the effects of an earthquake vary depending on its magnitude and on the degree of earthquake preparedness and mitigation measures implemented in the region affected by the temblor.[7,8] Other factors influencing the severity of the earthquake's impact include the day of the week, time of day, population density, location, distance from the epicenter (to an extent), local geological conditions, and building design.[9] Inadequate building materials, structural design deficiencies, and the absence of laws regulating building construction will increase susceptibility to seismic damage. In addition, earthquakes can cause long-term disruption to transportation, communication, and financial infrastructures.

Worldwide demographics also play a role. Many large population concentrations exist along major fault lines. These populations are at higher risk of earthquake-related morbidity and mortality.[10] Despite this high risk, population density continues to increase in many of these regions, exacerbating the potential for future injuries and deaths after a seismic event.

STATE OF THE ART

Earthquake Characteristics

To understand the issues involved with managing the earthquake threat, it is necessary to explore the basic concepts related to seismic events in some detail. Several theories exist that attempt to explain earthquake behavior. The concept most widely accepted by seismologists is the Tectonics Plate Theory. This theory is based on the structure of the earth's crust, and asserts that in the initial formation of continents, all of the earth's land mass was aggregated in a single unit. This unit subsequently fragmented, and the fragmented sections known as tectonic plates, began moving against each other (Figure 35.1).[8] These land sections remain in constant motion. Where the edges of these tectonic plates meet is referred to as a major fault line. Surrounding the major faults are minor ones that also give rise to seismic

Table 35.1: Earthquake Mortality

Year	*Location*	*Deaths*
1923	Japan	143,000
1927	China, Tsinghai	200,000
1948	USSR	110,000
1970	Peru	67,000
1976	China, Tangshan	255,000
1985	Mexico	10,000
1990	Iran	40,000
1993	India	10,000
2003	Iran	31,000
2004	Indonesia (with tsunami)	283,000
2005	Pakistan	80,361

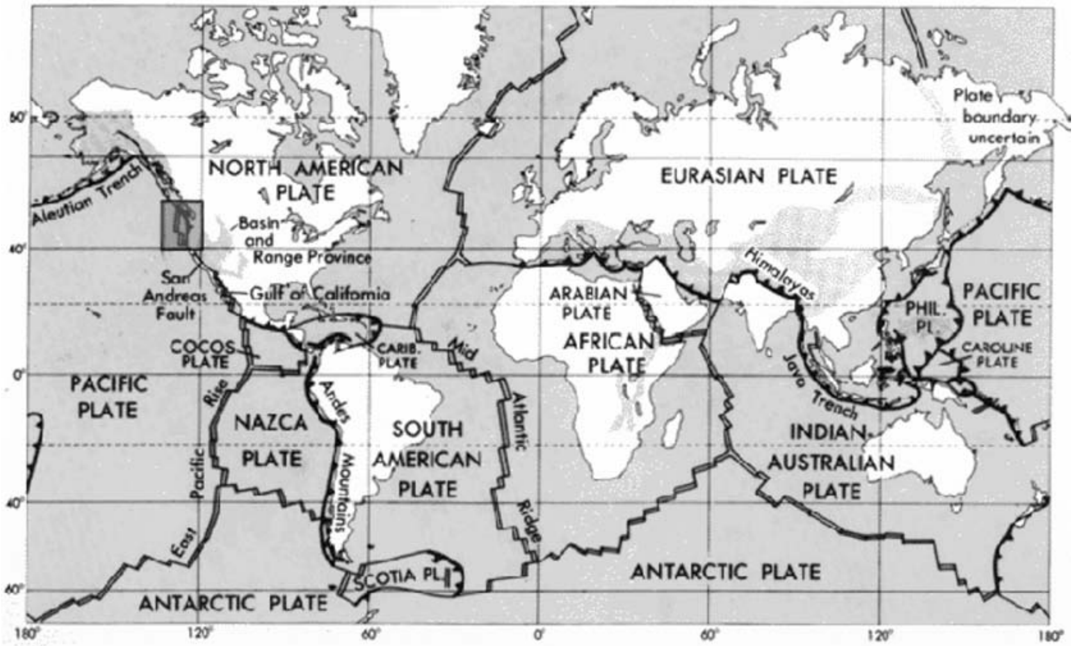

Figure 35.1. Major world faults. From: pubs.usgs.gov/gip/volc/fig37.gif.

events. A variable degree of deformation associated with increasing stress accumulates along fault lines as the land masses move past each other. Even though the Tectonic Plate Theory successfully explains most earthquakes, there are seismic events that it cannot adequately clarify, such as the activity in the New Madrid zone and around Charleston, North Carolina in the United States. The New Madrid zone is located along the Mississippi River Valley in the central United States, approximately 1,000 miles away from the nearest plate boundary. More information is needed to understand how earthquakes occur in these locations.[4,8]

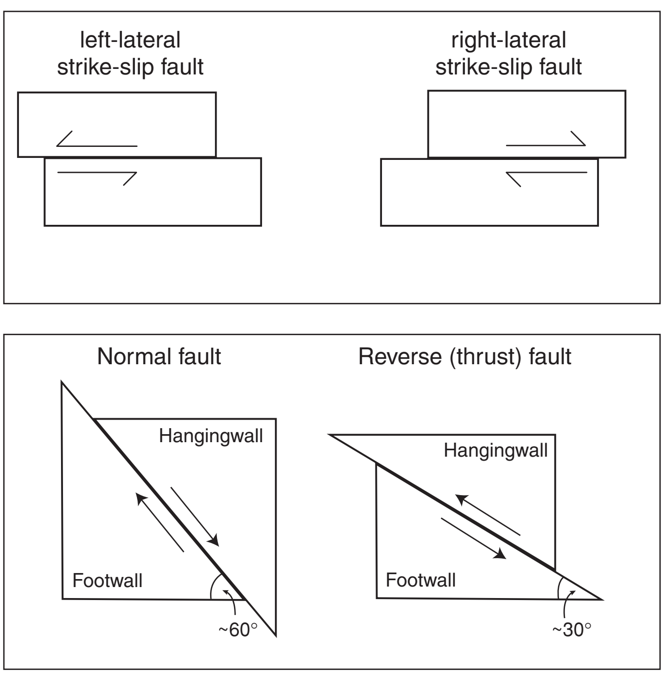

Figure 35.2. Types of fault motion characterizing strike-slip and dip-slip faults.

Tectonic plates move in relation to one another in three specific patterns described as strike-slip, dip-slip, and oblique-slip (Figure 35.2). Strike-slip faults occur when the plates slide horizontally past one another. Dip-slip faults occur when the plates slide over or under each other.[8] These are further characterized as normal faults (where the underlying segment moves upward) and reverse faults (where the underlying segment moves downward). Oblique-slip faults exhibit both types of motion when they rupture. The dip-slip faults are associated with the development of tsunamis.

Regarding terminology, the location where the fault rupture begins is known as the hypocenter (or focus) and is located below the earth's surface. The point that is located directly above the hypocenter on the earth's surface is called the epicenter (Figure 35.3). When an earthquake takes place, stress is relieved

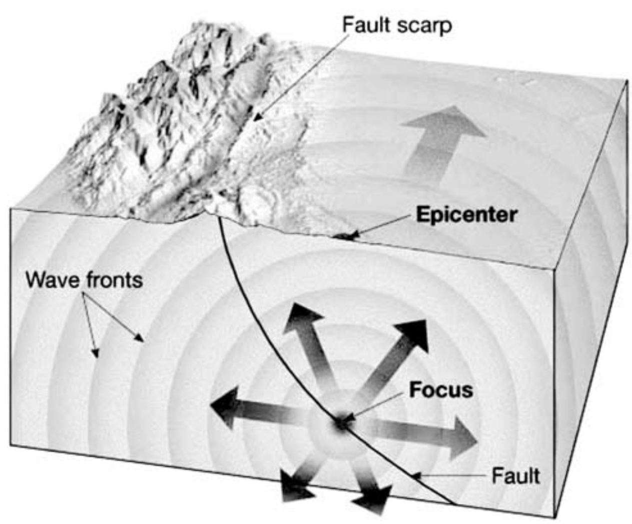

Figure 35.3. Relationship between hypocenter and epicenter. Modified from http://www.minerals.nsw.gov. au/_data/page/264/21_2.gif.

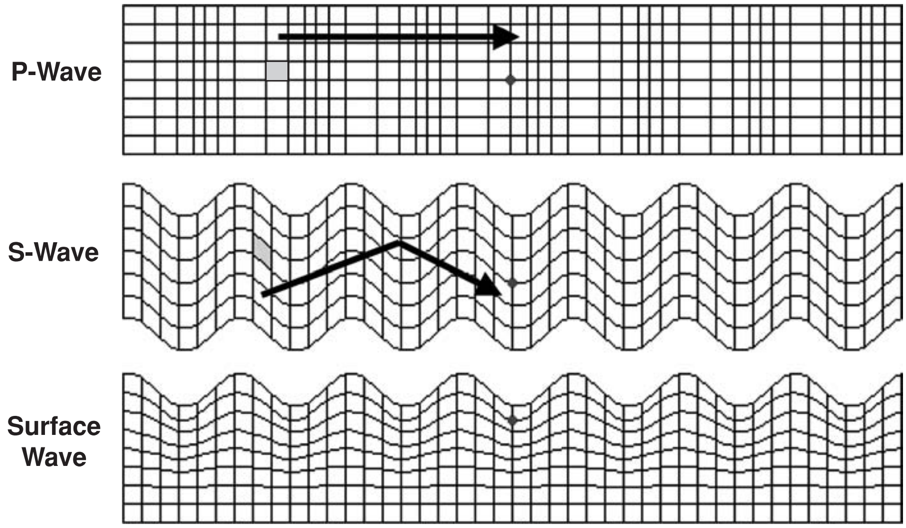

Figure 35.4. Earthquake shock waves. Modified from home.hiroshima-u.ac.jp/er/Resources/Image195.gif.

along the fault lines as the land masses shift and release energy. The energy is released in the form of seismic waves. Temblors produce three types of seismic waves: primary (P), secondary (S), and surface (L) waves (Figure 35.4). P and S waves are referred to as body waves, meaning that they develop at the hypocenter and radiate in all directions through the earth's interior.[8] The L waves are surface waves and can only move through the crust.

The P waves move in a longitudinal direction and are the fastest of the seismic waves, traveling at 4.8 km/second. The S or shear waves travel at 3.2 km/second and cause the earth to move at right angles from the direction of the P waves.[8] It is this difference in velocity between the P and S waves that allows determination of the epicenter. The different rates of travel between the P and S waves also produce two separate perceptions by individuals. The P wave generates an acoustic signal that sounds like an approaching train whereas the S wave produces a sharp jolt. The L or Love wave is a slow surface disturbance that causes swaying of tall buildings and large swells in bodies of water.[8] It is the major cause of damage and injury resulting from earthquakes.

The frequency and amplitude of the vibrations produced at the surface and the subsequent earthquake severity depend on the amount of mechanical energy released, the distance/depth of the focus, and the structural properties of the soil near the surface.[8,11] Distance from the epicenter is a poorer predictor of severity because the transmission strength of earthquake shock waves is influenced by ground composition, liquefaction, and landslide susceptibility. Soils with high water content transmit energy waves that cause significant mortality, morbidity, and structural damage even when located at great distances from the epicenter. In contrast, solid rock transmits earthquake energy with a minimum of vibration. This explains why areas situated far from the epicenter (in a liquefaction zone) can be potentially more severely impacted by seismic intensities than locations near the epicenter (on bedrock).[8]

Earthquakes are characterized by intensity and magnitude. Magnitude is the total energy generated by the temblor. This energy is measured with a seismograph and then converted using the Richter scale (Table 35.2). The Richter magnitude scale is a logarithmic scale that estimates the total energy released by an earthquake.[11] A change of 1 unit in the Richter scale corresponds to a 10-fold change in ground motion and a 32-fold change in radiated energy.[11] Measurements on the Richter scale below 2.0 are not usually felt and measurements on the Richter scale above 5.0 can cause damage. A major earthquake consists of a magnitude of 7.0 or greater on the Richter scale. A major earthquake can be preceded by less severe preliminary tremors known as foreshocks. There can also be smaller events after the main earthquake known as aftershocks, which can produce further damage and may necessitate evacuation of the area.[8,11]

Table 35.2: Richter Scale. (Data from Table 10.1, Carla W. Montgomery, "Fundamentals of Geology," Wm. C. Brown, 1993 – Original Data taken from Gutenberg and Richter, "Seismicity of the Earth and Associated Phenomena," Princeton University Press, 1954.)

Description	Magnitude (Richter Scale)	Number Per Year	Approximate energy released (ergs)
Great Earthquake	over 8.0	1 to 2	$> 5.8 \times 10^{23}$
Major Earthquake	7.0–7.9	18	$2–42 \times 10^{22}$
Destructive Earthquake	6.0–6.9	120	$8–150 \times 10^{20}$
Damaging Earthquake	5.0–5.9	800	$3–55 \times 10^{19}$
Minor Earthquake	4.0–4.9	6,200	$1–20 \times 10^{18}$
Smallest Usually Felt	3.0–3.9	49, 000	$4–72 \times 10^{16}$
Detected But Not Felt	2.0–2.9	300,000	$1–26 \times 10^{15}$

Modified Mercalli Scale		Richter Scale		Instrumental Intensity Scale				
				Perceived Shaking	Potential Damage	Peak ACC (%g)	Peak Vel (cm/s)	Instrumental Intensity
I	Felt by almost no one	2.5	Generally not felt, but recorded on seismometers.	Not felt	None	<.17	< 0.1	I
II	Felt by very few people			Weak	None	.17–1.4	0.1–1.1	II–III
III	Tremor noticed by many, but they often do not realize it is an earthquake.	3.5	Felt by many people.					
IV	Felt indoors by many. Feels like a truck has struck the building.			Light	None	1.4–3.9	1.1–3.4	IV
V	Felt by nearly everyone; many people awakened. Swaying trees and poles may be observed			Moderate	Very light	3.9–9.2	3.4–8.1	V
VI	Felt by all; many people run outdoors. Furniture moved, slight damage occurs.	4.5	Some local damage may occur	Strong	Light	9.2–18	8.1–16	VI
VII	Everyone runs outdoors. Poorly built structures considerably damaged; slight damage elsewhere			Very strong	Moderate	18–34	16–34	VII
VIII	Specially designed structures damaged slightly, others collapse.	6.0	A destructive earthquake	Severe	Moderate/Heavy	34–65	31–60	VIII
IX	All buildings considerably damaged, many shift off foundations. Noticeable cracks in ground.			Violent	Heavy	65–124	60–116	IX
X	Many structures destroyed. Ground is badly cracked.	7.0	A major earthquake	Extreme	Very heavy	>124	>116	X+
XI	Almost all structures fall. Very wide cracks in ground	8.0 and up	Great earthquake					
XII	Total destruction. Waves seen on ground surfaces, objects are tumbled and tossed.							

Figure 35.5. Comparison between the Modified Mercalli Scale, the Richter scale, and the instrumental intensities. Data were compiled and table was created by Schultz.

Measurement of the earthquake's intensity determines the degree of ground shaking in a particular location. Intensity is calculated using two separate methods: one is an objective approach using instrumentation and the other is subjective evaluation based on human observations and perceptions. The first method uses motion detectors to record peak ground velocity (PGV) and peak ground acceleration (PGA). The greater the degree of ground motion, the higher is the recorded velocity and acceleration. This information is referred to as the instrumental intensity. The second method, the modified Mercalli intensity (MMI) scale, relies on observing the extent of damage to property and from the perceived degree of shaking reported by people experiencing the earthquake.[7]

The MMI is a 12-point subjective scale (Figure 35.5). Using this scale, intensity determinations are made after an earthquake when local U.S. Postal Service employees are interviewed regarding their perceived shaking experience and the visible structural damage they observed. Different governmental workers may perform this task in other countries. Using one of the 12 categories on the scale, a value is selected that most accurately represents the degree of shaking and damage. This value is then assigned to the pertinent zip or postal code. Recording the MMI values for all zip codes in the earthquake zone yields a representation of the overall intensity. Although MMI scale measurements are subjective, they are generally valid. Researchers have found that MMI values correlate with structural damage, deaths, and traumatic injuries.[8,10]

PGV and PGA determinations are based on the degree of ground velocity and acceleration measured at localized points obtained by ground sensors placed in earthquake prone areas. Because these sensors are placed in only a few locations, the use of instrumental intensities as a worldwide measure is limited. If available, they provide precise estimates of intensity not influenced by the subjective perception of motion or damaged structures. Comparisons between the Richter scale, the MMI scale, and Instrumental Intensities are depicted in Figure 35.5. Instrumental intensities recorded during an earthquake are better predictors of injury and lethal outcomes than the rate of building collapse.[9,10,12]

Seismology, the study of earthquakes and the propagation of seismic waves, has made progress in estimating the probability of a strong earthquake occurring during any 24-hour period in certain parts of the United States, such as California. These predictions are based on evaluations of previous events and analysis of potential relationships between events. Seismologists cannot currently predict with certainty when or where the next earthquake will occur or its intensity level.[13]

MANAGEMENT ISSUES

The persistent threat of seismic events and the difficulties involved with mitigating their effects highlight the importance of disaster preparedness. When planning, the following should be considered: 1) modify the initial response of prehospital and hospital care, 2) maximize the effective and efficient use of community resources, 3) awareness of the most common clinical conditions seen after an earthquake and how to treat them, 4) acknowledge that outside help would probably take more than 24–48 hours to arrive.

Incident Command

In the initial period after an earthquake, a certain degree of uncertainty arises not only for the people in a community, but also in the healthcare system. Once it is clear that the demand on resources exceeds what is available under standard operating procedures, establishing a system of command and control, known as an Incident Command System (ICS), becomes indispensable to effective management.

ICS is a structure that can provide direction and rapidly establish control of the event. It is based on a concept initially used by California firefighters in the 1970s for effective coordination and resource control when battling wildfires. The ICS directs activity during the response through decisions made by a single individual known as the incident commander and implemented by a formal chain of command involving others in an organized fashion. By providing federal and state government agencies with a standardized system of command and control, complex situations can be managed more efficiently during a disaster, protecting lives and property. In cases in which multiple jurisdictions have a role in event management, the ICS becomes a Unified Command System and may include representatives from the state and federal levels in addition to local entities.[4,14] A detailed explanation of ICS can be found in Chapter 9.

An incident management system is used at each responder entities' Emergency Operations Centers (EOC). This is the location where personnel representing various organizations from the public and private sectors meet during an emergency event to: 1) coordinate response and recovery actions, 2) conduct strategic decision making, and 3) manage resource allocation.[4,14]

Prehospital Response

After an earthquake, victims' lives may depend on how rapidly they are extricated from collapsed buildings and how expeditiously they receive medical treatment. In urban areas of developed countries, it is common that paramedics are responsible for this type of initial prehospital care; however, in a large-scale earthquake they may be unavailable for this activity, particularly in systems in which they have primary responsibilities as firefighters. In systems not using paramedics, first responders can be police, firefighters, or other ambulance personnel. In some locations, such as California, firefighters receive cross-training as paramedics. Wherever fires occur immediately after an earthquake, such as occurred in the 1989 Loma Prieta temblor in northern California, the priority is to minimize the amount of damage resulting from these blazes.[4] Therefore human resources are initially directed to fire suppression. This can leave the affected area without paramedic support. Even though it was only a moderate-sized earthquake, during the Loma Prieta temblor, sections of San Francisco went without paramedic support in the critical early hours following the initial shaking because of the prioritization of fire suppression over rescue efforts.

Complicating the threat to the population, secondary events that increase the lethality of the initial earthquake can occur after seismic activity. Such events include fires, landslides, floods, and tsunamis, among others.[2,8] During the 1994 Northridge, California earthquake, fires and burns accounted for 6.1% of the fatalities and 7.3% of the hospitalized injuries, even though nonresidential buildings were the most affected and the fires were quickly controlled.[2]

Another common problem faced by industrialized societies after an earthquake is exposure of the population to released toxic materials stored in such facilities as chemical plants. Following the 1989 Loma Prieta earthquake, approximately 20% of the post earthquake injuries were caused by toxic materials.[7] Under these circumstances, chemical decontamination must be addressed to limit the number of exposed victims and property damage, and improve community safety. When dealing with the threat of chemical contamination, it is reasonable to consider directing human resources to assist with the decontamination processes instead of the rescue effort.

Communication between paramedics in the field and receiving hospitals can be disrupted after a seismic event. Notifying hospitals of victims' impending arrival becomes difficult, increasing the risk that healthcare resources cannot be effectively managed. Many individuals will not wait for the arrival of paramedics or other providers. Family and friends will frequently drive victims to the nearest hospital, overwhelming the facility's capacity. During the Puerto Limon, Costa Rica earthquake in 1999, most victims were transported by survivors.[15] During the Gujarat, India earthquake in 2001, most of the victims used private transportation to reach hospitals.[16] Major trauma victims will be brought to nontrauma centers and many patients without life-threatening injuries will arrive at trauma centers. This mismatch of medical needs and available resources can potentially overwhelm capacities and result in inefficient utilization. Even though this phenomenon is undesirable, it will be difficult to avoid during the first hours after an earthquake.

Even in well-developed systems in industrialized societies, breakdown of communication systems makes coordination of field care and disposition more difficult and jeopardizes the direction and coordination of all prehospital activities. Paramedic radios frequently rely on repeaters that can fail, making transmission of radio signals to the dispatchers or base stations providing contact with paramedics in the field difficult. Ambulances from different jurisdictions tend to use different frequencies, making communication between field units and the central coordinating body problematic. The creation of a globally recognized disaster frequency would make a significant contribution to the improvement of communication under these circumstances. Satellite or cellular telephones also have limitations.

Many systems have been developed to address the communication problems that arise after disaster events. A wireless transmission system for disaster patient care (WISTA) was developed to assist emergency personnel in treating disaster victims and coordinating medical resources.[17] Another communication innovation, the Wireless Internet Information System for Medical Response in Disasters (WIISARD) is a project by the University of California, San Diego designed to support disaster relief operations in the field.[17] Although these systems show promise, at the time of this writing, none has actually been implemented after an earthquake.

Movement in and out of a disaster zone is difficult following an earthquake. Significant damage occurs to transportation infrastructures such as roads, bridges, traffic signals and road lighting. During the 1994 Northridge earthquake, 15% of the fatal injuries were motor vehicle related, primarily as a result of the disruptions in traffic control devices.[10] Earthquake-related motor vehicle injuries were 5.23 times more likely to result in fatality than in a hospitalized injury.[2] Eighty one percent of deaths on public roadways following the Loma Prieta event were associated with the collapse of freeway structures.[10] Landslides, soil settlement, and slope failures, among others, increase damage to the highways. Ill or injured survivors who require transportation to medical centers will experience delays until the safest routes to hospitals are identified. The early use of law enforcement personnel (including State National Guard assets in the U.S.) to control important transportation areas can improve this situation.[4]

The initial prehospital response should be directed toward the provision of emergency medical assistance, and then followed by search and rescue activities.[7,15] In some studies, death and injury rates were 67-fold and more than 11-fold higher, respectively, for trapped victims in comparison to those not requiring extrication.[7,18] Injuries caused by collapsing structures or falling building components were 8.36 times more likely to result in fatalities than in hospitalizations.[2] Approximately 90% of the deaths in all earthquakes are the result of structural collapse.[8] There is a well-documented decrease in survival for victims trapped longer than 24–48 hours after an earthquake, as seen in the Campania-Irpinia earthquake (1980) in Italy and the Tangshan earthquake (1976) in China.[3,11] In Italy, a survey of 3,169 survivors showed that 93% of those who were trapped and survived were extricated within the first 24 hours and 95% of those who died expired before extrication.[18] Estimates of survivability among entrapped victims in Turkey and China indicate that within 2–6 hours, fewer than 50% of those buried were still alive.[3,12,18] In a study of the 1980 Italian earthquake, investigators concluded that 25%–50% of the victims who were injured and died slowly could have been saved if they had received initial life-saving treatment immediately.[3,7,12,18]

After an earthquake, an increased requirement for surgical services is expected during the first 72 hours; acknowledging this requirement is important for effective resource utilization.[8] Early rapid assessment of the extent of damage and injuries is necessary to help mobilize resources and direct them where they are most needed.[10] Rescue workers frequently perform triage, using a system similar to Simple Triage and Rapid Treatment (START). This methodology can theoretically sort patients into groups of increasing acuity; however, controversy exists regarding the efficacy of such systems and data supporting their use are limited. Two studies evaluating START triage have been published and suggest it may be useful.[19,20] The START system emphasizes basic life-saving measures such as opening an airway and applying direct pressure for external bleeding control but rescuers are instructed not to provide definitive care procedures at the scene. More information about the START system can be found in Chapter 12.

A significant number of victims who survive the initial impact subsequently die because of a delay in arrival of life-saving emergency medical care. One study investigating the 1988 Armenia earthquake reported that deaths might have been prevented if victims had received appropriate medical attention within the first 6 hours after the event.[3,18] A theoretical increase in survival would have been possible if trained urban search and rescue (USAR) teams had been available during the first hours after the disaster. USAR teams can help local leaders with structural assessment, advanced search and rescue techniques, and specialized medical training helping to limit the period of entrapment for victims.[21] The utility of USAR teams has, however, been questioned. It requires nearly 24 hours for a team to deploy from an unaffected region and begin search and rescue activities in the United States and even more time to provide international assistance, thereby limiting its usefulness for saving lives after an earthquake.[21] In the Northridge earthquake, 19 hours passed before the Riverside USAR team began operations at the Northridge Meadows Apartments.[4] The first U.S. USAR team required 48 hours to begin operations in Turkey after the 1999 earthquake.[4] A careful investigation of the organizational barriers preventing a rapid response by medical rescue teams is required to improve their ability to save the lives of the most seriously injured disaster victims.[15] Reports show that up to 90% of survivors are rescued by civilian volunteers within the first 24 hours after an earthquake event.[18]

Hospital and Community Response

Hospitals are the traditional source of medical care for victims after seismic events; however, hospitals can also be impacted by earthquakes, aggravating the initial imbalance between demand for medical care and surge capacity. Healthcare facility closure and evacuation are mandated if management staff identify environmental or structural factors that put patients' safety at risk. An early structural assessment performed by expert engineers or, if not available, on-site personnel is critical. Therefore, institutional disaster plans must include a hospital functional status evaluation.[22] Guidance for structural assessments is provided by the ATC-20 and ATC-20–2 documents, which were developed with the support of the U.S. Federal Emergency Management Agency, the National Science Foundation, and the State of California's Office of Emergency Services and Office of Statewide Health Planning and Development.[3] Structure-dependent collapse patterns are documented in the Federal Emergency Management Agency's Structural Engineer Training Manual.[21] During the Northridge earthquake, eight (9%) of 91 acute care hospitals were evacuated.[23] Six hospitals, two of which complied with current building codes, evacuated patients within 24 hours. Four of these institutions ordered complete evacuations, including the two institutions that met current building standards. The remaining two facilities ordered partial evacuations.[4,23] Two hospitals whose initial inspections revealed no critical damage and therefore continued providing patient care were subsequently evacuated and condemned. The first facility completely evacuated patients 3 days after the temblor and the second one after 14 days due to identification of structural damage that required demolition.[23] It appears that hospitals reported to be secure may later prove vulnerable. After the 2005 Pakistan earthquake, 65% of the hospitals in the affected area were destroyed or badly damaged.[24]

Hospitals that are damaged and cannot continue providing inpatient care need information to facilitate the transfer and evacuation of their inpatients. All else being equal, evacuation should be coordinated by the EOC if one exists to ensure effective resource utilization; however, hospitals can safely and effectively evacuate patients with or without assistance from an EOC. Although coordination with the EOC is desirable, if time is critical and communications are intact, hospitals can successfully evacuate patients directly. Such activity is facilitated if mutual aid agreements with other hospitals are already in place. During the Northridge earthquake, both strategies were equally effective.[23] Evacuation transport problems can often be solved by collaboration between military and civilian groups. In the 1999 Marmara earthquake in Turkey, military boats and helicopters were used to transfer patients to remote major cities.[24]

Hospitalized individuals in critical condition require extensive resources, which are limited after a seismic event. Evacuating the sickest patients first from hospitals appears to work best, lessening the burden on healthcare facilities while improving the chances for better care of remaining patients or arriving victims.[4,23] When time is critical and structural collapse is imminent, evacuating the healthiest patients first permits movement of the greatest number of patients in the least amount of time.[4] During the Northridge earthquake, one evacuating institution believed that patients were in immediate danger and chose to evacuate the healthiest patients first, successfully evacuating all patients (a total of 334) to nearby open areas in 2 hours.[23] Methods to evacuate patients from a hospital may vary. In the Northridge temblor, supervisors transported patients by using available equipment such as backboards, wheelchairs and blankets, among others.[23] Vertical evacuation of patients (moving patients from one floor of the hospital to another) should generally be accomplished using stairwells and not involve elevators until they have been inspected.

Functioning hospitals must activate their disaster plans to prepare for the influx of victims. Effective command and control of the facility's response requires the implementation of a system flexible enough to be used in medical institutions and not dependent on the presence of any specific individual. A proposed model used by many hospitals is known as the Hospital Incident Command System (HICS) and is based on general ICS principles. HICS has been effectively used during earthquake events.[4] More information on HICS is available in Chapter 20.

After establishing a command post and implementing HICS, hospital administration is primarily concerned with evaluating personnel availability, communications, and resources. Hospital staff, like the general population, use telephones as a major method of communication. Because standard telephones frequently fail, secondary communication methods should be available. Examples of such methods include: alphanumeric pagers, priority phones, fax machines, the Internet/e-mail, cellular phones, pay phones, wireless systems, ham radio systems, portable two-way radios, satellite telephone systems, and runners.

Hospital personnel who are at home after a disaster can be difficult to contact. Therefore, implementation of a disaster callback policy is necessary. Because communications may be disrupted, such a policy could state that personnel should report to work in a major disaster unless they are notified to stay at home. Disaster planners can expect that most hospital staff will remain at work and not abandon their responsibilities. After the Northridge earthquake, as in other earthquakes, the majority of staff remained on duty. Most workers who did not immediately report to the hospital had problems with either communication or transportation.[4] To maintain the flow of medical goods, notifying suppliers of an abrupt increase in demand for certain products may be difficult secondary to communication limitations. An agreement requiring suppliers to deliver a set amount of supplies after a disaster, such as a seismic event, should be established a priori.

In actuality, it is difficult for hospitals to meet the entire demand for medical assistance because they typically operate at a high census with little surge capacity for accepting additional patients. The solution to providing an effective medical response is optimizing the use of all available resources. This requires hospitals to establish plans for improving surge capacity after an earthquake, even if some structures are damaged.[7] Typical plans include use of additional space not traditionally designated for patient care, such as cafeterias, auditoriums and parking lots. After a temblor in Puerto Limon, Costa Rica (1999), the only treatment facility was declared structurally unsafe. This resulted not only in patient evacuations but establishment of treatment areas in the parking lot.[15] After the Northridge and Loma Prieta earthquakes, treatment areas were established outside the hospitals as well.[15]

In situations in which receiving hospitals become nonfunctional, community-based solutions to augmenting surge capacity can be used. One such model is the Medical Disaster Response (MDR) program. The main advantage of the MDR program is that victims receive rapid advanced medical care even if hospitals are damaged or destroyed. This project, which was developed by emergency physicians in southern California, focuses on the training of healthcare personnel in the management of unique medical problems encountered after earthquakes. It utilizes supplies stored in the community before an earthquake occurs, similar to the concept behind the Strategic National Stockpile, but at the local level. Under austere conditions, the MDR model directs the initial management of casualties by specially trained local personnel who use medical supplies at designated sites within the community.[3] Using this model, local healthcare providers in or near the disaster zone can respond immediately and deliver advanced patient care. Detailed discussion of the MDR project can be found in the literature.[3,25,26]

Information about the status of surrounding hospitals is valuable. Some will sustain damage and be unable to accept victims from the field. Others will be in the process of evacuation. Remaining functional hospitals can expect an increase in emergency department volume as well as requests to accept patient transfers from damaged institutions. Therefore, it would be extremely useful to establish a hospital communication system that could provide a rapid estimate of the number of remaining functional facilities. Implementation of such a system would permit these undamaged hospitals to estimate the potential demand for their services in the immediate postdisaster period. Healthcare institutions could then decide whether to cancel elective surgeries, discharge stable patients earlier than planned, and implement other components of their surge capacity plans.[27] Several communications systems currently exist but have not always performed optimally after seismic events.

It is tempting to assume that hospitals located near the epicenter will have a higher probability of structural damage. As such, incident managers may incorrectly assume that hospitals located farther away will remain functional and will preferentially direct patients to these facilities. Although this is true for institutions located a large distances from the epicenter, it does not appear these assumptions are correct for facilities located close to the epicenter. A study examining the association between distance from the epicenter and hospital evacuation found no relationship between these two variables (Figure 35.6).[28] All facilities studied were located within approximately 32 km of the epicenter. In contrast, a strong association existed between PGA and hospital evacuation, regardless of the institution's location. It may be appropriate for incident managers to consult earthquake shake maps before making patient transport decisions. In regions with ground motion sensors, computers can generate shake maps identifying the areas of greatest shaking within minutes after a seismic event occurs.

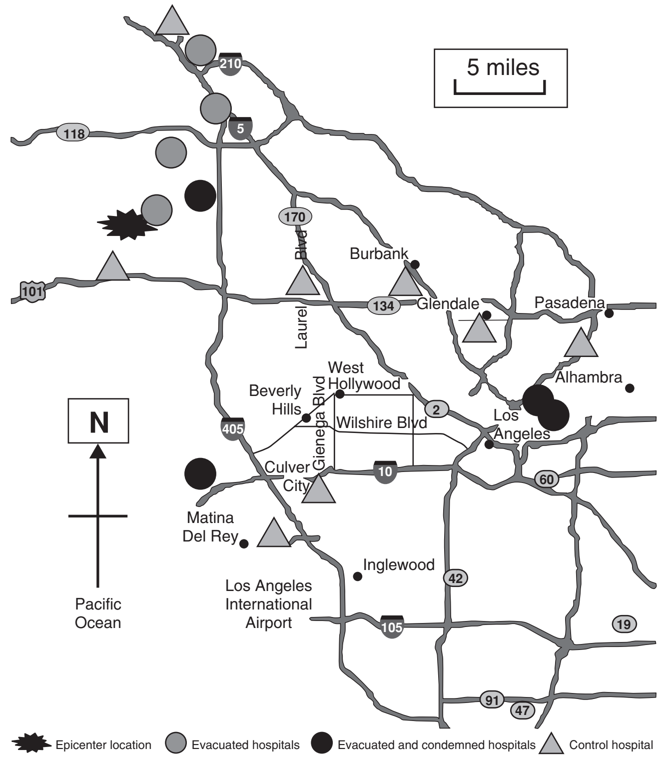

Figure 35.6. Epicenter and hospital locations, Los Angeles County, CA. This map shows the geographical locations of the study and control hospitals, as well as the epicenter of the 1994 Northridge earthquake. From Schultz CH, et al., *Ann Emerg Med.* 2007;50:320–326.

Surge capacity is critical for a health system's disaster preparedness. Deficient surge capacity limits the ability of healthcare systems to respond to disasters successfully.[29] Surge capacity plans require multidisciplinary collaboration to be successful. With regards to the personnel component of surge capacity, Schultz and Stratton proposed the creation of a database to provide rapid emergency credentialing of volunteers. If implemented, the strategy would offer an accurate, inexpensive, efficient, sustainable and U.S.-based Joint Commission–compliant tool for rapidly expanding healthcare personnel support for hospital patient care. This database is created from a list provided by each hospital of personnel and physicians with unrestricted privileges currently credentialed at the facility. It is shared with all participating institutions and a county healthcare agency. Volunteers who appear in the database could obtain hospital privileges at any hospital within the county for the first 72 hours after a disaster event.[29] Should the database be shared between counties, such individuals could receive emergency privileges in other jurisdictions as well.

Patient tracking and the creation of medical records can be problematic after earthquakes. Many patients will not have access to typical items that document personal information and identity (e.g., driver's license, medical insurance cards) or will have a health condition that makes gathering information from them impossible (e.g., altered mental status). Therefore, creating a medical record and tracking a patient's movement through the healthcare system can be challenging. Potential solutions include documenting descriptive information such as sex, estimated age, height, color of skin, unique skin marking (mole, tattoo, or scar), eye color, and possibly fingerprints in the medical record.[8] Using records created with generic fictitious names before an event can address registration issues. In settings in which patient volume overwhelms hospitals, documenting patient care may not be possible. After the Costa Rica earthquake, hundreds of patients received medical care even though documentation of these interactions was absent in many instances.[15] No widely accepted solution to the patient-tracking problem has yet been found, although some have suggested using bar codes or radiofrequency identification devices (see Chapter 25).

Building damage and structural collapse resulting in loss of life are predictable consequences of earthquakes. This serious problem is due, in large part, to lack of appropriate seismic construction codes in many countries, including wealthy nations.[18,30] A study of the 1976 Guatemala earthquake concluded that deaths and injury are critically dependent on housing damage and construction materials used.[18] Mitigation and preparedness are the only ways to save lives and preserve resources at the same time.[30] Engineering and epidemiological evaluations are fundamental for understanding the effects that seismic forces have on the different types of building structures.[31] Data collected on these seismic forces and subsequently analyzed will help to improve building design, casualty estimates, and disaster planning and preparedness.[15] Building codes developed for seismic areas are intended to prevent catastrophic structural failure and reduce mortality with the formation of large void spaces in any structure that does fail.[21] Implementation and enforcement of building codes will help prevent deaths and improve the safety of the population. Even though building codes can reduce morbidity and mortality from an earthquake, they are not 100% effective. During the Northridge earthquake, two of the hospitals that suffered significant nonstructural damage were constructed under the most updated building codes.[23] During the retrofit process, there was the unexpected discovery of failed welds in steel-frame buildings that engineers had incorrectly believed could tolerate earthquake forces.[4] In addition to improving building design components, other interventions that reduce injury involve nonstructural mitigation. Such activities address the most common cause of injuries in mild to moderate temblors. These include bracing bookcases to the wall, securing heavy electronic equipment, and using earthquake hooks to hang picture frames containing glass to prevent them from falling and shattering.

The first influx of patients is expected to arrive within 30–60 minutes after the temblor, probably suffering from minor injuries such as uncomplicated lacerations, contusions, or fractures. Because supplies may be limited in a disaster situation, hospital personnel should initially allocate resources to the more critical patients. Therefore, victims with uncomplicated conditions should be quickly evaluated and directed to an observation area. Treatment should be postponed until more detailed information regarding the overall demand for medical care is available. Many victims suffering from minor injures may not require hospital care at all. After the 1989 Loma Prieta earthquake, as many as 60% of those with earthquake-related injuries either treated themselves or received treatment in nonhospital settings.[7] It is noteworthy that neither age nor sex is considered a risk factor for injury. No consistent relationship between injuries and demographic factors has been reported in the literature.[9,10,18,32]

When treating uncomplicated lacerations during a disaster, providers should be concerned about an increased risk of infection and missed foreign bodies. To decrease these risks, some experts recommend allowing uncomplicated lacerations to close by second intention or to use the technique of delayed primarily closure. There is insufficient evidence to justify any particular treatment recommendation at this time.

The second group of patients to arrive is composed of those victims with more serious conditions such as crush injury. In developed nations, these victims are more typically transported by paramedics via ambulances because they were more difficult to extricate or transport by lay individuals. They may also suffer from other medical conditions, making their initial treatment more challenging. Depending on the scenario, the number and acuity of patients presenting for acute care at local emergency facilities may overwhelm available resources. Therefore, implementation of a triage process is necessary. Triage decisions must focus not only on patient acuity but, more importantly, on which individuals should be prioritized for medical or surgical treatment. START triage does not discriminate between those who will consume large amounts of limited available resources or those whose prognosis will remain poor despite aggressive treatment. To allocate resources more appropriately, a proposed algorithm called the Secondary Assessment of Victim Endpoint (SAVE) was created. The goal of this algorithm is to optimize reduction of victim mortality and morbidity by allocating resources only to those who will benefit. This means that not all victims will receive the same degree of care they would under normal circumstances. This treatment approach contradicts the usual medical philosophy of providing potentially unlimited care to each patient.[22]

The SAVE triage algorithm, which was designed for mass casualty events, is a triage pathway driven by estimated patient outcomes. It is based on outcomes data from trauma patients and those with other medical conditions who receive standard treatment. It arbitrarily recommends withholding aggressive medical care from those with less than a 50% chance of survival or from those who will essentially deplete all available resources.[26] Implementation of SAVE triage should only occur in situations in which the time for return to standard operations is unknown and so optimal utilization of limited resources is necessary.[26] A detailed discussion of SAVE triage can be found in the literature.[26]

The need for rapid screening tools to prioritize patient care in disasters has received a great deal of interest. Ultrasonography holds promise as a technology for evaluating mass casualty victims and has many benefits. It is 1) noninvasive, 2) portable, 3) easily repeatable, and 4) highly sensitive for intraperitoneal blood and other conditions. Newer indications for this technique in the evaluation of trauma patients include pleural effusions, pneumothorax/hemothorax, and fractures. The practical utilization of sonography has been studied in disaster settings (e.g., following Hurricane Katrina in the U.S. in 2005) and in the prehospital setting. Technologies have progressed to the point that ultrasound devices are available in handheld form. During the 1988 Armenia earthquake, physicians with two ultrasound machines were able to triage 400 blunt trauma patients in 48 hours.[33] Ultrasound has also been used in Kosovo, Afghanistan, and Iraq by the deployed military forces.[34]

Medical Issues

After an earthquake, victims experience major injuries and illnesses that will require treatment in hospitals. Typical examples include skull fractures with intracranial hemorrhage, spinal cord injuries, and intrathoracic, intraabdominal, and intrapelvic organ trauma.[7] Major medical complications described in previous earthquakes include hypothermia, wound infections, gangrene requiring amputations, sepsis, adult respiratory distress syndrome, exacerbations of chronic pulmonary disease such as asthma, myocardial infarctions, multiple organ failure, and crush syndrome.[7] Variable degrees of hypothermia were documented in patients evacuated from the Armenia earthquake of 1988.[18,21] Although not strictly a complication of seismic activity, many investigators have also noted an increase in childbirths after an event.

Crush injuries are associated with the development of compartment and crush syndrome, all of which are commonly found in earthquake victims. Crush syndrome, one of the most common causes of death in a seismic event, usually results from excessive pressure on limbs, which damages muscle tissues.[35] The life-threatening effects of crush syndrome include hypovolemic shock, acidosis, rhabdomyolysis, acute renal failure (ARF), electrolyte disturbances (hypocalcemia, hyperkalemia), acute respiratory distress syndrome, disseminated intravascular coagulation, and fatal cardiac arrhythmias.[7,36,37] Calculated mortality rates for patients with rhabdomyolysis and/or crush syndrome who required renal dialysis reach up to 40% or more.[38,39] In the 1988 Armenia earthquake, more than 1,000 victims trapped in collapsed buildings developed crush syndrome and 323 developed secondary acute renal failure requiring renal dialysis.[7]

During the Kobe earthquake, crush syndrome was observed in 13.8% of hospitalized patients and acute renal failure developed in half of these individuals.[35,37] After the 1991 Costa Rica earthquake, autopsies performed on a sample of victims showed crush injury as the predominant mechanism of injury and cause of death.[15]

Standard therapy for crush syndrome includes large amounts of intravenous fluids (more than 10 L/d), bicarbonate, mannitol (10 mL/h of a 15% solution), monitoring of cardiac rhythm and urine output, and dialysis.[35,37] Because there is a high risk for ARF and hyperkalemia, intravenous fluids must be potassium free. In the 1993 Turkey earthquake, researchers noted that some of the victims transferred from the field received solutions containing potassium.[36] In patients who require dialysis, implementing a protocol using intermittent hemodialysis during short sessions supervised by experienced personnel allows the treatment of several patients per day with a single machine.[35,37] Continuous renal replacement therapy and peritoneal dialysis are less efficient in removing potassium in comparison to intermittent hemodialysis.[35,37] Lower mortality rates are seen when patients with crush injury–associated ARF are treated with adequate dialysis at intensive care facilities and under the supervision of healthcare professionals.[39]

In the austere environment that frequently follows an earthquake, prevention of crush syndrome may be difficult. Large volumes of intravenous fluid are limited. In these situations, amputation or fasciotomy may be the only treatment available to prevent the otherwise inevitable morbidity and mortality resulting from uncontrolled crush syndrome. A victim can deteriorate quickly to the point of death as the crush-injured area is extricated from the collapsed structure.[21,37] During the 1976 Tangshan earthquake in China, patients died suddenly of cardiac arrest soon after extrication, presumably due to hyperkalemia.[15] When a high degree of suspicion exists that crush syndrome and associated hyperkalemia will develop during or immediately after rescue, it is recommended to delay extrication until personnel can institute therapy to threat metabolic derangements (several liters of intravenous isotonic saline).[15,35,36] If this treatment is not available, amputation of the involved extremity is an option. Another suggested approach to this situation is application of a tourniquet to the compromised limb before the patient's extrication. Theoretically, this could avoid sudden death due to the ensuing reperfusion of the crushed extremity.[40] No data currently exist to support this intervention.

When treating compartment syndrome, it is recommended that fasciotomies should be done only when clear indications are present, such as with intracompartmental pressure measurements above 30–35 mm Hg.[37] This suggestion is based on the risk of infection related to the procedure itself, which increases the morbidity and mortality of the victim. If, however, the procedure is performed at a stage when all muscle is still viable, and the wound is kept open with sterile dressings to allow healing by secondary intention, infection is rarely seen. Administration of antibiotics may also improve the prognosis, although this is controversial.[40] Medical management of compartment syndrome by using mannitol has been proposed as an effective and less hazardous alternative to surgical intervention.[38]

Amputations also play a role in facilitating extrications and in the removal of severely mangled extremities. The mangled extremity severity score is a tool that can assist medical providers in making the decision about whether to amputate an injured lower extremity in cases in which survival of that limb is questionable (Table 35.3).[41] A total score of 7 or greater indicates that there is a high probability the lower extremity will be unsalvageable despite aggressive treatment and that amputation should be considered.[26,40,41] This assessment has a specificity between 90% and 100%, making it acceptable for use in disaster settings. In this situation, a guillotine amputation performed at the most distal site possible is best and has a low incidence of infection even without antibiotics.[40]

Table 35.3: Mangled Extremity Severity Score (MESS) Score

Skeletal/Soft Tissue Injury	
Low energy (stab; simple fracture; civilian gunshot wound)	1
Medium energy (open or multiple fractures, dislocation)	2
High energy (shotgun; military gunshot wound, crush injury)	3
Very high energy (as above, plus gross contamination, soft tissue avulsion)	4
Limb Ischemia	
Pulse reduced or absent but normal perfusion	1
Pulseless; paresthesia; reduced capillary refill	2
Cool, paralyzed, insensate, numb	3
(Score doubled for ischemia longer than 6 h)	
Shock	
Systolic blood pressure maintained >90 mm Hg	0
Transient hypotension	1
Persistent hypotension	2
Age (y)	
<30	0
30–50	1
>50	2

Adapted from: Robertson PA. Prediction of amputation after severe lower limb trauma. *J Bone Joint Surg Br.* 1991;73(5):816.

Painful procedures such as amputation, fasciotomy, and fracture reduction require effective anesthesia and analgesia. Available options are the use of regional anesthetics (nerve blocks) and administration of systemic medications. Even though they may be an attractive option, regional blocks can produce inconsistent results. Ketamine administration is another reliable method for achieving effective procedural anesthesia and analgesia.

Ketamine, a dissociative agent, has been categorized as a fast, short-acting, safe, and effective drug that preserves airway reflexes and supports the cardiovascular system. In a review of 11,589 patients treated with ketamine, only two healthy patients required intubation.[3] Ketamine has been used safely and effectively by nonmedical persons in unmonitored, austere environments in Afghanistan to facilitate field amputations.[3] In the absence of contraindications, ketamine can be administered safely via the oral, intravenous, rectal, and intramuscular routes. The recommended dosage for intravenous administration is 2 mg/kg and for intramuscular injection, it is 4–6 mg/kg.[3,40]

Intravenous fluids may be limited in the first 48 hours after a seismic event. Therefore, common patterns of practice must be modified regarding the type and amount of fluids used in a disaster setting. There are limited data that support the use of hypertonic saline for initial resuscitation and normal saline for early maintenance.[3,42] Doses of 4 mL/kg of hypertonic saline seem to be safe and effective in trauma patients, burn victims, and children.[42,43] After patients improve with hypertonic saline challenges, they can be supported with normal saline. Concerns about the development of hypernatremia and a hyperosmolar state limit the amount of hypertonic saline that can be used. The main objective in the switch of resuscitation fluids is reducing the volume of normal saline that must be kept in inventory for initial patient stabilization. Liter bags of saline are bulky, heavy, and require significant space for storage. Medical personnel can initially resuscitate two–four times the number of patients with a given volume of hypertonic saline as they can with the same volume of normal saline. Solutions of 5% dextrose in quarter normal saline could be given to patients unable to ingest fluids or who require hypotonic hydration.[3] More information is needed to know the optimal intravenous solution for resuscitation and stabilization of disaster victims.

Patients suffering from abdominal trauma should be resuscitated with hypertonic saline boluses. Some experts recommend maintaining blood pressure in the moderate hypotensive range, targeting a systolic of 90 mm Hg or mean arterial pressure of 60 mm Hg. They suggest that normalizing blood pressure may be associated with increased internal hemorrhage and exacerbated morbidity and mortality.[26,42] Definitive evidence for or against this approach is lacking. Adults who do not respond to fluid resuscitation should be reevaluated with regard to the continuation of aggressive care. The use of ultrasound can quickly confirm the presence of significant intraabdominal hemorrhage. In these situations, if intraperitoneal bleeding is identified, current resources are limited, and surgical intervention is unavailable, consideration for the provision of comfort care only is warranted. Children with abdominal trauma should be treated aggressively because many will survive without operative intervention.[26]

After a catastrophic earthquake, by the time substantial outside medical resources arrive to the disaster area, most victims have either received initial treatment or are dead; however, the need for maintaining medical care, supporting the damaged healthcare infrastructure, and supplementing limited resources persists. Groups that arrive after the immediate response phase is over are critical to preserving the lives of survivors. Disaster Medical Assistance Teams are available in some countries with variable missions and response times. One important function they can provide is to care for ambulatory patients in any location. These teams can decrease the healthcare burden on emergency departments by offering another option for medical care in the days to weeks after the earthquake. Also, the Renal Disaster Relief Task Force (RDRTF), created by the International Society of Nephrology in 1989, can increase surge capacity for renal dialysis. These teams can provide additional dialysis capacity for existing renal patients as well as victims suffering from crush syndrome. The positive impact from these task forces was demonstrated following the Marmara earthquake in Turkey in 1999 and the Yogyakarta earthquake in Indonesia in 2006.[35,44,45] The RDRTF is composed of three divisions: the American, European, and Pacific groups.[35] Disaster Medical Assistance Teams and the RDRTF are meant to be self-sufficient and to establish patient care capability with limited consumption of community resources. The time required for these teams to arrive at the disaster zone is often more than 48 hours (sometimes weeks in remote areas), limiting their effectiveness in reducing the burden of acute patient care in many cases.[44] These teams will help in the reconstitution of the basic medical care system because hospitals, clinics, and medical offices may be destroyed or incapacitated.

An important area to consider is access to information by the public. In an event like an earthquake, locating individuals quickly is extremely difficult. In the immediate aftermath, many victims will leave the area, die, or be hospitalized. Patient transfers are common and victims will often receive care in facilities far from where they live. The creation of a public information center will decrease the time and effort people will spend looking for relatives and improve family reunification.

Nontrauma-related Medical Conditions

A review of pertinent literature reveals that up to 20% of the patients hospitalized after earthquakes suffer from nontrauma-related conditions.[12] Unlike the direct health effects of disasters, indirect health effects are predicable and preventable.[31] The conditions most commonly seen are acute exacerbations of chronic conditions such as diabetes, chronic obstructive pulmonary disease, acute coronary syndromes and myocardial infarctions, end-stage renal disease, anxiety, hypertension, and the onset of spontaneous abortions, among others.[7,45] Beginning on the third day following the 1999 Chi-Chi earthquake in Taiwan, medical diseases became the most common cause for hospitalization.[12] After the 1985 Mexico City earthquake, there was an increase in the number of spontaneous abortions, premature births, and normal deliveries, making those conditions the primary reasons for admission in chronic care facilities.[7] Healthcare professionals should be aware of the possibility that an increased incidence in these medical conditions will occur following earthquakes, and they should be prepared to treat them.

Myocardial Infarctions

Increased numbers of patients presenting with conditions related to cardiovascular disease such as myocardial infraction and cardiac arrest have been reported after earthquakes.[4,31] A 50% increase in cardiac deaths was reported in the first 3 days following the 1981 Athens 6.7-magnitude earthquake.[4,7] The existence of this phenomenon suggests that it may be caused by psychological stress resulting in an increase in catecholamines, vasoconstriction, or a hypercoagulable state and not to an increase in physical exertion.[4,7,31] The incidence of sudden cardiac death rose dramatically in the first 24 hours after the Northridge earthquake, and then decreased in the following 6 days. This suggests that those who died immediately after the earthquake were already susceptible to cardiac events and would probably have died in the next several days. It appears the earthquake may have accelerated the process.

In most studies, increases in cardiac mortality were reported to occur within a few days following earthquakes; however, after the 7.2-magnitude 1995 Great Hanshin-Awaji earthquake, augmented cardiac mortality was reported over a period of weeks.[31] Earthquakes that cause chronic stress among the population during the recovery and reconstruction stage may result in prolonged cardiac events. In addition, increased mortality and worsening prognosis from myocardial infarction can be due to loss of standard treatment resources because of hospital damage. Further investigation is needed to clarify the factors affecting regional variations in terms of the extent and duration of increased cardiac mortality after an earthquake.[31]

Chronic Obstructive Pulmonary Disease

Respiratory injury is a major cause of death among victims of earthquakes. Early mortality caused by airway obstruction, asphyxiation, and dust-induced fulminant pulmonary edema is one of the possible scenarios. Part of the increased incidence in respiratory diseases after earthquakes is attributable to the inhalation of dust produced by collapsed structures during early search and rescue activities.[7]

End-stage Renal Disease

After a seismic event, there is an increase in the number of patients with end-stage renal disease whose conditions deteriorate. Dialysis-dependent patients cannot receive their treatments on schedule because the water and electricity required for this process are often unavailable after earthquakes. In addition, dialysis centers and dialysis material may be destroyed and dialysis center personnel may be lacking either because of transportation issues or becoming victims themselves. In addition to the paralysis of communication and transportation systems, centers with the capabilities to perform dialysis can be overwhelmed by new patients with ARF secondary to crush syndrome as well as by patients with chronic renal disease whose usual site of care is not functional. The immediate options for increasing surge capacity for dialysis patients are either to decrease the number of weekly dialysis sessions for each patient or to shorten the duration of each session, as was done after the Marmara earthquake in 1999.[45] In the aftermath of this seismic event, officials not only implemented shortened periods for dialysis treatment but also issued specific patient instructions to follow strict dietary and fluid restrictions. Compliance with these recommendations was high. As a result, despite less frequent dialysis, weight gain and blood pressure among these patients did not differ when compared with the predisaster period.[45] As new temporary centers for dialysis open or alternate facilities are made available, patients can receive their treatments at nearby satellite outpatient units until damaged facilities are restored.[37]

In the first days after a disaster, dialysis-dependent patients should strictly follow recommendations for fluid restriction and should avoid foods rich in potassium. In the situation in which dialysis treatment centers are inoperative or cannot be reached, potassium exchange resins kept in the home can serve as a useful temporizing measure to prevent life-threatening hyperkalemia.[45] In an extreme situation in which the physician needs to prioritize treatment between patients with acute or chronic renal failure, dialysis should be administered first to those with ARF. These individuals, if they survive their critical state, are more likely to live longer and healthier lives.[45] Disaster plans should consider management strategies for chronic renal patients who are dependent on dialysis, because they will consume a large amount of resources that are needed in the aftermath of a large temblor.

Management of Psychological Distress

Experiencing the impact of a disaster can negatively affect responders and victims, resulting in enormous emotional consequences. Responders may need supportive psychological services in addition to the general population. Community needs assessments must include all potential patients. Specific analysis should include information about age, race, cultural background, socioeconomic status, and special needs populations so that programs can be developed to meet the requirements of these diverse groups. The Red Cross is often the first agency to begin coordinating mental health programs and provides crisis counseling for extended periods of time.[46] Skills that are most often needed include training and experience in the prevention and management of posttraumatic stress disorder, trauma and bereavement counseling, debriefing, and crisis intervention.[46] Mental health workers should be available 24 hours a day. In addition, it is crucial to provide individuals who can assist with the debriefing of the mental health teams at the end of their shifts. Community groups that desire a role in the mental health response must be identified and trained before an event to be effective.

Epidemics

After an earthquake, the affected area is potentially predisposed to epidemics of diseases normally endemic in the population. The most important factors that contribute to an area's vulnerability to infectious diseases are the loss of adequate water supplies and sanitation systems. Failure of these systems increases the risk for development of water-borne diseases. In addition, earthquakes lead to population displacement and crowding, both of which have been proven to increase infectious disease transmission.[47] Despite these theoretical risks for such epidemics, it appears unlikely that they will actually occur.[4,8] Only two articles in the literature reported outbreaks after an earthquake. A malaria outbreak was reported after the 1999 Costa Rica earthquake.[47] In addition, after the 1994 Northridge earthquake, a coccidiomycosis outbreak was reported.[47] It appears that mass vaccination campaigns, based solely on the fear of possible epidemics are inappropriate. An epidemiological surveillance system should direct such interventions based on measured disease activity.

Disposal of Bodies

Decaying corpses represent a concern to the public and to health authorities; however, the belief that an increased risk of disease transmission exists due to decomposing dead bodies in the aftermath of major disasters is a myth. Authorities should be aware that the health hazards related to unburied human remains, principally those of trauma victims, are negligible. Mass burials or cremations, which require the use of enormous amounts of fuel, destroy any evidence for future identification, and do not respect some religious rituals, are not justified on the basis of public health concerns.[48,49] One situation in which handling human remains can represent a health risk is during epidemics of transmittable infectious diseases. Even in these situations, there is no reason to deprive families of their wishes to manage their dead relatives according to their customs, as long as they follow certain safety measures.[47] In addition, it is important to identify victims. This has relevance not only to regional governments but also to provide family members a greater degree of stability and closure in reference to their losses. Fingerprints, photographs, dental records, imaging, and DNA analysis can be used to help identify victims.[49]

Prevention

The most important factors required for reducing earthquake mortality reside in the institution of local and federal pre-event disaster mitigation and preparedness plans.[15] These plans must include preparedness for early extrication of trapped victims and early treatment of immediate medical conditions, with effective use of available resources. Implementation of an effective incident management system along with previously negotiated mutual aid agreements and transportation networks, including airlifts, can also influence the prognosis of victims.

Disaster preparedness plans should focus on ways to augment prehospital response to minimize the lethal impact of earthquakes and to maximize life-saving potential within the first 24 hours after the disaster event. Prehospital providers must initiate abbreviated patient assessment protocols designed for disasters rather than those used during everyday responses. Immediate needs assessments that are associated with an efficient organizational structure are required to optimize the disaster response. This must be done with the coordination of state, local, national, and international agencies working together to achieve a common goal. It is of great importance to incorporate data obtained from formal training exercises into the disaster planning process and to develop interorganizational relationships among entities that will participate in a disaster response.

The Joint Commission requires hospitals seeking their accreditation to include an evacuation strategy in their emergency management programs. Institutions must periodically test their evacuation plans by using drills that model the disruption of emergency departments' and hospitals' normal activities.[50] Although the Joint Commission also requires that these types of disaster drills include the regional responders needed in an earthquake, hospitals often do so in an ineffective manner, failing to realistically assess overall preparedness.

Critical actions taken before, during, and after a disaster may save lives and minimize property damage.[10] Communities that are at risk for earthquakes must adopt effective response strategies to decrease losses after an event. Substantial numbers of victims are rescued by community members in the first hours after an earthquake. Therefore, to decrease morbidity and mortality, planners should train local residents in search and rescue activities. To reduce the number of deaths suffered by extricated victims, care should be provided for life-threatening injuries within the first 6 hours.[10] Because insufficient and uncoordinated medical responses are often reported in the aftermath of earthquake events, more attention to a local medical response plan, such as the MDR program, is warranted. In addition, individuals must secure items such as bookshelves and computers as an injury-prevention technique. Anchoring loose objects can substantially reduce injuries. After the Northridge earthquake, 16 hospitals were individually reviewed and reported that most of the injuries resulting in hospital admission were caused by falls or by being hit by objects.[36] Many tools and devices are currently available for securing both heavy and smaller objects.[9]

Education in earthquake risk reduction should be a major focus for healthcare and community members. Educational programs must include 1) the training of teams for search and rescue operations and needs assessments; 2) how to identify safe sites where people can be relocated after the event; 3) training healthcare professionals about conditions commonly seen in earthquake victims and treatments for them; 4) how to maintain pharmaceuticals and supplies needed for the most common medical conditions after an earthquake; 5) how to assess the structural safety of facilities that are essential in the operation of disaster responses (e.g., hospitals) and upgrading them as necessary; 6) how to plan for alternate water supplies; 7) preparing plans for the maintenance of viable vehicle transportation corridors; 8) how to access and operate emergency communication systems; and 9) training teams to assess nonstructural damage and determine whether buildings are safe for reoccupancy.[8]

RECOMMENDATIONS FOR FURTHER RESEARCH

Although investigators examining the medical consequences of seismic events have made significant progress, additional work is necessary to further improve the care and outcomes of earthquake victims. These endeavors will require a true transdisciplinary approach involving participation by individuals from multiple medical, health, and nonmedical specialties. A few projects with the potential for achieving this goal follow.

A rapid and accurate estimate of casualty numbers and the extent of their injuries is necessary to coordinate the size and type of healthcare resources required to provide care to earthquake victims. Delays in obtaining this information will lead to an inappropriate or inadequate medical and health response. Current estimates are based on generalized information gathered from previous seismic events and do not reflect individual variations in building construction or population density. In addition, current casualty estimation computer programs do not provide estimates in real time and are not specific for earthquakes because they do not fit the model on which the software is based. New models are needed that can utilize population data for individual locations and rapidly generate estimates based on observed building damage. Designing such models is possible using data-mining techniques combining new engineering building damage classification data and population injury information. Such innovative research has yet to be funded.

If a large-magnitude earthquake occurs in a densely populated area, implementing a system for triaging medical casualties will be necessary. There are several triage systems available but data on their effectiveness are limited. Most research to date has focused on triage tool assessment using drills or models thought to approximate the types of victims caused by seismic activity, such as individual trauma patients. More investigations are required of mass casualty triage system performance based on meaningful outcomes data in actual earthquakes to clarify which of these tools is most appropriate.

The field management of victims suffering from crush injuries remains controversial. If resources are plentiful, standard treatment protocols apply. Under austere conditions, however, the most appropriate approach to such victims is unknown, especially when supplies of intravenous fluids are limited. The roles for field fasciotomies, amputations, tourniquets applied to crushed extremities before extrication, and the use of hypertonic saline require additional study. Animal models for crush injury exist but have not been widely used to investigate these aspects of crush injury management.

The large number of victims generated by a powerful earthquake will require hospitals to quickly increase surge capacity. Research has identified the major components of this process and programs exist to support some aspects of surge capacity, including the U.S. National Pharmaceutical Stockpile, community-based programs such as the MDR Project, the Emergency System for Advanced Registration of Volunteer Health Professionals, and the creation of Federal Medical Stations in the U.S. It remains unknown, however, how effective these programs will be. Further investigation is needed to examine what interventions will be successful under actual disaster conditions. If current programs fail to adequately address surge capacity, disaster experts must identify new approaches that can meet the rapidly expanding demand for care.

Identifying the areas most heavily damaged by an earthquake is important. These locations are not evenly distributed near the epicenter but are scattered over a wide area affected by the temblor. Because most deaths and injuries result from building damage, quickly obtaining such information can provide responders with the locations where most victims will be found. In addition, it can suggest which hospitals remain functional and which are evacuating patients. The current technology using ground motion sensors that measure PGA and PGV can generate shake maps within minutes of a seismic event. These maps depict the intensity of ground motion over a wide area. Although this information suggests areas of higher and lower probability for structural failure, it is insufficient to reliably predict building damage. More sophisticated software that incorporates ground motion along with soil conditions and types of building construction could yield a more accurate view of building damage and subsequent injury potential.

Disaster management focuses on needs assessments of the affected population, the efficient utilization of resources, the prevention of further adverse health effects, and the evaluation of relief program effectiveness to plan for future disasters.[48] Improvements in disaster mitigation and responses will require a carefully organized, multidisciplinary evaluation of the consequences associated with these events. Therefore, a government-sponsored national or international research center for the multidisciplinary evaluation and study of disasters is needed.

SUMMARY

Earthquakes are spontaneous events whose consequences are associated with an increase in morbidity, mortality, and costly property damage. Understanding the challenges that arise after seismic events can assist with planning, improving strategies for mitigating their effects, and assisting with the coordination of local resources in more effective ways. The medical management of earthquake victims remains a difficult challenge; however, the amount of data on this subject continues to increase, allowing the development of new recommendations. Implementation of field triage protocols (e.g., START and SAVE) and the use of a unified command system are vitally important in supporting early organizational efforts in the chaotic environment that surrounds disasters. Acknowledging that hospitals will be overwhelmed during the first 24–48 hours helps responders prepare for that reality, supporting plans to augment surge capacity and decreasing victim mortality and morbidity. Hospital structures remain susceptible to seismic damage and must prepare and test reliable evacuation plans that incorporate effective strategies used successfully in previous events. Knowledge of common medical conditions that arise after an earthquake, such as crush syndrome, respiratory symptoms, renal failure, fractures, and lacerations can help healthcare professionals more effectively manage these medical problems. In addition, refining plans for the management of chronic medical conditions and the appropriate disposition of dead bodies is important to improve earthquake response.

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36

Tsunamis

Samuel J. Stratton

OVERVIEW

A tsunami is a series of waves created when a massive volume of ocean water is rapidly displaced. Tsunami waves are created as the mass of displaced water radiates relative to gravitational forces across an ocean or sea. Commonly, submarine earthquakes are associated with tsunamis, but other geophysical events causing mass displacement of water will generate tsunami waves. These may consist of underwater landslides, volcanic eruptions, meteorite impacts, and submarine explosions, including nuclear detonations.[1] Tsunami events are best classified as sudden-impact disasters.

The term tsunami is of Japanese origin from the words "tsu" meaning harbor and "nami" meaning wave.[1] Tsunamis usually occur in a series of nonrhythmic waves as opposed to a single wave. The first tsunami wave to approach a shore is often not the largest in the series. In open ocean, tsunami waves can have a wavelength of up to 700 km (435 miles) and propagate at speeds of 640 km (400 miles) per hour.[2] In open water, tsunamis may have a wave height (amplitude) of only a few centimeters. Upon reaching shallow water, however, the waves slow and build to heights with inertial energy well beyond those of wind-generated waves (Figure 36.1).

Tsunamis can cause severe damage to coastal areas as they "run-up" onshore and dissipate wave energy caused by the massive displacement of ocean water. The destructive effect of a tsunami is controlled by the submarine topography in front of the land area that the tsunami approaches. A sloping beach or land positioned on a submarine ridge will sustain damage from the direct impact of high waves, whereas a wide and shallow continental shelf will absorb most of the wave energy and protect a land mass behind it.[2] Tsunamis are different from wind waves and tidal movements because of the large amount of energy they contain and the long, wide character of the waves.

Tsunamis present in two different forms: local and ocean-wide waves. Local tsunami waves arise when earthquakes or undersea disruptions occur near a shore. Local tsunamis can be occur after an earthquake or subsurface event has been detected by residents of the shoreline that is at risk. Local tsunami waves run-up to shore with little warning other than the preceding event causing displacement of water. In the 2004 Indian Ocean Tsunami, 130,000 persons in the coastal area of Aceh Province, Indonesia near the originating earthquake were killed by direct effects of the tsunami and earthquake.[3] The same earthquake generated an ocean-wide tsunami that killed 145,000 persons on distant shores throughout the Indian Ocean in Thailand, the Maldives, India, and Sri Lanka.[3] Ocean-wide tsunamis are generated by distant earthquakes or submarine events that may or may not be felt by affected shoreline residents. A classic example of an ocean-wide tsunami is the 1960 Chilean tsunami that was generated by a magnitude 9.5 earthquake off the coast of southern Chile, causing devastation in Chile. The tsunami waves spread across the Pacific striking Hilo Hawaii 14.8 hours after the initial quake, killing 61 persons with the highest wave measuring 10.5 m (35 ft); it continued on to run-up on the coastal area of Sanriku, Japan killing 142 persons.[4]

Historically, tsunamis have occurred in all the oceans of the world, with the coast of Maine struck in 1926 and ancient reports of tsunamis in the Mediterranean Sea.[5] Most tsunamis of consequence strike in the Pacific Ocean. Here they cause significant destruction because ocean topography frequently includes land masses on the edges of ocean canyons rather than on a continental shelf, as is the case with the east coast of the U.S.[6] The Pacific Rim is also highly active with earthquake activity, raising the risk for tsunamis.[7]

STATE OF THE ART

On-shore Tsunami Effects

As tsunami waves run-up onto coastal areas, there is churning of silt, sand, and organic matter that is then thrown onto the shore. Onrushing seawater, sand, and debris cause direct damage to structures and roads (Figure 36.2). In addition, persons in the path of the tsunami waves are swept into on-rushing waves. They suffer drowning and aspiration of seawater with suspended material as well as blunt injury from heavy debris captured by the waves. Tsunami waves destroy and damage essential service areas,

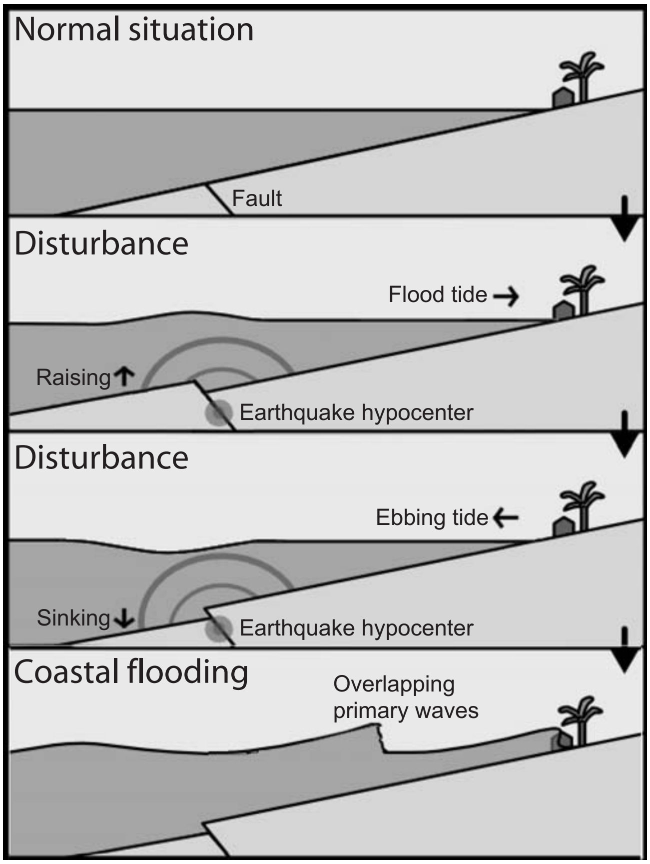

Figure 36.1. Diagram showing the generation of tsunami waves by a submarine earthquake. With disruption of the ocean floor, energy is transferred to the water mass causing displacement of a large mass of water. The energy of the ocean floor disruption is then dispersed in the form of a water mass or wave. When the tsunami strikes a shoreline, the energy stored in the form of water mass is dissipated on the shoreline. See color plate.

waste management systems, flood control systems, and structures. Because tsunamis are high-energy waves, boats and other offshore objects can be torn from moorings. These objects, along with anchors and other fittings, are thrown violently against the shore causing direct damage to sea walls, buildings, and other objects in the path of the wave. Once tsunami waves run-up on shorelines, it is not uncommon for automobiles, buses, refrigerators, trees, large rocks, and other debris to be thrown against any object in the path of the waves. Many coastal areas have electrical lines close to shore, raising the risk for disruption of these lines and secondary electrical injury to humans and animals. The rolling, crushing nature of tsunami waves can cause release of biological toxins from storage containers, automobiles, electrical devices, gasoline stations, and other damaged sources.[8]

As tsunami waves recoil, debris and toxins are pulled into the ocean with forces that are close to that of the force of the oncoming waves (Figures 36.3, 36.4). Because tsunami waves present in series, debris, chemicals, and suspended material are churned and thrown back and forth to the shoreline and ocean. In addition to damage from heavy objects, toxins, and silt, tsunami run-ups are associated with on-shore fires as natural gas lines and flammable materials and liquids are exposed.[8]

Figure 36.2. During tsunami events heavy debris is churned onto and off shore as shown by this large coral rock thrown on shore in the Solomon Islands during the 2007 tsunami. (Source: United States National Oceanic and Atmospheric Administration, by John Beba, Woodlark Mining Limited.) See color plate.

Tsunami waves have little effect on deep-water structures as they traverse open waters. They dissipate large amounts of energy as they run-up to shore. Near shore coral reefs and ecosystems can be severely affected by tsunami strikes, causing long-term loss of near shore marine life and habitats that can take centuries to replace.[8] Loss of coastal marine ecosystems can lead to loss of fishing grounds and affect tourism and other human industries. Tsunami run-ups in industrialized coastal areas can cause release of environmental toxins including paints, oils, gasoline, detergents, and solvents. Release of these toxins can affect both marine and human populations for extended periods. Furthermore, release of human and animal biological waste can contaminate and damage food and water supplies for extended periods.

Tsunami waves striking industrialized areas often break natural gas and electrical supply lines. As water recedes, the risk of fire is high from ignition of natural gas supply lines and other combustible material left in the wake of the waves. Many of the

Figure 36.3. Sri Lanka 2004 tsunami wave striking shore, submersing bases of trees and low-lying buildings. Note the forceful churning of water as the wave is striking. (Source: United States National Oceanic and Atmospheric Administration, by Chris Chapman, Cambridge, UK.) See color plate.

Figure 36.4. A Sri Lanka 2004 tsunami wave receding and pulling debris and objects into the ocean with forces that nearly equal the energy of the incoming wave. (Source: United States National Oceanic and Atmospheric Administration, by Chris Chapman, Cambridge, UK.) See color plate.

secondary fires are caused by ignition of oil products, including gasoline, diesel fuel, plastics, and solvents. Because water alone will not extinguish these types of fires and these burning materials are lighter than water, subsequent on-rushing tsunami waves can spread fire and burning debris throughout the affected area. Both thermal and chemical burns of survivors are to be expected when tsunami waves strike industrialized shorelines.

IMMEDIATE TSUNAMI RISKS FOR HUMANS AND ANIMALS

Drowning is the obvious risk for humans and animals when a tsunami strikes an inhabited shoreline. Many persons survive the initial effects of an oncoming rolling wave but are swept to sea to drown in open ocean waters that are churning as tsunami waves strike. Because of this phenomenon, children, women, and the disabled are more likely to drown during a tsunami strike because they may lack the strength to hold onto stationary objects and avoid being swept out to the open ocean.[3] Attempts to survive by clinging to floating debris are often futile because the waves strike and recoil from the shoreline in a churning, mixing motion.

Figure 36.5. This picture taken in Karaikal, India after the 2004 Indian Ocean tsunami shows the debris field left by the tsunami waves. High-force movement of heavy debris and sharp objects within a tsunami wave cause major injuries to exposed humans and animals. (Source: United States National Oceanic and Atmospheric Administration, by Joseph Trainor, University of Delaware, Disaster Relief Center.) See color plate.

Table 36.1: Immediate Tsunami Injury Risks

Submersion
Drowning
Aspiration lung injury
Tympanic membrane rupture
Blunt force injury
Crush injury
Closed head injury
Solid organ blunt force injury
Spinal injury
Cervical spine injury
Compression fracture thoracic and lumbar spine
Orthopedic injury
Long bone fracture and contusion
Dislocation of shoulder, elbow, knee, digits
Amputation of digits, hands, feet
Pelvic fracture
Eye injury, both blunt and penetrating
Soft tissue injury
Laceration
Contusion/abrasion
Penetrating trauma
Foot injury from sharp debris
Penetrating thorax/abdominal injury
Burn
Thermal
Chemical
Dental trauma

In addition to drowning, death occurs by blunt force injury as heavy objects are thrown against persons and structures as the advancing waves hit the shore. Fatal crush injury and blunt trauma are reported as the second most common cause for death related to tsunamis.[9] Mortality is also associated with impalement by large pieces of glass and sharp, protruding metal, wood, and vegetable matter formed and exposed by the forces of the tsunami waves (Figure 36.5). Descriptions of persons found impaled through the torso on bamboo shoots, metal rods and pipes, and splintered tree branches and trunks are not uncommon. Closed head injury secondary to blunt trauma and blunt force solid organ injury with subsequent hemorrhage are also recognized causes for fatal injury related to tsunami events.[9] Building collapse from tsunami waves undermining structural foundations is another cause for crush injury.[9]

Prolonged serious medical conditions resulting directly from tsunami events are uncommon and most persons either survive to be "ambulatory" or are killed suddenly during the event.[3,10] Table 36.1 lists the injuries that can be anticipated in survivors. Lacerations, soft tissue injuries, and orthopedic injuries are most often encountered in the aftermath of a tsunami strike. Because those suffering these injuries are in a contaminated environment, tetanus prophylaxis is a primary concern. In opposition to standard practice in which most soft tissue wounds and lacerations would be immediately sutured or closed, wounds presenting during the acute disaster phase of a tsunami event are often left open to heal by secondary intent or delayed primary closure after thorough irrigation and debridement because of the contaminated nature of the injuries and concern for retained foreign bodies.

Eye injuries secondary to flying debris and direct injury are common during tsunami events. Frequent episodes of tympanic membrane rupture are also reported and are most likely caused by pressure gradients when one is submersed in the water of a rolling wave. Facial injuries and dental trauma are also to be expected.

Orthopedic injuries are predominately long bone fractures but also include pelvic fracture and spinal injury (including cervical spine injury and compression fractures of thoracic and lumbar spine regions). Amputation of digits and partial hand and foot amputations are also commonly reported and are the result of crushing and severing caused by heavy floating debris churned within tsunami waves. Dislocations of the shoulder, elbow, and knee have also occurred often during tsunami events.

Pulmonary injury due to aspiration of contaminated water is frequent in relation to tsunamis.[3] Although pneumothorax due to blunt chest injury and barotrauma would be expected, it has not been reported as a predominate injury. Thermal and chemical burns are reported and expected because caustic toxins can be released from containers and fires occur in the aftermath of a tsunami strike.

Table 36.2: Elements of a Rapid Epidemiologic Assessment

1. Determine the overall impact of the event
   - Geographical extent
   - Number of affected persons
   - Estimated duration
2. Assess the impact on health
   - Number of casualties
   - Number injured
   - Number with illness
   - Number well and unaffected
3. Determine the integrity of the healthcare system
4. Determine the specific health needs of the survivors
5. Assess the disruption of essential services that contribute to public health
   - Water
   - Power
   - Sanitation
   - Communication
   - Shelter
   - Food
6. Determine the extent of resources needed by local authorities for adequate response and recovery to the disaster

PUBLIC HEALTH ASPECTS OF TSUNAMI EVENTS

The immediate public health concerns with tsunami events include loss of shelter, food, water, and clothing supplies. Starvation and hypothermia or sunburn and sun exposure are common public health concerns immediately after a tsunami strike.[9] Survivors are often left partially clothed without access to potable water or food. Because debris, including broken glass, splintered trees, and destroyed buildings, are distributed throughout the immediate environment by the waves, mobility is limited and access to food, water, and shelter is difficult. After tsunami events, initial public health activity generally include environmental health actions to develop safe, protected shelter and ready access to drinking water and clothing.[3] Providing food supplies appropriate to the cultural norms for the area struck by the tsunami is an important public health priority.

When the immediate needs of the surviving population have been addressed and survivors have moved to safe locations, organized assessment of health-related needs should be conducted. Initial assessment may be by survey of shelters and survivor collection points, but random-cluster analysis of the affected community is often preferred as soon as feasible.[11] Knowledge of local health risks and challenges is essential in planning and conducting a rapid health analysis. For example, if it is known that malaria is endemic in an area struck by a tsunami, those doing a health assessment would survey for accessibility to protective mosquito netting for sleeping quarters and access to DEET or other appropriate mosquito repellents. An interesting illustration of knowing important local health hazards occurred during the recovery phase of the 2004 Indian Ocean tsunami. Outside experts made unnecessary strong recommendations for intensively complicated cholera vaccination programs in areas struck by the tsunami when cholera was not a threat and had not been present in the area for decades.[12] Information obtained during rapid public health assessments of an affected population is used to plan and implement immediate health responses. Table 36.2 lists the elements most often addressed during a rapid health assessment following a sudden onset event such as a tsunami. The focus of these health assessments is to make prompt estimates of the health needs of an affected population.[11] Visual inspection, interviews with key personnel, and surveys are the mainstay tools for rapid health assessments.[11]

Examples of the importance of health assessments in tsunami events is effectively illustrated by the World Health Organization evaluations done during the December 2004 Indian Ocean tsunami. Initial rapid health assessments done immediately after the event showed that burial of the dead, sheltering survivors, waste and debris removal, and provision of water and food were crucial first efforts to prevent public health problems within the surviving populations. Later health assessments showed that malnutrition, childhood diarrhea, hazardous waste management, and disposal of rotting animal carcasses were a priority. Importantly, rapid health assessments detected measles cases among children in eastern areas of the affected area, allowing for an intensive measles vaccination program that prevented a measles outbreak among a generally unvaccinated pediatric population.[13]

TSUNAMI WARNING SYSTEMS

Although tsunamis can be classified as sudden onset events, there are often periods of warning before a tsunami wave impact. Local tsunami run-up to a coastal area is often preceded by a submarine earthquake or volcanic eruption that can be felt by those occupying hazardous areas of the shoreline. Understanding the association of tsunamis with earthquakes and other underwater disturbances allows for escape to higher ground or inland areas.

As ocean-wide tsunami waves approach a land mass there is often a profound receding of the water along a shoreline as the tsunami rolls in. Understanding an association between profound receding of shore waters and incoming tsunami waves can allow for initial movement of those at risk away from the shore (Figure 36.6). There have been many anecdotal reports of animals unexplainably rushing to higher ground minutes before the

Figure 36.6. The initial receding of water from shore before the run-up of a tsunami wave during the 2004 Indian Ocean tsunami. During this "warning" phase of a tsunami run-up, rocks and sand that are normally submerged along the outer shore become exposed. This receding of the ocean serves as a warning for those along the shore to move to higher ground to avoid a possible incoming tsunami wave. (Source: United States National Oceanic and Atmospheric Administration, by Chris Chapman, Cambridge, UK.) See color plate.

approach of a tsunami as if they are able to sense the incoming wave.

In 1949, the United States created an organized official tsunami warning system with headquarters located in Honolulu.[14] In 1960, an earthquake occurring off the southern shore of Chile caused severe local damage and generated an ocean-wide tsunami that impacted Hilo, Hawaii, resulting in significant destruction and killing approximately 60 residents. The same tsunami waves proceeded to Japan where they inflicted substantial damage and killed 200 people. After this 1960 tsunami event, a coalition of Pacific nations was formed to develop a warning system to prevent future damage by ocean-crossing tsunami waves. With support of the United Nations, the international Pacific Tsunami Warning Center (PTWC) was developed.[14] Until 1967, the PTWC had responsibility for warning Pacific nations of ocean-wide tsunamis. In 1967, following a severe 1964 Alaskan earthquake and tsunami, the West Coast and Alaska Tsunami Warning Center (WC/ATWC) was established. Today, the WC/ATWC has responsibility for issuing tsunami warnings for Alaska, British Columbia, Washington State, Oregon, and California. The PTWC monitors the rest of the Pacific.[15,16]

When the 2004 Indian Ocean tsunami occurred, an organized warning system did not exist for the Indian Ocean area. Subsequently, the PTWC has added the Indian Ocean, South China Sea, and Caribbean to those areas monitored and warned of tsunami risks.[15]

The PTWC currently has 26 participating international member states.[16] Multiple forms of technology are used to determine tsunami risks and events. These technologies include earthquake sensing and information devices, drifting and moored ocean data buoys, satellite observation equipment, Argo floating buoys, integrated on-land observation sites, high-frequency coastal radar, and the Shore Coastal-Marine Automated Network. Equipment supporting this network is located in lighthouses and shore stations that monitor weather and seismic activity.[16,17]

A standard terminology has been developed for tsunami alerts that are released from tsunami warning centers. A "tsunami advisory" indicates that a threat exists but that no tsunami has been detected. A "tsunami watch" indicates that an earthquake or other high-risk tsunami-generating event has been detected and coastal areas are to standby for further information and alerts. A "tsunami warning" indicates that a tsunami has been generated or that conditions are serious enough for coastal communities to take responsive actions. Information generated with a tsunami warning will include earthquake magnitude, originating location, and arrival times of waves.[18]

MITIGATING THE EFFECTS OF TSUNAMIS

Tsunami waves are hazards unique to coastal areas of the world. They are a predictable hazard because the origins of tsunamis are known to be earthquakes, submarine volcanoes, landslides, and other sources for displacement of large volumes of water. Human inhabited coastal regions that are in areas of geophysical activity places persons at direct risk for tsunami disaster effects. The coastal region known as the Pacific Rim is a well-recognized tsunami hazard zone.

Human habitation and activity in low-lying coastal lands puts people at direct risk for tsunami injury and loss. Furthermore, recreational use of low-lying coastal lands places visitors to these areas at risk for injury and death from tsunamis. Building structures for human habitation near low-lying shorelines in tsunami hazard areas raises the risk for death and injury as well as economic loss from tsunamis. As with many hazards, ignorance of the threat or ignoring the risks posed by tsunamis leads to inevitable calamity. Such consequences can be avoided by simple community planning and education.

Japan, a country that has been repeatedly struck by tsunamis, has been environmentally proactive in protecting human populations from the waves' effects by building sea walls along shorelines facing open ocean. Tsunami sea walls range up to 4.5 m (13.5 ft) in height and afford an initial break for potential incoming tsunami waves[19] (Figure 36.7). Using the same rationale, open low-lying beaches in areas of southern California in the United States utilize earthen barriers behind open beach to dissipate the energy of incoming storm waves and potential tsunamis. Maintenance of natural wet lands, forest, and vegetation that often lie immediately adjacent to open beach areas helps dissipate the energy of incoming tsunami waves and further affords protection for inland structures and habitats. Building standards and laws that limit the use of low-lying coastal lands for construction of houses, factories, schools, airports, energy plants (including nuclear power plants), and other essential human activity is a proactive method for decreasing the risk posed by tsunamis. Despite this, human encroachment into coastal zones has placed much of the world's population at risk for injury and death due to tsunamis.[20–22] Such decisions are characterized by the need to satisfy political and short-term economic goals rather than the need to implement rational decisions regarding housing and industrial zoning. Individuals responsible for these decisions often lack an understanding of the potential risks.

Community planning for the emergency response to potential tsunami events is important for decreasing risks. As with planning for other disasters, initial community efforts should include a hazards assessment of the affected area. Low-lying coastal lands facing open ocean are at obvious risk for tsunami run-up. In addition, harbors and waterways must also be


Figure 36.7. A protective sea wall constructed to repel and limit potential tsunami damage along the shoreline of Nice, France. This tsunami sea wall was constructed after Nice was struck by a tsunami triggered by a construction-generated shoreline landslide. (Source: author.) See color plate.

considered as these entities have the potential to transmit and sometimes funnel the energy of a tsunami inland. Topographical mapping of shorelines is particularly helpful in identifying potential areas at risk. Generally, areas that are less than 10 m (32.8 ft) above sea level are at highest risk for tsunami damage.[19]

The key element of tsunami disaster planning is providing a strategy for rapidly evacuating persons in the path of an incoming wave to locations inland and at higher elevation (>10 m). As noted earlier, tsunamis are sudden-impact events, but usually can be predicted immediately prior to occurrence. A system for warning those at risk of an incoming tsunami after a triggering event (example, an offshore earthquake) will allow for protective evacuation to higher ground inland. In many areas of the Pacific Rim, warning sirens have been installed to rapidly alert those in an area of immediate risk. Warning posters and signs identifying the most efficient route to higher ground are also placed in high-risk areas to facilitate evacuation. Placement of evacuation route direction signs are important interventions. It has been repeatedly noted that many people become directionally disoriented when incoming tsunami waves strike. Total evacuation of a tsunami run-up zone is important as anyone in low-lying areas is at risk for injury or death. This includes emergency first responders and security-law enforcement personnel. More sophisticated plans in developed countries not only include evacuation of emergency first responders and security personnel to higher ground, but simultaneous movement of essential portable equipment with the personnel.[21,23]

Key to the success of potential emergency evacuation plans is pre-event education of those at risk. The resident population must know basic information about tsunamis. Knowledge of the meaning of warning sirens allows persons to respond more quickly when the alarm is sounded. In addition, it is important to educate those visiting, inhabiting, or working in coastal areas that extreme and sudden raising or receding of the ocean shoreline can be a clue to an incoming tsunami. Persons in tsunami hazard areas should be aware of signage that directs people from the risk zone. Other important tsunami information includes understanding that the waves come in series and that the first tsunami wave may not be the largest. Furthermore, intervals between waves are not constant and can be markedly asynchronous. After arrival of the initial tsunami wave, further waves in the series can be spread out and may not strike the shore for more than 2 hours. Because of the predictable delay in arrival of the complete tsunami wave series, rescue personnel and equipment are generally held back 2 hours from the onset of the first wave to prevent their becoming victims.

It has been noted that tsunami warnings sometimes attract sightseers to the coastal area, causing impairment in attempts to evacuate. Control of evacuation perimeters is important. Communication by standard landlines and wireless (cellular) telephones is often ineffective due to system overload and not available to emergency operations and rescue personnel. Alternate communication methods using radio systems in redundant configurations should be considered for potential responders. Organized amateur radio operators have been valuable in helping communicate and facilitate coordination of response in past tsunami events.

Recovery efforts are often prolonged following tsunamis and, after injured survivors have received medical care, mimic public health emergencies. Mortality rates have been high in proportion to nonevacuated survivors among those directly in the path of a tsunami waves. Management of the dead and accounting for those lost and probably washed out to sea is an early recovery concern along with providing care to survivors.[24] For the management of survivors, ambulatory care supplies such as tetanus vaccine, sterile irrigation solutions, fracture splinting materials, and dressings are often the first to be depleted.[10] The disaster's impact on the mental health of victims are a particular concern.

Populations that must be considered when planning for tsunamis include visitors and tourists. Many coastal areas are popular vacation locations and those visiting may not be familiar with the risk. This was particularly true with the 2004 Indian Ocean tsunami event. In some areas impacted by this disaster, approximately half of the survivors requiring medical services were tourists and visitors.[3] Basic response information for visitors and tourists in tsunami hazard areas should be considered part of comprehensive planning.

RECOMMENDATIONS FOR FURTHER RESEARCH

Although standard plans have been developed for emergency evacuation of areas threatened by incoming tsunamis, there has been little research into the quickest and safest evacuation methods. General recommendations suggest those threatened by tsunamis should seek higher ground, but time taken in moving to higher ground may not be as effective as moving into upper stories of solidly constructed multistory buildings. The development of safe and effective maneuvers for avoiding personal injury from tsunamis represents a significant future research opportunity.

The local and international management of large-scale tsunami events is an area that research can help improve. In January 2007, Claude de Ville de Goyet published a comprehensive article describing health lessons from the 2004 Indian Ocean tsunami. His observations are summarized in the following paragraphs. This tsunami event provides a wealth of information.

Between 227,000 and 275,000 persons were lost or died as a result of the tsunami, with 1.7 million displaced.[3,12] The tsunami affected several countries and varying cultures, with Indonesia and Sri Lanka in states of government instability at the time of the tsunami strike.[12] Although thousands of reports and observations of the event are available in journals or on the Internet, few scientifically rigorous studies have been published at the time of this writing. The tsunami-related issues noted by de Ville de Goyet form a basis for a core research agenda for future tsunami disaster research.

De Ville de Goyet provides the following observations in his paper on the 2004 Indian Ocean tsunami.

1. Funding was not a primary obstacle to an effective relief response. At a global average, $7,300 was committed per affected survivor. Yet external responses to the event fell short of being effective, suggesting that abundant financial resources and technology do not guarantee a successful recovery effort.[12]
2. Few decisions were made based on needs assessments. Accountability of many nongovernmental organizations and United Nations agencies was to their donors rather than to the survivors and local governments. Decisions by outside agencies regarding the types of donations and aid offered were based on political pressures and media influences as opposed to basic epidemiological needs assessments and evaluations.[12]
3. The national public health capacities of the affected countries were minimally impacted by the disaster except for Aceh Province, Indonesia. In Banda Aceh, which was also impacted by earthquake forces, there was loss of healthcare delivery resources. Otherwise, infrastructure damage and human injury and loss occurred in the coastal areas, with inland areas remaining intact. The tsunami did not damage hospitals and public health resources directly. During a tsunami event, people who are in the coastal impact areas drown, die of trauma caused by loose debris, or survive with injuries but remain ambulatory.[10,12] Local, organized responses to tsunami events using inland resources that withstand or are not affected by the tsunami waves have been more successful than medical assistance organized from outside a community.
4. For the Indian Ocean tsunami event, international humanitarian standards were not adapted to local contexts. The "Sphere Handbook" is an internationally accepted standard for disaster response that uses a needs-based approach to compensate for disaster losses.[25] International standards published in the Sphere Handbook rely on a strong rights-based approach, which was not a predominate norm in many of the countries affected by the tsunami.

The rigid application of lofty international standards to local situations without adapting to local norms during the Indian Ocean tsunami event caused negative consequences. Responding international organizations targeted populations they could access easily for which the standards could be met, rather than seeking out those populations in locations more difficult to reach. This resulted in an over concentration of resources in urban areas. Furthermore, tourists and refugees became a primary focus as opposed to those locals trying to survive in rural regions and who experienced a more primitive existence prior to the event. There was also an overextension of the emergency phase and delay in the recovery phase. The continued influx of donated resources provided an incentive to focus on obtaining more material and volunteer aid rather than moving to the more difficult recovery actions required. The international response resulted in a dilemma for local health departments and providers because the medical standards provided during the international response could not be sustained after relief efforts ceased. The disaster response medical resources donated and supplied by outside organizations exceeded the local standards available before the event.[12]

The emergency construction of duplicate health centers and medical clinics by international responders resulted in competition between these agencies and was an example of inappropriate international aid.[12] Those providing international aid quickly overwhelmed Aceh and Sri Lanka, causing confusion and frustration for victims of the disaster. Further, the incoming aid workers and equipment added to the stress of managing the event for local emergency operations administrators. This increased demand for logistical support resulted in a second disaster, as local managers struggled to coordinate the invading relief workers and their equipment.[12]

Marginalization of local health authorities by international responders was another problem that occurred. On-site access to foreign assets, such as air transportation, equipment, and communication systems was limited to international responders. Those in the local response groups who were familiar with and culturally aware of the affected populations were left to struggle using pre-event methods and resources. As already noted, local responders not only had to manage the disaster with existing limited resources, but had the added burden of attempting to coordinate and direct incoming responders from the international sector.[12]

An additional factor compounding the difficulties caused by international response groups in the aftermath of this event was the overstating of epidemic risks. The occurrence of major secondary epidemics following sudden-impact disaster events is not the norm.[26] Although there was no evidence for epidemic risks during the tsunami event, humanitarian agencies stimulated fear of epidemics and diverted attention from recovery efforts. Rather than focusing on basic disaster medical science using surveillance techniques and health education, the international effort concentrated on immunizations for cholera, which is logistically and technically complex. This cholera immunization campaign resulted in the loss of scare operational resources for a nonexistent threat, ignoring more obvious threats such as the large numbers of children who were not immunized for measles. This very real hazard was minimized by some international "experts." The little-publicized but substantial threat from measles was identified and immunization was successfully conducted using standard field surveillance and immunization programs for high-risk populations.[27] As demonstrated here, health priorities should be based on sound public health hazard and risk assessments that usually require field work as opposed to theoretical pontification. For the affected population, repairing the environmental (water and sanitation) and economic (fishing and food production) infrastructure proved to be an immediate health priority.[12]

Medical and public health problems encountered following tsunamis have been described in a general sense, but primarily for the acute recovery or response phases. The long-term effects on health have been minimally described and this area represents a great opportunity for further research.

SUMMARY

Tsunami waves represent high-energy massive movements of water generated when enormous volumes of ocean are displaced by events such as earthquakes and submarine volcanic eruptions. The coastal regions of the Pacific Ocean are the areas of highest risk for tsunamis, but these disasters can strike anywhere that an ocean or sea meets a coastline. Injury and destruction from tsunamis occur as the waves strike the shoreline. The most common cause of death from tsunamis is drowning, followed by blunt injury resulting from loose debris thrown inland by tsunami wave run-up.

The essential elements for prevention of tsunami injury and damage are limiting construction in exposed coastal areas, developing sea walls and coastal protection barriers, and educating those at risk to seek higher ground immediately when the threat of tsunami is high. Recognizable warning systems and planned evacuation routes are keys to tsunami-response planning. It is important to understand that tsunami waves come in series and that the first wave to strike shore is not necessarily the largest of the series.

As with other sudden-impact disasters, most of the mortality related to the event occurs immediately with the onset of the event. The majority of survivors requiring medical resources are not critically ill. Most are in need of ambulatory medical care and attention to existing chronic diseases (such as diabetes) that were present prior to the event. Predominate immediate public health needs are for shelter, water, food, clothing, and mental health support. Epidemics are uncommon in relation to tsunami events. Local health agencies and governments are best at managing the response to a tsunami event and international aid organizations should remain in the background and coordinate their responses with local authorities.

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Winter Storms

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OVERVIEW

Severe winter storms can be life-changing events that isolate and disrupt families; shut down schools, businesses, and government; prevent air, ground, and water transportation; and destroy large components of agricultural and service industries. Public safety can be threatened when roads are impassable, power grids are down, and telecommunications are inoperable.

Humans can exist in extremely cold environments, but their physiology remains geared mostly for the tropics from which the species originated. Adaptation to cold is most importantly behavioral. Heat loss is slowed or prevented by avoiding contact with cold surfaces and ingestion of cold substances, sheltering from wind and precipitation, wearing of protective clothing, and physically moving to a warmer location. Peripheral vasoconstriction and shivering only modestly and temporarily protect humans exposed to significantly cold temperatures.[1] The consequences of many winter storms make it difficult or impossible for unprepared or unassisted humans to achieve the behavioral modifications necessary to mitigate the direct effects of cold or to obtain the resources needed to maintain health.

This chapter discusses the problems winter storms pose, how they fit into the continuum from minor annoyance to major disaster, and what can be done to prepare for future events that threaten the welfare of those in their paths. The disaster life cycle – mitigation, preparedness, response, and recovery – used here includes a continuous loop of planning and preparedness; warning, if any; the event itself; immediate response, which is almost always local; rapid assessment to identify needed resources; definitive response with ongoing surveillance and repeated assessments; recovery to baseline; and system improvements to increase preparedness for the next event.

Scope

Winter storms are relatively uncommon causes of disasters in Canada, the United Kingdom (U.K.), and the United States (U.S.). This is especially true in the U.S. when compared to flooding and other severe storms, which individually and collectively have constituted the bulk of Presidential disaster declarations.[2] In the 5 decades prior to the 2007–2008 winter season, the Federal Emergency Management Agency (FEMA) had listed 99 winter storms resulting in federal emergency declarations and 148 resulting in major federal disaster declarations. These represented 3% and 8.5% of the totals in each category, respectively.[3] Since 1980, the U.S. National Climactic Data Center documented 70 weather-related disasters that each cost over 1 billion (normalized to 2002 U.S.) dollars in economic damages.[4] Four involved catastrophic winter storms in the 1990s with a combined mortality of almost 500 people.[5] On the other hand, the scope of any individual potential injury/illness-creating event (PICE) in any country does not need to be as great as these to significantly alter baseline societal patterns and have a major negative regional or national economic impact.[6] These smaller events can still cause patients to access the healthcare system. The 2007 winter season witnessed two major storms affecting dense population centers in Europe and North America, resulting in increased human morbidity and mortality, and significant damage to societal infrastructures.

From January 15–19, 2007, a cyclone over the Netherlands generated a "European windstorm" with high, sustained winds and gusts up to 202 km/h (120 mph). Power was severed to more than 50,000 homes in the U.K. alone. Several major highways across Europe were forced to close, commuter rail traffic was slowed, and hundreds of commercial flights were cancelled. Ferries were halted on navigable waterways, one freighter ran aground, and another carrying hazardous cargo had to be abandoned. Overall, this storm named "Kyrill" caused widespread damage across the British Isles and Western Europe and resulted in 47 deaths. Falling objects and motor vehicle collisions (MVCs) seemed to dominate as mechanisms of fatal injury.[7]

Three major winter cyclones also made their way across North America the same month: 1) from Texas to southeastern Canada, January 11–16; 2) from Texas to the Carolinas, January 16–19; and 3) across the U.S.–Canadian border, January 19–24. More than 1 million people were without power for days during some portion of the 2-week period. Large portions of several U.S. states, plus the entire state of Oklahoma, were declared disaster areas. MVCs accounted for the majority of the 87 deaths attributed to the storms.[8]

Table 37.1: Winter Weather Definitions According to the U.S. National Weather Service Glossary

Avalanche. A mass of snow, rock, or ice falling down a mountain or incline. In practice, it usually refers to a snow avalanche.
Blizzard. The following conditions are expected to prevail for a period of 3 hours or longer: sustained wind or frequent gusts to 56 km/h or greater and considerable falling or blowing snow reducing visibility frequently to less than 402 m.
Blowing Snow. Wind-driven snow that reduces surface visibility. Blowing snow can be falling snow or snow that has already accumulated but is picked up and blown by strong winds. Blowing snow is usually accompanied by drifting snow.
Coastal Flooding. The inundation of land areas adjacent to bodies of salt water connected to the Atlantic Ocean, Pacific Ocean, or Gulf of Mexico caused by sea waters over and above normal tidal action. This flooding may impact the immediate oceanfront, gulfs, bays, back bays, sounds, and tidal portions of river mouths and inland tidal waterways.
Cyclone. A large-scale circulation of winds around a central region of low atmospheric pressure: counterclockwise in the northern hemisphere, clockwise in the southern hemisphere.
Drifting Ice. In hydrological terms, pieces of floating ice moving under the action of wind and/or currents.
Drifting Snow. Drifting snow is an uneven distribution of snowfall/snow depth caused by strong surface winds. Drifting snow may occur during or after a snowfall. Drifting snow is usually associated with blowing snow.
Drizzle. Precipitation consisting of numerous minute droplets of water less than 0.5 mm in diameter.
Flood. Any high flow, overflow, or inundation by water that causes or threatens damage.
Freeze. A freeze is when the surface air temperature is expected to be 0°C or below over a widespread area for a climatologically significant period of time.
Freezing Rain. Rain that falls as a liquid but freezes into glaze upon contact with the ground. Freezing drizzle, fog, and boat/ship spray also occur.
Heavy Snow. Snowfall accumulating to 10.2 cm or more in depth in 12 h or less, or snowfall accumulating to 15.2 cm or more in depth in 24 h or less.
Ice Fog. A suspension of numerous minute ice crystals in the air or water droplets at temperatures below 0°C, based at the earth's surface, which reduces horizontal visibility. Also called freezing fog.
Ice Jam. In hydrological terms, a stationary accumulation that restricts or blocks stream flow.
Ice Storm. Describes occasions when damaging accumulations of ice are expected during freezing rain situations. Significant accumulations of ice pull down trees and utility lines resulting in losses of power and communication. These accumulations of ice make walking and driving extremely dangerous. Significant ice accumulations are usually accumulations of 6.4 mm or greater.
Lake-effect Snow. Snow showers that are created when cold, dry air passes over a large warmer lake, such as one of the U.S. Great Lakes, and picks up moisture and heat.
Nor'easter. A strong low-pressure system that affects the Mid-Atlantic and New England states in the U.S. It can form over land or over the coastal waters. These winter weather events are notorious for producing heavy snow, rain, and tremendous waves that crash onto Atlantic beaches, often causing beach erosion and structural damage. Wind gusts associated with these storms can exceed hurricane force in intensity. A nor'easter gets its name from the continuously strong northeasterly winds blowing in from the ocean ahead of the storm and over the coastal areas.
Rain. Precipitation that falls to earth in drops more than 0.5 mm in diameter.
Sleet. Pellets of ice composed of frozen or mostly frozen raindrops or refrozen partially melted snowflakes. These pellets of ice usually bounce after hitting the ground or other hard surfaces. Heavy sleet is a relatively rare event defined as an accumulation of ice pellets covering the ground to a depth of 12.7 mm or more.
Snow. Precipitation in the form of ice crystals, mainly of intricately branched, hexagonal form and often agglomerated into snowflakes, formed directly from the freezing (deposition) of the water vapor in the air.
Snow Flurries. An intermittent light snowfall of short duration (generally light snow showers) with no measurable accumulation (trace category).
Snow Shower. A short duration of moderate snowfall. Some accumulation is possible.
Snow Squall. An intense, but limited duration, period of moderate to heavy snowfall, accompanied by strong, gusty surface winds and possibly lightning (generally moderate to heavy snow showers). Snow accumulation may be significant.
Wind Chill. Increased wind speeds accelerate heat loss from exposed skin, and the wind chill is a measure of this effect.

This information is in the public domain. It was retrieved from the National Weather Service Glossary.[9]

Winter Storms

Definitions used in this chapter are listed in Table 37.1.[9] Winter precipitation comes in the form of rain, freezing rain, sleet, and snow.[10] Colder temperatures and strong winds may magnify the ruinous effects of each on the environment. They also have direct individual and combined effects as wind chill on exposed humans and animals. Predominately warm climates may not experience freezing precipitation at all, but heavy winter rains and wind can place people and property in danger, especially through flooding. In colder climates, flooding may also occur secondary to ice jams obstructing flowing bodies of water, or as a consequence of melting ice and snow, although these events may not necessarily be related to a storm. Snow avalanches

Figure 37.1. Power lines can be downed by the direct weight of ice or by trees and limbs felled by ice, as in this example from Springfield, Missouri, following a January 2007 ice storm. This photograph is in the public domain. It was retrieved from Wikipedia at: http://en.wikipedia.org/wiki/Image:Icestorm_003.jpg. See color plate.

and snow runoff flooding are discussed in other sections of this chapter.

Winter storms are generally categorized by the type of precipitation (in the preceding paragraph)[10] or by storm type (i.e., blizzards, ice storms, lake-effect storms, and nor'easters).[10,11] Each has its own unique features with common elements that include the following:

- Cold has direct effects on people, property, and electrical and mechanical systems. Damage can be temporary or permanent. Frostbite and hypothermia are the two medical conditions most commonly associated with cold environments. They can occur indoors when power failure limits heat generation or outdoors when people are stranded in a storm, conducting necessary activities, or during winter recreation.
- Frozen precipitation creates wet conditions that can accelerate heat loss from humans and animals. Unlike liquid water that runs off surfaces, ice and snow accumulate on objects adding significant weight to structures that may not be designed to withstand the added stress. Ice can pull down power and telecommunication lines (Figure 37.1), crush roofs of buildings, and collapse bridges. Ice flowing on rivers can also damage bridges and watercraft. Ice jams may cause upstream flooding.
- Dangerous movement results from slick ground conditions, degraded visibility, and icing conditions that affect air and water transportation. These conditions inhibit the ability of people to obtain supplies and resources, as well as make it difficult to obtain assistance when help is needed. They also may indirectly contribute to falls, MVCs, recreational accidents, and other injuries related to snow removal and cleanup operations.

All these features of winter storms create hazardous situations, which slow emergency response and increase the risks for responders.

At lower elevations from October to April, populations of American, Asian, and European countries in extratropical northern latitudes are at risk from the effects of winter weather. However, regional probabilities for specific types of storms differ. As illustrated in Figure 37.2 for the U.S., winter storms are more frequent in northern states, mountainous regions, and east of the Great Lakes. They rarely occur in the southern U.S., but ice storms are especially treacherous when they do.

Human Impact

As with all PICEs, the impact winter storms have on society is what defines their magnitude. Regions having little experience with winter storms often have the least prepared populations and therefore are at even greater risk. These areas may also have local and state governments with the least capacity to respond rapidly and effectively. Unprepared communities can exponentially increase the human and economic impact of an event. For instance, 1 m of snow blanketing rural areas of America's Great Plains may minimally disrupt populations and their associated agricultural and ranching industries. In distinction, 1 cm of ice from New York City to Washington DC could paralyze major commercial, financial, and governmental centers.

Understanding the human impact of catastrophic events, so that society can be better prepared for future challenges, is the primary mission in the fields of emergency management and disaster medicine. With regard to winter storms, the medical literature mostly covers the last 3 decades. The health effects of storms that move up the Ohio River Valley from the Texas Gulf Coast and the so-called nor'easters have been the types most extensively reported in the English-language medical literature. This is due to their relative frequency and great potential impact on large population and economic centers in the north-central U.S. and northeastern seaboard.

Perhaps one of the most studied was an ice storm that affected an area of North America centered over the St. Lawrence River and extending east toward Nova Scotia, occurring on January 4–10, 1998. It left more than 4 million people without electricity – some for up to 33 days – mostly in southern portions of Ontario, Quebec, and Nova Scotia in Canada, and northern New England in the U.S.[12] Those persons displaced from their homes in Ontario, who could not move in with a relative or friend, constituted almost 5% of the affected population, placing approximately 140,000 persons in 454 emergency shelters.[13] Some Canadian hospitals were without power for 3 weeks.[14] Estimated total damages for the two countries amounted to 4–6 billion U.S. dollars.[12] One of this chapter's authors participated in the U.S. federal disaster response to northern New York State in the aftermath of this storm.

Mortality

Determining that an individual's death resulted from extreme temperatures is a diagnosis of exclusion and difficult to make without awareness of risk factors and circumstances. Databases likely underestimate the problem, as some types of reporting are not required, no precise case definitions exist, and there is little quality control over death certificates.[15] Nonetheless, U.S. data suggest that mortality from excessive cold is less common than from excessive heat.[16] However, this might not be true on a regional basis, or in countries with different climates.

Deaths from all causes in the U.S. are more common in January than in any other month. This is especially true for the elderly, and this higher mortality rate has been specifically

Figure 37.2. Winter storm hazards in the United States. This figure is in the public domain. It was reproduced from the National Weather Service's pamphlet entitled *Winter Storms: The Deceptive Killers.*[23] See color plate.

linked to colder periods.[17] A study of four consecutive winters in Minnesota showed a slight increase in mortality during cold days, but a greater increase in cardiovascular mortality during periods following snowfall.[18] One report covering six consecutive January months in Pennsylvania found that there was a 1.27-times (95% confidence interval [CI] = 1.12–1.44) increased relative risk of dying during "extreme climatic conditions" – defined as when the temperature was less than −7°C or more than 3 cm of snow had fallen.[19] A British study noted a statistically higher risk of dying in winter months during the years from 1986 to 1996 (1.5% higher for every 1.5°C decrease in temperature), especially if no central heating was used in the household (odds ratio 95% CI = 1.009–1.022).[20]

The exact risk of storm-related mortality from all causes is not well known. No universal requirement exists to report that an individual's death is, or is not, directly related to a weather phenomenon. Because of this, any generalized data must be viewed skeptically, unless the dataset from which it is derived is specified. For instance, textbooks published in 2006 and 2007[21,22] have stated that 25% of deaths are in people who are outdoors in the storm, and most of the rest die in automobiles.[23] However, these numbers come from a U.S. governmental organization that had no mechanism by which to obtain representative data. Therefore, planners cannot rely on these statistics to predict where resources will be needed to mitigate mortality rates before, during, or after a storm.

A massive blizzard in New England on February 6, 1978, was followed by two public health reports regarding mortality. Twenty-seven storm-related fatalities were identified in Massachusetts, but no overall increase in total mortality was appreciated.[24] In Rhode Island, on the other hand, researchers concluded that there was an increase in total mortality in the first 5 days following the storm,[25] although statistical methods were not used to compare the study group with an unexposed cohort.

Morbidity

During and immediately after a winter storm, the emergency department (ED) will be the first functional area affected. It is the location where ambulances bring patients from the community and where the public is accustomed to seeking unscheduled care. This assumes any given healthcare system can maintain its capabilities, or rapidly implement its preexisting plans or ad hoc processes to increase surge capacity.

A Massachusetts study of 15 hospitals found a significant decrease in ED visits on the day of the blizzard in February 1978, but daily census rapidly returned to baseline.[24] A survey of five major hospitals in northeastern New York State noted a similar trend after a January 1996 blizzard, but this was followed by a marked increase in ED volume the next day.[26] Only one literature article specifically reported the effects of a winter storm on a pediatric ED. The author found that the total daily census increased 35% in the 36 hours before a blizzard hit eastern Pennsylvania and Delaware in January 1996, decreased to very low levels during the storm, then slowly returned to normal over the next 4 days.[27] A postevent spike frequently reported in adult and combined adult/pediatric EDs was not seen, although there was an increase in the percentages of higher-acuity problems and near tripling of the admission rate.[27]

Following a particularly heavy snow storm in a region of the U.S. where snow is expected, common storm-related mechanisms of injury (in descending order of frequency) included slips and falls, MVCs, being struck by falling objects, carbon monoxide (CO) poisoning, and those related to equipment use such as chainsaws and snowblowers. A number of additional problems resulted from deficiencies in access to customary care, lack of home heating due to power loss, and inability to discharge patients to their existing home situation.[26]

Similar findings were reported from a single university medical center in the aftermath of an ice storm that hit North Carolina in December 2002, and interrupted power to 1.3 million homes.[28] Ice more commonly snaps power lines and fells trees than does heavy snow. Therefore, it was not surprising that individuals struck by falling objects during assessment and cleanup operations was the most common patient presentation. An epidemic of CO poisoning was also seen at the same institution. These mechanisms accounted for all the life-threatening injuries, except one elderly patient who likely became hypothermic after a stroke. Slips and falls, injuries associated with darkness, and burns rounded out the other causes of injury. In this study, investigators could not reliably determine that MVCs resulted from storm-related conditions in many instances, so they were not examined specifically.[28]

One of the first epidemiological reports documenting an increased incidence of fractures associated with a winter storm was published by Ráliš. The storm in question produced 5 days of snow and ice over a 1 week period around the 1978–1979 New Year.[29] In a U.K. ED that saw more than 93,000 patients per year, the number of patients with fractures increased by 2.85 times normal, peaking at a rate of 1 in every 5 patients. In descending order of frequency, the locations of fractures were the wrist and forearm, foot and ankle, hand, hip, leg, chest and spine, and head.[29] Others in the U.K. noted similar patterns when they subsequently reviewed their own experiences in the early 1980s.[30–32]

In the midwestern U.S., ice storms have led to numerous orthopedic injuries in patients presenting to EDs. Falls on ice, particularly in the elderly, more commonly resulted in extremity fractures than falls during equivalent periods of snow cover in St. Louis.[33] In the 9 days after a winter storm passed through the city of Indianapolis in February 1994, 327 injuries in 259 individuals who slipped on ice were seen at just one central hospital. Most were back injuries of various types, but more than one-third of patients were diagnosed with fractures of the nonaxial skeleton.[34] Following the 13-day ice storm of January 1998, Canadian EDs reported more than one-third of the injuries seen were directly storm related.[35] This was also true in both adult and pediatric populations in Montreal.[14] Montreal General Hospital alone performed 60 emergency orthopedic operations for storm-related injuries.[14]

CO poisoning is generally associated with winter months and its incidence can be increased by a storm that causes widespread power losses. Production of CO usually results from burning fuel indoors for heat, electricity generation, or cooking when alternative means are not readily available.[36] Exhaust fumes filling automobiles from snow-obstructed tailpipes is another mechanism of CO poisoning following winter storms.[37]

The rate of CO cases increased after a winter storm disrupted power to a large portion of the Seattle–Tacoma area of the northwestern U.S.[38,39] Thirty incidents resulted in 81 cases at 13 hospitals through the 3-day storm in January 1993. Another spike in CO cases occurred after two winter storms in late 1996.[39] Following the North American ice storm of January 1998, more than 1,000 cases of CO poisoning from at least 700 individual incidents were reported in Quebec alone, and this was likely fewer than actually occurred.[14] Four hospitals in rural Maine reported 42 incidents causing 100 cases with up to 8 patients arriving from a single scene.[40] Approximately half that number was reported for two EDs in just one Ontario city.[41] After a December 2002 ice storm in North Carolina, a single university hospital saw 200 cases of CO poisoning in 1 week,[42] and another one in a different city saw 48 after the same storm.[28]

An increased incidence of fatal and nonfatal acute coronary syndromes (ACS) has been associated with winter storms in several reports.[18,43,44] Specific risk factors could not be identified in a small cohort of patients surviving myocardial infarctions after a January 1979 blizzard in Chicago.[45] Short-term cold exposure was not believed to be the cause of increased ACS when a Canadian study examined 15 years of epidemiological data.[46] On the other hand, a Dutch study concluded that windchill might have a greater effect on cardiovascular risk than cold air itself.[47]

Heavy snow shoveling has been shown to elicit sustained heart rates near age-calculated maximums with aerobic oxygen demands similar to arm-crank ergometry.[48] Although a Canadian study concluded that the incidence of “heart attacks” was independent of snowfall, the ones that did occur were more likely to follow shoveling.[49] In distinction, an American study of ten EDs in one New York county after a January 1996 blizzard found a 6.6-times increased relative risk (RR) of ACS events. These occurred primarily following snow shoveling, and often in persons without histories of coronary artery disease.[50] Comparing consecutive January months from 1991 to 1996, a Pennsylvania study noted increased RRs of cardiac mortality in males. The risk increased for progressively younger age groups: 1.28–2.21 for those $>$ 65 years old; 1.32–2.38 for those 50–64 years old; and 2.35–5.35 for those 35–49 years old (RR 95% CIs).[19] In another study, the rate of noncardiovascular illnesses was not noted to change.[50]

With regard to pregnant women, onset of term labor was statistically more common with the low atmospheric pressures associated with weather fronts and nor’easters in one central Massachusetts study. However, the difference was interpreted as not clinically significant.[51]

Accidental hypothermia can occur at virtually any ambient temperature, but it is more strongly associated with cold air and cold water submersion.[52,53] Death rates in the U.S. are 0.08–1.99 per 100,000 population in the contiguous 48 states, although, as expected, they are higher in Alaska.[54,55] Therefore, accidental hypothermia is not a common cause of death but it is a potentially preventable one.

CURRENT STATE OF THE ART

Many paradigms for disaster response have been proposed. The American Medical Association has promulgated the acronym DISASTER in its Basic and Advanced Disaster Life Support training courses,[56,57] but efficacy data are lacking and other systems may be equally effective. Regardless of the approach, decision makers must know a problem exists before they can implement preparedness plans and devote resources to a targeted and coordinated response. It is usually easy to detect that a winter storm has dropped precipitation on a given region, but its

Table 37.2: Potential Impact of Winter Storms[59]

Index Category	*Maximum Snowfall Rate*	*Maximum Snowfall Amounts*	*Potential Wind Speeds*	*Maximum Snow Depth Drifting*	*Nature of Societal Disruption*
1	<2.5 cm/h	<25 cm	Weak	<50 cm	Minimal (h) to Nuisance (up to 1 d)
2	2.5 cm/h	50 cm	Strong	100 cm	Nuisance (up to 1 d) to Inconvenience (a few days)
3	5.0 cm/h	75 cm	Gale	200 cm	Inconvenience (a few days) to Crippling (several days)
4	7.5 cm/h	100 cm	Gale or hurricane	300 cm	Crippling (several days) to Paralyzing (up to 1 wk)
5	>7.5 cm/h	>125 cm	Gale or hurricane	>500 cm	Paralyzing (up to 1 wk)

Reproduced with permission from the American Meteorological Society with modifications for clarity.

human impact is much more difficult to determine, especially when aerial overflights and on-the-ground access to affected areas are limited. Establishing an incident command structure (see Chapters 9 and 19), regardless of size, should bring together the resources officials need to determine the security and safety of affected areas, identify hazards to responders, and coordinate the support necessary to begin rescue and recovery efforts.

Winter Hazards

Storms and their aftermaths affect both populations and societal systems, the latter of which includes responding to community emergencies and delivering healthcare outside and inside hospitals. Public health surveillance and interventions, emergency medical services (EMS) systems, and regional hospital capacity can all be adversely affected by power losses, hazardous driving conditions, and cold environments.

Weather Information

One of the purposes of government is to protect the pubic welfare, particularly with resources not available to individuals or private groups. Most developed nations have one or more methods of notifying their populaces of important weather conditions that may adversely impact people or property. In the U.S., this responsibility begins with the National Weather Service (NWS).

The NWS may issue a "winter storm watch" when "the risk of a hazardous weather or hydrologic event has increased significantly, but its occurrence, location, and/or timing is still uncertain."[9] The purpose of a watch is intended to alert the population at risk to initiate protective actions. Once its weather predictions are more certain, a "winter storm advisory" or "winter storm warning" may be issued – or the message may be more specific, such as "blizzard warning."

- The term "advisory" highlights special weather conditions that are less serious than a warning. They are for events that may cause significant inconvenience, and if caution is not exercised, could lead to situations that may threaten life or property.[9]
- The term "warning" is issued when a hazardous weather or hydrologic event is occurring, is imminent, or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property.[9]

Although print media is useful for long-range forecasts (i.e., > 24 h), broadcast media and the Internet are the most common methods used for more immediate notifications of approaching winter storms. The U.S. National Oceanic and Atmospheric Administration (NOAA) All-Hazards Weather Radio broadcasts important information directly from the nearest NWS office around the clock.[58]

Storm severity categories may help populations at risk, emergency response organizations, and other public and private facilities (e.g., government centers and hospitals) prepare for potential effects. Hurricanes and tornadoes each have a well-known severity index associated with them: 1–5 for the former and 0–5 for the latter (see Chapters 33 and 34). A five-level categorization scheme for winter storms has also been proposed.[59] It is based on intensity – directly proportional to atmospheric pressure gradients – and duration – inversely proportional to forward speed, when slower speed equates to more precipitation over any given area. Although many factors may modify the characteristics of a specific event, based on storm and population features, the overall index category may help predict a storm's impact (Table 37.2). While not in as widespread use as the categorization schemes for hurricanes, impact predictions can similarly be modified moment-to-moment as constantly updated weather data are received and analyzed.

Responder Risks

Working in cold environments can be risky for the ill prepared.[60] Emergency responders who venture into these conditions must be ready for hazardous driving or flying conditions; the effects of cold, wind, and wet conditions on themselves, their patients, and their vehicles; and on potential problems with communications created primarily by atmospheric conditions or secondarily by damage to power and telecommunications systems.

Responders must also ensure that their equipment and supplies are functional in cold environments. Vehicles must be well maintained and prepared for operations in cold weather or under slick surface conditions. This is true for all ground-based vehicles, which are subject to maintenance standards at the local and national levels if the equipment is government-owned. These same standards may not apply to vehicles owned by individuals or businesses (e.g., utility companies). The same applies to rotary-wing aircraft used as ambulances or for other public service applications, the maintenance and operations of which are even more stringently controlled, especially as regards weather.

Winter environments are harsh on vehicles. Engine and transmission oils become more viscous at lower temperatures and vehicles require longer warm-up times when kept in unheated locations. Any water in fuel lines may freeze, thus obstructing flow to the engine. Block heaters can help keep fluids somewhat warmer to facilitate prompt starting. Windshield wipers can clear the windshield of liquid water droplets, but as rain freezes, or turns to sleet or heavy wet snow, buildup can hamper visibility. Headlamps can also become covered with wet snow, reducing the light output reaching roadways to almost nothing. Snow may obscure directional signals, parking lights, and emergency flashers, making it difficult for other motorists to see vehicles at sufficient distances to avoid collisions on slick roadways.

Responding to emergency scenes is hazardous, even without the dangerous road conditions and limited visibility caused by winter storms, as well as the increased risk of becoming stranded far from shelter. EMS, fire, and law enforcement personnel usually receive formal instruction on emergency driving and gain important experience on the job. On the other hand, driving instruction for winter weather is often only didactic in nature. Few response organizations provide hands-on training that allows drivers to push their limits under real conditions in controlled situations where the potential for personal injury or property damage is minimized. Similarly, few utility companies and other public service organizations – including those delivering healthcare in fixed facilities such as clinics and hospitals – provide any driver training to those who must respond to an outdoor or building worksite. When road conditions exceed driver abilities, the number of emergency scenes may increase, and thereby compound the overall demand for rescues and out-of-hospital medical responses.

When driving during or after a winter storm, speed must be reduced for both traction and visibility concerns. Heavy snowfall and windswept snow can cause near "white out" conditions with visibility less than 50 m. Slick conditions on road surfaces will increase stopping distances. Negotiating hills and curves may be difficult. Even stepping out of vehicles can be hazardous, as slips and falls can injure responders. Parking or exiting a vehicle on a roadway can be very dangerous when other vehicles are moving around it. Distracted by flashing emergency lights, other drivers may lose control of their own vehicles causing impacts with emergency response equipment and their crews or with other vehicles, causing more injuries that will consume even more automobiles.

Black ice is a term referring to a thin layer of ice that cannot be seen when it is adherent to darkly colored road surfaces. Yet it is just as treacherous as an icy surface several centimeters thick. This invisible ice layer can develop in minutes when a wet roadway at the freezing point suddenly becomes colder due to evaporation via wind or with the loss of the sun's heat (e.g., clouds, sunset, or shade).

Crashes and vehicle incapacitation can result in response personnel being stranded while driving in inclement weather, ice, or heavy snow. Radio communications may be degraded and cellular telephones may be nonfunctional during or immediately after a winter storm. Response personnel must be prepared for the inability to communicate with their own dispatch authority, other emergency response agencies, and an Emergency Operations Center (EOC). Medical control for patient care advice or authorizations beyond an EMS crew's standing orders or scope of practice might be limited. Communications problems may also make it difficult to call for assistance, if stranded.

All emergency response personnel venturing into the winter environment must have operational guidelines for a communications outage or cold weather vehicle failure. Most authorities recommend stranded motorists stay with their vehicles – although caution to guard against cold injury, if not heating the interior, and CO poisoning, if running the engine or using some other kind of heat source.

Many emergency response vehicles, which operate in areas likely to receive ice and snow, are equipped with chains. These can be attached either directly to their tires or to a deployable apparatus under the chassis. In the latter situation, at the touch of a button, chains are rotated on a horizontal axis near the tires resulting in enhanced traction equivalent to chained tires.

Response personnel must be properly attired, equipped, and trained for work in cold, windy, and wet scenarios. Typical clothing worn by EMS responders on a day-to-day basis may not adequately protect them from the elements, as winter storms may force them into prolonged scene times in outdoor environments, to which they may be unaccustomed.

Care should be taken to select clothing that will minimize the risk of injury yet maximize dexterity and function. The overarching goals would be preservation of core body heat and minimizing exposure of skin to cold air and surfaces. Such garments, while important, are insufficient alone to protect responders. Rescue personnel must be knowledgeable about environmental conditions so that proactive and reactive behaviors prevent problems before damage occurs or mental status is affected to the point that behavior is no longer compensatory. The following are recommendations for the prevention of cold-induced challenges.[52,61,62]

- Maintain adequate hydration, nutrition, and get sufficient rest. Being in excellent physical condition is a definite advantage. Use of tobacco products is detrimental to good circulation. Clean, healthy skin is protective for cold injury, but washing too frequently can dry and damage the skin's protective barrier.
- Wear garments that provide thermal insulation and trap air between fabric layers. The mnemonic for prevention of COLD stands for clean fabrics; opening for ventilation during exercise, to avoid wetting perspiration; loose layers to retain insulating air pockets, and allow for donning and doffing layers as conditions change; and dry garments, which must be changed if they get wet. Make sure the head is well insulated, because significant body heat can escape from the exposed scalp.
- Avoid tight-fitting clothing and restrictive gloves or boots. Liners improve the insulation of both. When dexterity is not needed, mittens are more effective at retaining heat than are gloves.
- A balance must exist between external water impermeability, and the risk of retaining sweat inside protective garments that cannot breathe. Particularly with regard to the feet, wet conditions soften the skin, which can lead to debilitating nonfreezing injuries like trench foot. Even damp socks should be exchanged for dry ones, so extras must be available.
- Protect exposed skin surfaces from cold and windy air, as well as from cold liquids and surfaces. Avoid damaging skin through ultraviolet radiation directly from the sun or

indirectly from reflection off ice, snow, water, windows, or light-colored building surfaces.

- Use the buddy system. Trained individuals, who consciously and frequently check each other, will decrease the likelihood of insidious frostbite and hypothermia.

A discussion of the precautions needed for specialized responses, such as cold water or mountain rescue, is beyond the scope of this chapter.

Local Medical Responders

Winter storms may severely limit the ability of first responders to reach callers in a timely manner or to find victims during a community needs assessment or deliberate search. Once located, the delivery of care to these victims may occur in a relatively austere medical environment for periods of time that may far exceed those to which EMS personnel are accustomed. Transportation to a permanent or temporary medical facility, or even to a heated shelter with power and food, may be so treacherous that the risk/benefit ratio is higher than staying in place. Response organizations and systems must consider how to best plan, train, operate, and recover in these environments.

Human access, care, and evacuation (HACE) is a term coined by Mark Gebhart and James Gruenberg of the National Center for Medical Readiness (personal communication). The concept describes the situations faced by emergency responders in performing their out-of-hospital duties after a call for help has been initiated and will serve as an outline for the next discussion.

Access

The austere environment associated with storms can significantly limit responders' ability to access known victims, or search areas to locate missing victims. Much has been written regarding tactics, techniques, and procedures for searching for victims who cannot call for help after an area has been hit with freezing precipitation. However, virtually nothing has been published on best practices for EMS personnel, who must access persons who have requested urgent assistance.

Because such efforts would certainly require coordination with other public safety agencies (e.g., fire and law enforcement) the effort should be managed through a local or regional EOC functioning under an incident command structure. Utility companies also participate when downed power lines or ruptured natural-gas or water pipelines threaten the safety of responders. In advance of a winter storm, a local EOC could prohibit ambulances from traveling off snow-plowed roadways, yet still be responsive to requests for assistance. Response assets could be reorganized into task forces, such that a call for medical assistance would result in dispatch of a fire engine with personnel, a snowplow, and a four-wheel-drive vehicle with a command officer and a medic. These resource groupings could be kept intact between calls. Public health representation could also facilitate collection of data for a rapid needs assessment.

Care

Despite governmental regulations and industry guidelines on vehicle operations, there are fewer standards regarding storage and use of onboard medical equipment and pharmaceuticals in cold weather. Ground-based ambulances can often be parked in a shelter or garage while awaiting calls. This is rarely an option for helicopters that must respond rapidly, especially when they are hospital based. Three studies have examined the temperature inside medication containers stored on rotary-wing ambulances, two from North America[63,64] and one from Europe.[65] Both identified temperatures far outside the range recommended for pharmaceutical storage, although the clinical impact of this is unknown. An important exception would be cold intravenous fluids, which could be potentially harmful to many patients if given in any significant quantity.

Individual out-of-hospital patient care should remain essentially unchanged, as long as responders are aware of the increased occurrence of cold weather conditions and consideration is given to potential delays in access and evacuation. Illnesses may be more advanced or complications of injuries may be more manifest when access is delayed. Additionally, the duration of care may be extended for longer than EMS and rescue personnel are otherwise accustomed. Depending on limitations in evacuation options or extensions of transportation times, the duration of on-scene medical care may last for hours, or perhaps even days, in extreme circumstances.

Evacuation delays can necessitate hemorrhage control methods less familiar to civilian EMS responders. Application of clot enhancing agents such as fibrin, microporous polysaccharide microsphere, mineral zeolite, or poly-N-acetylglucosamine (chitosan) may be useful adjuncts.[66,67] Exsanguinating extremity hemorrhage may require control with a proximal tourniquet, either by inflating a blood-pressure cuff or applying a prefabricated or field-expedient device.

Delayed response to patients with advanced disease is less concerning for the responder community because people often postpone seeking medical care, even in the absence of a storm. On the other hand, injured patients are likely to seek care immediately, yet medically trained providers may have difficulty accessing them rapidly. Delayed complications (e.g., established wound infections, gangrene or tetanus, and compartment syndromes) or progressive conditions (e.g., increased intracranial pressure, pulmonary contusions, and slow intracavitary hemorrhage) may be less familiar to EMS personnel. Their scope of practice may only allow for supportive care, even when delays in evacuation to definitive care could result in loss of life or limb.

With regard to cold weather conditions, frostbite and hypothermia are the most common. The out-of-hospital management of these conditions should focus on removing the patient from exposure to the cold insult and supporting the patient during evacuation to a higher level of care. Active rewarming is difficult in the field. In situations of widespread power loss, the only source of added heat may be the interior of an evacuation vehicle. Other techniques may be available, if specialized equipment is positioned in the response vehicle and functional. In general, though, active rewarming is normally conducted at a medical facility.[52]

Cold injuries can be divided into nonfreezing and freezing categories. The former includes pernio, trench foot, and immersion foot. Pernio results from the combined effects of wet and cold skin, but may occur in dry nonfreezing conditions. Trench foot follows chronically wet feet exposed to near-freezing temperatures and made relatively ischemic by vasospasm and increased tissue pressure induced by standing. Immersion foot results from skin that has become waterlogged from prolonged cold water immersion.[61] Injuries that actually freeze tissue include frostnip and frostbite.[62]

Pernio, also called chilblains, is a localized inflammatory condition of the skin, which results from an abnormal tissue response that develops over 12–24 hours after cold exposure. It most commonly manifests as tender, bluish or purplish, subcutaneous nodules in exposed areas. These lesions are often associated with edema or blister formation. A history of Raynaud's phenomenon is not uncommon. Treatment consists of local massage to stimulate blood flow and slow rewarming at normal room temperatures. Active rewarming with higher temperatures significantly increases the intense burning and itching associated with resolution.[61,68,69] Nifedipine, a dihydropyridine calcium channel blocker, may have a role in hastening clearance of the lesions with less discomfort and may also reduce the likelihood of recurrence.[70]

Trench foot and immersion foot are clinically indistinguishable. They both progress insidiously through three phases: prehyperemic, hyperemic, and posthyperemic. Intense vasospasm causes skin blanching and mottling in the prehyperemic phase. Peripheral pulses may be diminished and capillary refill is usually prolonged. Continued exposure results in anesthesia and gait disturbances from damage to sensory and proprioceptive nerves.[61,68] Rewarming creates a hyperemic condition with erythema, petechiae, swelling, pain, and hypesthesia – yet is still associated with prolonged capillary refill.[71] Epidermal sloughing may occur.[61] Nerves controlling voluntary muscular action and vibratory sensation may be adversely affected.[61] Therefore, the goal of treatment is rewarming core body temperature without directly warming the affected body parts, so as to keep the metabolic demands of the injured tissue low.[61,68] The posthyperemic phase is not normally seen in the field, unless evacuation is significantly delayed after rewarming.

Frostnip, which heralds the beginning of tissue ice-crystal formation, is a warning sign that frostbite is imminent. Vasoconstriction leads to pallor, localized pain, and sensory numbness. Clinical manifestations can be readily reversed by preventing additional cooling and by rewarming the affected body parts.[61,68]

Frostbite represents freezing of extra- and intracellular water with cell injury or destruction leading to tissue damage, which can be compounded by microvascular stasis and ischemia. Typical symptoms progress from feeling local cold to loss of sensation.[62] Pain may occur in a "watershed" area between frostnip and frostbite, typically more proximal to fully involved areas of distal tissue damage. Frozen skin may appear a waxy yellowish white or translucent bluish color. It may be frozen solid.

Prevention of further cooling should be the primary goal prior to in-hospital management of frostbite.[62,72] Wet, or possibly frozen, clothing should be gently removed. If stuck to the skin, other portions of any garments can be cut away, leaving frozen bits of clothing adherent to the skin.[73] Out-of-hospital rewarming of frozen tissue is generally discouraged, unless evacuation to definitive medical care will be significantly delayed.[72]

A 10-year Canadian study found that delay to medical care was one factor associated with poor frostbite outcome, so delayed access or prolonged evacuation times may have implications for prognosis.[74] One author has suggested 2 hours of field time as a cutoff to begin thawing in the field, but only if no chance of refreezing is possible.[75]

In these settings, the position of the International Commission for Alpine Rescue might provide the most useful extrapolation from mountaineering to victims stranded by a winter storm.[76] Guidelines are divided into whether the victim is out in the open or inside shelter but commonalities include: removal of wet clothing; orally administered warm fluids; and aspirin up to 1 g or ibuprofen up to 800 mg, if available. In shelter, if a warm 37°C bath is considered for active rewarming, the patient should not be allowed to subsequently use the effected body part that has been warmed, which includes walking if the feet are involved, until after definitive care has been rendered. Because edema will ensue as the part is warmed, the area should be elevated and dry dressings loosely applied.[76]

Prevention of further cooling is also the primary goal for the out-of-hospital treatment of hypothermia.[52,53,72,77] However, other field management options are limited. Patients with mild hypothermia (i.e., core body temperature 32–35°C and still capable of shivering) may warm themselves by being covered with dry, heat-retaining clothing, blankets, or other items. These interventions allow endogenous heat production through metabolism and the shivering reflex. These constitute the passive external rewarming technique. Active external rewarming involves the addition of exogenous heat to the body through a warm environment or radiant heaters. These can be supplemented by warm oral or intravenous fluids. These methods of active internal rewarming have only a minor temperature-raising effect, although an added benefit results because many victims of hypothermia are also dehydrated.

Bradycardia is frequently observed at core temperatures less than 28°C. In severe hypothermia, when the temperature is less than 25°C, more life-threatening cardiac dysrhythmias occur. Development of new atrial fibrillation is ominous, as it may herald the risk for subsequent ventricular fibrillation. When dysrhythmias complicate hypothermia, the treatment of choice is rewarming. Medications are not likely to be helpful until the heart is warm.[78] Transthoracic pacing is possible, but not required in most cases.[78,79]

Evacuation

Just as winter weather can affect the ability of first responders to access victims, it can also make it hazardous or difficult to transport them from out-of-hospital locations to medical facilities. The usual assets may not be available. Standard ambulances may be incapable of driving to or from the scene. Few have four-wheel drive, so responders may need to use nonmedical vehicles of expediency. Moreover, helicopters are frequently incapable of flying. In a Canadian study, 30% of requested helicopter EMS missions were aborted due to weather. This was the next most common reason behind the 42% combination of the helicopter not being the appropriate vehicle and cancellation by medical control.[80]

Determining the most appropriate destination for patients should be guided by local protocols, but the environment may force additional considerations in a disaster setting. Some medical facilities may be directly affected by the weather. Impaired ground and air accessibility, power losses, and staff absenteeism are just a few of the reasons a hospital or other facility can lack capacity to receive new patients. Other facilities may be overwhelmed by high patient volume and higher patient acuity in a storm's aftermath. Routing of transportation assets directly to centers offering specialty services may be required for pediatrics, major trauma, serious burns, and hyperbaric oxygen therapy; however, transportation to these locations can be dangerous in hazardous winter conditions.

Finally, the possibility of being stranded during evacuation can complicate patient care, forcing paramedics to treat patients for much longer durations than medical training, supply quantities, and vehicle power were designed. The availability of medical control telecommunications to assist medics in these unfamiliar situations is frequently uncertain.

Local Medical Receivers

The most significant problems for hospitals often relate to inadequate staff (e.g., inability to surge with off-duty personnel due to weather, on-duty staff overworked due to lack of relief) or capability degradation (e.g., interruption of facility water and power and supply depletion). Nonetheless, patients will arrive seeking care for a variety of baseline and storm-related problems. As in the out-of-hospital setting, the care delivered to individual patients is similar to what is required in other situations, except that cold-induced injury, hypothermia, CO poisoning, and other storm-associated issues may complicate management. Establishing disaster triage protocols to screen victims for these potentially occult problems may enhance ED operations.

Primary Triage

Because the ED is the focal point for victim reception, it is also the site for initial triage of persons requesting medical care. All individuals must be screened for emergency conditions whether or not their problems are attributable to the storm. In addition to standard triage questions for potentially serious illnesses and injuries, high indexes of suspicion for frostbite, hypothermia, and CO poisoning are required. Triage personnel should specifically ask about exposure to cold, wet, or windy conditions, as well as the possibility of exposure to burning fuels. Such diligence is necessary to limit the risk of missing these potentially occult conditions in the face of an unrelated chief complaint.

If sufficient resources are available for the volume and acuity of conditions, little or no adjustment to routine operations is necessary. However, any excessive patient need or limitation in healthcare capacity may require a different approach to triage and activation of facility disaster plans. Protocols should address the probability of various conditions, establish reasonable diagnostic parameters recognizing the potential limitations in laboratory and radiology services, provide management guidelines, and identify admission and discharge criteria.

Emergency Care

Traumatic injuries directly related to the inclement weather include those sustained during outdoor movement (e.g., slips and falls and MVCs), cleanup efforts (e.g., snow clearing, tree removal, and utility repair), and recreational activities (e.g., sledding and snowmobiling). As most of these mechanisms are familiar to emergency professionals, only those unique to winter weather will be covered in this chapter.

Snowmobiles can be important methods of transportation in some northern areas. Snowmobile collisions involve drivers, passengers, pedestrians, and people being pulled on sleds. Most injuries are musculoskeletal, but head, chest, and abdominal injuries occur frequently. Injuries around the knee are common, and fractures of the femur and tibia represent almost half of the injuries. In a study of snowmobile collisions in Canada, 74% of victims required surgery with a mean of 1.6 operative procedures per patient.[81]

Patients with complex wounds caused by a variety of mechanisms may present to the ED. Many follow the use of power equipment for clearing debris, fallen trees, and snow. Chainsaw injuries

Figure 37.3. Typical snowblower injury. The patient placed his hand into the running auger to remove a chunk of ice with resulting open fractures of the index and long fingers. The avascular, denervated index finger was amputated at the metocarpalphalyngeal joint. Photograph courtesy of William H. Dice, MD. See color plate.

occur throughout the year,[82] but snowblower injuries can be expected following a heavy snowfall.[83] In a 1997 storm in Rhode Island, seven of 11 patients injured by snowblowers indicated that they placed their hands into a running machine, although three of the remaining patients said that the machine was off at the time of injury. Amputation was common as were fractures and tendon injuries. Ten hand injuries were managed in the ED by hand surgeons and one required inpatient treatment. The majority of cases involved the index, long, and ring fingers (Figure 37.3).[84]

Management of open wounds should follow traditional wound care guidelines. Wounds should be thoroughly described with emphasis on size, shape, depth, foreign material, local perfusion, distal circulation, tendon function, neuromuscular strength, and two-point discrimination prior to induction of anesthesia. Plain radiography should be routine. Computed tomography scanning or ultrasound may be used to further evaluate for deep foreign bodies.

Bleeding and pain must be controlled prior to imaging studies. Resuscitation may be required, and significant blood loss might necessitate transfusion. Administration of blood products in the face of a winter weather emergency should be carefully considered because of the limited ability to replace banked blood. Both regional anesthesia and procedural sedation are useful adjuncts to ED evaluation and management of large complex wounds.

An important prerequisite for complete assessment is a bloodless field. Arterial bleeding can be controlled by ligating small vessels or using a blood-pressure cuff inflated proximally. This tourniquet technique can be applied for up to 2 hours while vascular control is achieved, the wound is explored, and copious irrigation is accomplished.

All open injuries from power tools should be considered crushed and contaminated, and thus require thorough cleaning to remove gross debris and reduce bacterial load. A pulsatile lavage system using 130 kPa (19 psi) and high flow rates is recommended. Irrigation should be performed within 6 hours of injury to get the best results.[85] Use of a 19-gauge catheter attached to a 30- or 60-mL syringe can achieve an adequate stream pressure of

35–55 kPa (5–8 psi). Clean tap water is an acceptable alternative to saline for irrigation of wounds.[86] Debridement of devitalized tissue is important.

Because a winter storm might delay presentation of patients with complex wounds and availability of consultants may be limited, emergency physicians and others performing primary patient evaluations should consider delayed primary closure in some cases, especially in those whose wounds are more than 6 hours old. If not limited by restrictions on travel or personal resources, the patient can return for daily dressing changes prior to definitive debridement and closure in 3–5 days. Nonoperative ED management of fingertip amputations is accepted practice, although telephone consultation with a hand specialist is advised prior to repair.[87]

Tetanus prophylaxis is an important consideration for complex wounds. Every patient with a wound is susceptible to tetanus, even though there are few reported cases in developed nations. Public health authorities recommend a tetanus toxoid booster when there is evidence of a complete initial vaccination series. In the absence of primary immunization, tetanus immune globulin plus tetanus toxoid is recommended with referral for the second and third doses of tetanus toxoid to complete primary immunization at a later time.[88]

The use of antibiotics by any route in the management of simple wounds offers no clear advantage in preventing infection.[89] Physicians should consider the potentially limited availability of pharmacies and the ability of a patient to return for complications when recommending antibiotics or other medications. Use of antibiotics for noninfected simple wounds is a questionable practice and is generally not supported in the literature. However, wounds that involve tendons, bones, nerves, or large vessels generally include antibiotics in ED management.

In addition to trauma, the winter environment is further associated with cold injuries and hypothermia in individuals representing a wide demographic range.[73] Disabled persons, the elderly, and the socially disadvantaged are at particular risk.[52,74] Electrical failures lead to use of alternative power and heat sources that are associated with CO poisoning.[40] Patients can succumb to permanent disability or even death if healthcare providers do not actively assess for clinically occult primary or complicating conditions secondary to CO exposure.

Freezing (e.g., frostbite) and nonfreezing (e.g., trench foot and immersion foot) cold injuries are debilitating and should be anticipated. The risk for cold injury is markedly higher in both African American men and women than in whites of either sex.[90] Additional risk factors include alcohol or drug use, psychiatric disease, motor vehicle trauma, and motor vehicle breakdown.[54,55] Patients with prior cold injury appear to be susceptible to recurrence.[74]

Symptoms and signs of cold injury begin when skin temperature falls below 15°C, and vasoconstriction reduces blood flow. Skin changes occur when extracellular ice crystals form at temperatures below 0°C. Intravascular sludging begins, endothelial leakage occurs, and edema develops. Findings associated with cold injury are based on the changes associated with tissue ischemia and the freezing process.[73]

Frostbite is definitively managed by active rewarming without massage. A practical, three-step approach is required to manage frostbite efficiently: 1) remove any constricting or wet clothing, gently drying the involved area, and protecting it from evaporative cooling and direct pressure with loosely applied dry dressings and padding to halt ongoing insults; 2) examine affected skin areas for signs of ischemia, change in texture (e.g., waxy, inflexible, solid), presence of blisters, and loss of sensation; and 3) rewarm affected parts rapidly until all skin out to the most distal portions appears perfused and pliable.

In the ED, frostbite is treated with rewarming, hydration, wound care, and pain control. Rapid rewarming is the immediate objective once frostbite is discovered. Dry external heat is not appropriate for frostbite. Rewarming should take place in a water bath at 40–42°C, usually for 15–30 minutes until signs of skin reperfusion are evident (i.e., red or purple color and pliable texture). Systemic fluid resuscitation is usually not required, as it is in thermal burns. Once the part is rewarmed it should be elevated, splinted, and the toes and fingers separated with cotton. Rewarming is painful and parenteral opioid analgesics are usually required. Debridement of the blisters that form after rewarming is controversial and is generally not performed in the ED.

Use of thrombolytic agents has shown some promise in reducing tissue loss when given within 24 hours of rewarming.[91] Other attempts to use agents to enhance blood flow into and through thawed tissue have not been successful in clinical studies. Heparin, dextran, intra-arterial reserpine, hyperbaric oxygen, and surgical sympathectomy have been used in frostbite treatment without dramatic changes in tissue salvage.[91]

Frostbite may be categorized as deep or superficial, although some clinicians use a grading system of 1–4. Classification is made after rewarming. Favorable prognostic signs in superficial frostbite include sensation to pinprick, blisters containing clear fluid, and normal skin color. Poor prognostic signs in deep frostbite include nondeforming hard skin, loss of sensation, blisters filled with dark or bloody fluid, and nonblanching cyanotic skin color.[68]

Tools are not available in the ED to define the full extent of cold injury and provide a prognosis for tissue loss. The standard of care includes a "wait and see" approach to amputation that can be quite prolonged because mummification may take up to 3 months. Researchers have studied, with limited success, the value of magnetic resonance imaging and magnetic resonance angiography in predicting tissue viability.[92] Technetium-99m (^{99m}Tc) scanning has also been used to identify tissue that will require amputation.[93] One study in France of severely frostbitten hand injuries suggested that ^{99m}Tc scanning in the first few days after rewarming predicts the level of amputation for 84% of cases.[94] However, other studies suggest that ^{99m}Tc images do not accurately identify eventual levels of gangrene.[92] Generally, surgeons are reluctant to decide on an amputation level until complete demarcation occurs several months later.

Patients can experience long-term symptoms from their cold injuries. Deep frostbite is associated with cold sensitivity, increased sweating, pain, hypersensitivity, and skin color change. Superficial frostbite is associated with persistent cold sensitivity, numbness, and loss of sensation.[62] Nonfreezing trench foot can result in muscle atrophy and contractures.[61] Cold injuries may result in chronic occupational impairment.

The incidence of accidental hypothermia is a public health issue year-round, especially as it relates to socially disadvantaged persons. These groups are at risk for being disproportionately affected by a winter storm. Other groups may also be affected if they are displaced from their residences by power failures or structural damage. Hypothermia can masquerade as other illnesses, especially in people with risk factors for altered mental status, syncope, and dysrhythmias. It can also be missed in trauma victims, who have more obvious challenges. Hypothermia can be overlooked in patients who are homeless, use alcohol or drugs, or have chronic conditions such as diabetes, hypothyroidism, and psychiatric illness.[95] Triage procedures should include core temperature measurement during cold environment disasters.

Hypothermia coupled with infection is associated with increased mortality. Patients with slow rewarming rates (0.5–1°C/h) and low serum albumin are more likely to harbor infections. Hypotension, slow rewarming rates, and bradycardia might be predictors of death during or soon after rewarming.[96] Sepsis should always be included in the differential diagnosis of all degrees of hypothermia.

Victims of trauma, particularly vehicle crashes, are at risk for hypothermia as a result of delays in discovery, extrication, or evacuation. Trauma patients with a core temperature less than 34°C might have a 35% increase in mortality.[97] Hypothermia is associated with electrolyte abnormalities, acid-base disturbances,[98] coagulopathy, and thrombocytopenia.[99] Hypothermic coagulopathy appears to be similar to disseminated intravascular coagulation and might require management with plasma, clotting factors, and platelets. Partial thromboplastin and prothrombin times should be measured early in the evaluation of trauma patients who might be hypothermic.

Complete blood count, basic metabolic profile, and arterial blood gas analysis may be helpful in assessing hypothermic patients. Temperature correction of blood gas results is unnecessary during initial management. Severe hypothermia can be associated with lower cardiac output from loss of plasma volume and correlates with a rise in hematocrit of approximately 2%/°C decrease in core temperature.[52] The loss of intravascular fluid can potentially decrease renal blood flow by 50%, which may result in renal failure. In the absence of significant electrocardiographic changes, correction of low potassium is generally not required because warming reverses the abnormality.

Endotracheal intubation and mechanical ventilation are necessary for patients with respiratory failure or cardiac arrest. Traditional rapid-sequence induction drugs are acceptable for hypothermic patients; care is needed to minimize airway and cardiac stimulation because of the risk of ventricular fibrillation. Life-threatening arrhythmias associated with hypothermia are notoriously difficult to manage.[78]

Preventing additional heat loss from wet clothing and skin, and exposure to ambient air is the first step in the ED management of hypothermia. Attention is then directed to core rewarming, which is the major focus of activity to reverse the untoward effects from lowered core temperature. Passive and active external rewarming techniques are recommended for mild hypothermia, when core temperatures are greater than 32°C. Covering the patient with blankets accomplishes rewarming by containing and reflecting heat generated by the patient's own metabolism. As in the out-of-hospital setting, active external rewarming with radiant warmers or heated air can supplement this approach. These techniques can raise body temperature 0.5–0.8°C/h.[73]

Moderate and severe hypothermia require more aggressive management with active core rewarming – methods being mostly determined by physician expertise and hospital capabilities. Although core temperature "afterdrop" is an anecdotal observation when active external rewarming is used, the clinical significance of central pH and temperature changes reported when the periphery and core are warmed concurrently remains elusive.[100]

Indicators of irreversible hypothermic cardiac arrest include serum potassium concentrations of greater than 10 mEq/L or fibrinogen less than 50 mg/dL.[95] When potentially reversible cardiac arrest complicates hypothermia, cardiopulmonary bypass (CPB) is the treatment of choice when available.[101,102] The warming rate for CPB is 1–2°C every 3–5 minutes. A mechanical chest compression device might be useful when the availability of CPB is delayed.[103] Other indications for CPB are solidly frozen extremities, rhabdomyolysis, or failure of other rewarming techniques.[95] An alternative to CPB is hemodialysis, which achieves similar rewarming rates, and offers some advantage when electrolyte abnormalities, metabolic acidosis, or renal failure complicate hypothermia.[104]

Most hospitals are not equipped to perform emergency CPB or dialysis. Active internal rewarming by aerosol inhalation, gastric lavage, bladder lavage, and warm enemas may be appropriate for moderate hypothermia but are mostly ineffective for victims with severely depressed core temperatures.

However, thoracic and peritoneal lavage are alternative therapeutic options in the ED. In either technique, two intracavitary tubes are placed under aseptic conditions. Sterile water or crystalloid fluid warmed to 40–42°C is allowed to circulate through either the chest or peritoneal cavities from one tube to the other and drain by gravity. Thoracic lavage is an effective method of active internal rewarming[105] and can achieve warming rates of 3–6°C/h.[106] Thoracic lavage might be preferable because the heart is warmed directly. Peritoneal lavage is an additional effective method that can achieve warming rates of 2–4°C/h.[107] They can be performed together.

CO poisoning is another winter-related condition, which can be confused with nonspecific viral syndromes and other common causes of headache because patients most commonly present with headache, nausea, and dizziness.[108] People with other medical conditions such as heart or lung disease might be more susceptible to the effects of CO and present to the ED for treatment of chest pain or shortness of breath.[109] Severe CO poisoning contributes to ischemic myocardial injury and can double mortality rates.[110]

Depression, dementia, and psychosis have been reported between 2 and 28 days after CO poisoning. Carboxyhemoglobin concentration does not, however, reliably predict delayed neurological sequelae such as an inability to concentrate, learning impairment, memory loss, and abnormal motor function.[111]

The standard measurement for the presence or absence of CO is blood carboxyhemoglobin concentration. Pulse oximetry is unreliable when CO is present because artificially high saturation readings are associated with carboxyhemoglobin.

The treatment for CO poisoning is a high concentration of inspired oxygen. The half-life of CO breathing room air is approximately 5 hours. The half-life decreases to about 1.5 hours on 100% oxygen by either face mask or ventilator and to 0.7 hours using hyperbaric oxygen therapy.[108,112] Hyperbaric chambers traditionally used to treat CO poisoning are located at fixed facilities but success has also been reported with portable chambers.[113]

Generally, hyperbaric oxygen therapy is indicated for any history or persistence of syncope, altered mental status, neurological impairment, or myocardial ischemia, as well as for most pregnant patients.[108] Hyperbaric treatment might also be indicated in patients found to be at higher risk for long-term cognitive impairment (i.e., patients >36 years old, exposure >24 h duration, or "higher" carboxyhemoglobin levels).[114] One study suggested that hyperbaric treatment reduced one in six cases of delayed neurological conditions when treatment was begun as late as 24 hours after poisoning.[115] Others studies have found little benefit of hyperbaric treatment when delayed longer than 6 hours.[116] In any case, hyperbaric facilities may be scarce resources that are difficult to access during the aftermath of a winter storm.

Because hyperoxia is associated with hypocapnia, which in turn decreases cerebral blood flow, one study of healthy volunteers indicated that ideal treatment of CO poisoning might include maintenance of normocapnia.[117] An animal model suggested that hyperventilated intubated patients breathing higher concentrations of CO_2 to maintain an arterial p_aCO_2 of 5.33 kPa (40 mm Hg) might eliminate CO twice as fast,[118] but the clinical significance of this in human CO poisoning is unknown.

In terms of preparedness for epidemics of CO poisoning, one report of an epidemiological spike during a winter storm found that almost four of every five patients arrived between 18:00 and 06:00 hours.[39] In this study, the 81 patients were distributed over 3 days and 13 hospitals,[39] so the impact on individual EDs in that urban area was not too great. Even at a large university medical center in North Carolina, an epidemic of 200 cases in 1 week resulted in the need for hyperbaric oxygen therapy that outstripped available chambers in the area.[42] The chamber at Hôpital du Sacre-Cœur de Montréal was used to treat 45 patients in the first 9 days after the Ice Storm of ’98.[14]

Secondary Triage

Secondary triage to specialty centers can be interrupted by degraded conditions at sending and receiving facilities in the midst of a weather emergency. Interfacility patient transportation in inclement weather or over dangerous roads can be a serious challenge. Regional referral centers have been created for services not available at all hospitals. Examples include such specialty services as trauma, burns, and hyperbaric therapy. Rural and suburban hospitals could require all of these services in association with a winter storm event. In situations where resource needs exceed availability, these facilities can be overwhelmed.

A scarce specialty resource may be unavailable. Therefore, contingency plans must be in place for community hospitals to manage cases on a temporary basis that are normally transferred under less constrained circumstances. Increased needs and evacuation delays may require all healthcare professionals to adjust procedures. Tertiary care centers should be prepared to increase capacity for those they can receive and provide enhanced consultative services by telecommunications to facilities unable to transfer patients (see Chapter 23).

Disposition

ED and hospital discharge planning may require coordination in ways that are atypical and challenging. Displaced persons frequently find it difficult to return home. Physicians must consider several issues when discharging such patients. Is the patient’s home still intact? If so, will the patient go to a home without power, heat, or communications? If not, will the patient go to a shelter that may limit their ability to care for themselves? Other options include patients remaining at the hospital for longer periods. However, this can potentially limit the number of additional admissions. Moving patients to less crowded hospitals is difficult due to existing road conditions or weather affecting or aeromedical transportation. Even when patients can be discharged, home healthcare services (e.g., oxygen, pharmaceuticals, and nursing care) or the ability to return for additional treatment (e.g., chemotherapy or dialysis), on which they depend, may not be available. Follow-up clinics may not be open for days or weeks.

Healthcare Systems

Winter storms may limit the capacity of first receivers to manage patient flow to their institutions. Patients often find their own transportation or are transported by others to community Eds, regardless of their capacity to accept new victims. During these mass casualty situations, the standards of care are often modified, so the most good can be done for the most people. To achieve this goal, providers should shift to a “minimal acceptable care” standard. These and related concepts are discussed in more detail in Chapter 3.

Permanent Facilities

The most critical systems for hospital operations are[119]

- Physical plant
- Utilities
- Personnel
- Supplies and equipment
- Internal and external communications
- Transportation
- Supervisory and managerial support

These can all be adversely impacted by winter storms. Power loss may affect lighting, medical equipment, and safety systems. Frozen pipes may block ready access to clean drinking water, water for personal hygiene, and sewage outflow. Hazardous road conditions may make it difficult for the next shift or surge personnel to report for work. Those already on duty at a facility may have to work extended shifts, or additional days, without relief. Supplies become depleted and are not replaced and malfunctioning medical equipment is not repaired due to lack of technicians.

Information on winter storm impact on individual healthcare facilities can be found in articles on medical care, but healthcare systems studies have not been published. Reports from institutions that have chosen to share their experiences are strictly anecdotal, but are illustrative of potential problems others may face in the future.

A November 1996 ice storm occurring in Washington State interrupted power to approximately one-third of its population and a number of hospitals. One trauma center required six diesel generators to maintain operations. Had it not received power from a secondary utility feed, it might have been without electricity for 12 days.[120]

In the aftermath of the Ice Storm of ’98, many Canadian hospitals operated on generator power for almost 3 weeks.[14] Even in the absence of a disaster situation, one report identified significant facility power losses on the day of a mid-autumn heavy snowstorm. At one hospital, a complete power loss forced nurses to hand-ventilate patients in its intensive care unit for 45 minutes.[26] Facilities must know what equipment does not receive power from emergency generators.[120]

During a 2006 October snowstorm in western New York, power failure at a county water treatment plant threatened the potable water supply to the regional trauma center and children’s hospital. The hospitals' supply of water was placed in jeopardy and delivery of bottled water was difficult or impossible due to icy roads.[121,122]

Telecommunications may be interrupted for a variety of reasons. This may affect telephones and pager systems. One hospital had to arrange for emergency delivery of numerous cellular telephones just to communicate within the facility itself.[122]

Public and private transportation may be dangerous, difficult, or impossible. Therefore, staff absenteeism can be a significant concern in the aftermath of winter storms. Managers have employed emergency vehicles to transport personnel to work and relieve those on duty at the time of a storm.[26]

Transportation can also be problematic in three other situations: moving victims from the community to hospitals or other healthcare facilities; accomplishing interfacility hospital transfers for access to specialty care; and discharging some patients to home or to skilled nursing facilities. After the Ice Storm of '98, some hospitals opened additional ward beds for discharged patients who could not return home.[121] Providing home healthcare services was a challenge noted after an ice storm occurring in southeastern Oklahoma in December 2000.[122]

Sheltering employees and their families (including pets in some cases) often becomes an additional function of a fixed facility. During the prolonged crisis following the Ice Storm of '98, Montreal General Hospital set up shelters for employees and their families in unused portions of the facility. It provided free food service and child care in order to ensure it had enough staff to meet patient needs.[14] Ottawa Civic Hospital opened two oncology floors to house staff for up to 3 weeks.[121] Others have reported implementing similar strategies, or utilizing nearby compassionate-care facilities.[120]

Healthcare facilities have also taken in displaced persons.[122] One psychiatric hospital in Ontario sheltered many of the neediest people in its community but then found that its personnel had to care for the medical needs of several elderly boarders.[123] Providing shelter services in addition to supporting an increased ED or inpatient census may require additional security assets.[121]

Temporary Facilities

A variety of temporary facilities might be established by governmental and nongovernmental organizations to mitigate the human impact of severe winter storms. Most of these would be for the purposes of providing shelter from the elements and acting as distribution centers for water and food, although limited first aid services might be available at some. In the context of a community's emergency operations plan, the likelihood of limited ground movement in a storm's aftermath would argue for staffing these facilities and notifying the public of their locations in advance of expected severe weather. The media could use public service announcements to direct persons in need to the shelters that remain functional after the event.

Temporary shelters can house and care for those who are displaced from their homes due to structural damage or from the lack of power or heat. Community centers, schools, churches, and government buildings are commonly used for sheltering. Some of these buildings may remain connected to a functioning power grid or have emergency generators facilitating the provision of heat, water, and amenities such as microwave ovens and televisions – all of which can make the disrupting experience of sheltering more tolerable. However, the number of toilets, the availability of shower facilities and food preparation areas, and the need for extra security for large numbers of occupants might stress these facilities. Loud background noise, lack of privacy, and poor sleep cycles in such conditions lead to mental health issues. These include anxiety and depression, substance abuse, psychosis, suicidal ideation or attempts, and long-term sequelae such as posttraumatic stress disorder.

Infectious diseases can be difficult to control in shelters. Bacterial and viral upper respiratory infections, gastrointestinal disturbances, and other maladies can be spread rapidly between persons living under these conditions. Sheltered populations may be at greater risk if shelter officials have limited medical or public health training or the supply of sanitation items such as antibacterial hand wipes, alcohol-based hand sanitizers, and surface disinfectants is limited.

If a potentially contagious disease is identified, measures should be undertaken to isolate infected and exposed persons. This can be exceedingly difficult in an austere shelter environment as separate rooms in which to segregate individuals or families are frequently lacking. Curtains or hanging sheets and arranging cots to prevent face-to-face relationships are useful techniques to mitigate transmission risk. Infected individuals should be restricted from group events (e.g., meals, social activities, and gatherings for announcements) to prevent cross contamination. In the event of gastrointestinal problems, strict sanitation must be enforced at toilet facilities, and these should be cleaned and disinfected more often than usual.

The availability, storage, preparation, and distribution of water and food are a concern in any sheltering situation. During disasters, food is often donated by nongovernmental organizations and local ad hoc community-based groups. It is also provided by institutions such as hospitals, nursing homes, jails, and other facilities accustomed to preparing large quantities of food on a regular basis. Proper storage is also an issue for perishable items. Any leftover foods must be stored properly to avoid spoilage.

Care should be taken to ensure that personnel are adhering to health codes. Prepared food must be kept heated or cooled to proper temperatures during preparation, storage, and service to avoid the potential for large-scale food-borne illness, which can also disable rescuers and healthcare workers if they ingest the supplied food. Local, regional, state, or federal public health officials can be consulted before an event for assistance with planning and early after a storm for assistance with implementation of food management programs.

Pots, pans, and utensils used to cook food must be thoroughly cleaned. If a shelter is without running water but has access to delivered water, a three-bucket system can be used. Hot, soapy water in the first bucket is used for washing and subsequent containers are used for a two-stage rinse. Alternatively, personnel can take dishes and food preparation equipment to another location for washing. The use of disposable plates, bowls, and utensils can make it feasible to feed hundreds of people and reduce the need for washing of dishes, but this approach comes with additional logistics issues of supply replenishment and waste disposal. The same would apply to prepackaged meals.

In disaster situations requiring additional healthcare capacity, consideration should be given to using resources developed for other purposes. The Modular Emergency Medical System (MEMS) created primarily for a response to biological terrorism is an excellent example of this dual-use approach in the U.S. If prepared and integrated prior to an event, the concept provides a framework for expanding community healthcare capacity as required. Under MEMS, one or more high-volume reception

Table 37.3: Some Possible Survey Questions During Modified Cluster Sampling of Households in Areas Affected by a Winter Storm

- Not enough water or food
- No home (displaced or difficulty returning)
- No running water
- No electricity
- No heat
- No functioning toilet
- No telephone
- No personal vehicle
- No access to commercial or public transportation
- Unable to obtain needed medications or home health services
- Injuries
- Illnesses (acute or chronic)
- Need for medical care
- Need for counseling
- Special needs (disabilities, extremes of age, mental health issues, pets, other)

Homes and shelters can also be inspected by assessment teams for hazardous conditions. Public service information, education, and limited medical care may also be provided.

This information is in the public domain. It was modified from the CDC.[128]

and triage facilities, known as Neighborhood Emergency Help Centers, can be established directly within affected areas. These provide initial community healthcare that is more easily accessible when victims do not have ready access to transportation.[124] When hospitals are overwhelmed, managers can establish one or more off-site inpatient facilities known as Acute Care Centers. These are staffed and equipped to manage large volumes of patients with less serious problems, thus allowing hospitals to concentrate on more seriously ill and injured individuals.[125]

Rapid Needs Assessments

Rapid assessments[126] for identifying immediate challenges created by a winter storm and determining potential resources required to mount an effective response are necessary to avoid a dysfunctional approach. The fundamental challenge is rapidly gathering reliable and useful data when operation of ground and air transportation vehicles might be difficult or dangerous. Snowmobile drivers and Nordic skiers may be useful in these situations.

Modified cluster sampling is an epidemiological method often advocated by the U.S. Centers for Disease Control and Prevention (CDC). This process gauges the impact on communities that have sustained severe property damage that make egress and ingress difficult in the initial aftermath of an event.[127,128] The technique involves sampling 30 randomly selected clusters of land in the affected area. Assessment teams attempt to interview persons still present at these locations. Typical questions are listed in Table 37.3. Data are collected and analyzed to estimate rates, which are then extrapolated to total population numbers based on pre-event census information.

This sampling method was used with success 3 days after Hurricane Andrew hit Florida in August 1992.[129] It was also used in rural Maine following the Ice Storm of '98, but the severe limitations on travel delayed the survey 10 days.[130] Nonetheless, results of the assessment revealed that 14% of the affected population was still without electricity, 18% were using gasoline-powered generators, and 68% had their utility power restored in that time frame. Many had no telephone service but most had access to public service broadcasts through either radio or television.

Needs assessments can also identify victims with injuries and illnesses, either related or unrelated to the storm. Illnesses may be new or exacerbations of chronic conditions from exposure to the cold environment or inability to access customary care. Healthcare access – in the forms of EMS availability or capabilities of individuals and families to travel to medical offices, clinics, and hospitals – can also be assessed. Of particular note in the CDC's assessment after the 1998 ice storm, potentially hazardous sources of CO were identified in many homes without electrical power. Only 8% had working CO detectors.[130]

External Response

Major disasters disrupt or overwhelm local response capacity to such a degree that assistance from outside the affected area may be required to help mitigate the human impact of the event. Regional resources may be held at the county, province, or state levels – the exact terminology differs between countries. As such, specifics are beyond the scope of this chapter. The important concept is that any response must be coordinated through an incident management system capable of linking all of the necessary resources.

When local and regional resources do not have the capacity to significantly mitigate the effects of a PICE, national or international resources are often necessary. In the U.S., the President must declare a federal disaster after formal requests by the governor(s) of the state(s) affected (see Chapter 9). With regard to winter storm response, FEMA's snow-assistance policy focuses on record or near-record snowfalls for an area to qualify for aid.[131] Therefore, local and state governmental and nongovernmental organizations must be prepared for storms of lesser magnitude. Since inherent delays in mobilizing any federal governmental or military response are inevitable – unless these assets are positioned pre-event in advance of an approaching storm – planners must acknowledge that local resources will be the only response in the first 3–4 days after an event.

A Disaster Medical Assistance Team (DMAT) is a community-based federal government asset designed to provide medical care during a disaster or other local, regional, or state event. A team can also be federalized in support of a national event outside its jurisdiction of attachment. There are approximately 50 DMATs in the U.S. Each team is sponsored by an organization such as a public safety agency, hospital, or nonprofit public or private group. DMATs are composed of physicians, physician assistants, nurses, pharmacists, respiratory therapists, paramedics, emergency medical technicians, and a variety of healthcare, logistical, and administrative personnel. DMATs consist of 50–125 members to ensure that a sufficient number of people can deploy from their day-to-day jobs on short notice. Approximately 35 are typically chosen for a particular mission.

DMATs are designed to function as rapid-response elements to supplement local medical care until other resources can be mobilized or the situation is resolved. They deploy as a self-sufficient unit with medical equipment and supplies, climate-controlled tents, electrical generators, and other support equipment necessary to establish a base of operations. They can treat up to 250 patients per day in a fixed or temporary site. They can

Table 37.4: Internet Resources for Public Individual and Group Preparedness Information

Canada	
Public Health Agency	http://www.phac-aspc.gc.ca/cepr-cmiu/index.html
United Kingdom	
Department of Health	http://www.dh.gov.uk/keepwarmkeepwell
United States	
American Red Cross	http://www.redcross.org/services/prepare/0,1082,0_252_,00.html
Centers for Disease Control and Prevention	http://www.bt.cdc.gov/disasters/winter/factsheet.asp
DisasterCenter.com	http://www.disastercenter.com/guide/winter.html
Emergency Management	http://www.fema.gov/plan/index.shtm
Health and Human Services	http://www.hhs.gov/disasters/emergency/naturaldisasters/cold/index.html
National Weather Service	http://www.nws.noaa.gov/om/brochures/wntrstm.htm
Occupational Safety & Health	http://www.osha.gov/SLTC/emergencypreparedness/guides/winterstorms.html
Ready.gov	http://www.ready.gov/america/publications/allpubs.html

Many local and state governments, nongovernmental organizations, and universities also have useful information.

also potentially supplement the staff at existing local healthcare facilities, although credentialing issues have limited this role to date. Responsibilities of DMATs may include triage, provision of high-quality medical care in austere settings, and preparation for evacuation to more appropriate healthcare facilities. DMAT personnel may also be deployed to more distant facilities to assist in receiving large numbers of patients. DMATs are discussed in more detail in Chapter 9.

Multiple DMATs have deployed in response to northeastern U.S. ice storms. They have provided needed medical care to communities or when local doctor's offices, clinics, and pharmacies had closed due to lack of power or inability of staff to travel to their places of employment. The majority of DMATs supported local hospital staffs, allowing them to rest, tend to their families, and address damage to their property. Some members assisted local nursing home staff in caring for residents while others conducted shelter clinics on a rotating basis.

Following the Ice Storm of '98, a mobile mission was devised. A utility vehicle was stocked with equipment, supplies, and medications. Support staff accompanying the vehicle included a physician, a nurse, and a paramedic. This traveling clinic visited each shelter in the area daily. Several house calls were also made to check on families who remained in their homes. Some were treated in place for pneumonia, viral syndromes, Streptococcal pharyngitis, and other minor illness and injuries. Many people displaced from their homes and staying in shelters had forgotten to bring or exhausted their supply of regular medications. DMAT teams provided small amounts of these medicines until local pharmacies were functional and people could safely travel to pick up prescriptions.

Public Information

The ultimate goal of any public educational effort is to prevent problems before they occur. To achieve this endpoint, the CDC in the U.S. has called for standardization of public health messages issued for a variety of events.[132] One purpose of this initiative will be "to receive, manage and disseminate alerts, protocols, procedures and other information for public health workers, primary care providers, and public health partners in emergency response."[133] This program is supported by a publication from the National Disaster Education Coalition entitled a *Guide for Standard Messages* specific to winter storms.[134]

Medically related information disseminated to the public and to healthcare personnel should be based on evidence where it exists. Areas of focus should be the causes of morbidity and mortality associated with winter storms: cold exposure; CO poisoning; and injuries such as MVCs, slips and falls, snow removal, and those involved in recreational activities.

Cold Exposure

A number of risk factors are associated with accidental hypothermia. These include extremes of age (particularly <1 y and ≥ 60 y), male sex (likely behavioral), ethanol ingestion, treatment with neuroleptic medications (often used in patients with psychiatric conditions), hypothyroidism, and malnutrition. Two populations at particularly high risk are: 1) relatively young participants in outdoor sports and recreational activities, who sustain overwhelming cold stress, and 2) "vulnerable populations" exposed to moderate indoor cold stress, most specifically the elderly.[17] In a longitudinal study of 47 elderly people in the U.K., a progressive decrease in thermoregulatory capacity associated with increasing age was noted.[135] Numerous reports have documented greater morbidity and mortality in the elderly following winter storms.[17,33,52,74] Similarly, ethanol ingestion and psychiatric illness were found to be risk factors for frostbite. In one Canadian study, 77% of cases presented with one of these as the cause of impaired mental capacity.[74]

Little has been written and almost no research performed on the impact of public information campaigns in preventing frostbite and hypothermia. The U.K. has been conducting a campaign called "Keep Warm – Keep Well" for a number of years.[136] However, publications of any public health research regarding its impact on reducing cold-associated morbidity and mortality could not be found in open sources.

Assuming an intact power supply and Internet access, some public resources may be found in Table 37.4. Alternatively, documents could be printed in advance of a disaster in preparation for possible power loss. Local organizations could also develop similar educational products for their own public awareness programs.

Carbon Monoxide Poisoning

As always, prevention is the key to mitigating the impact of CO poisoning. Because CO is colorless and has no detectable odor or noxious properties, preventive measures should involve a combination of public information campaigns and detector/alarm devices.

Efforts to increase public awareness must consider uneven ethnic distributions in the epidemiology of CO poisoning. Therefore, awareness programs must be individualized to each specific region or jurisdiction.[137,138] In the 1993 storm affecting the largest urban population center of Washington State, the majority of patients poisoned with CO from indoor cooking with charcoal briquettes were ethnic minorities. Asians represented the largest group, most of whom did not speak English. By comparison, all cases caused by gasoline-powered electricity generators involved non-Hispanic whites.[39] Newspaper, radio, and television were extensively utilized in an educational campaign and one fire department even distributed 2,000 leaflets door-to-door. However, all warnings were communicated only in English.[38] In Rochester, New York, public education may have contributed to the modest reduction in absolute numbers of CO poisoning cases seen during an ice storm in 2003 compared with a similar storm in 1991. On the other hand, there was a significant decrease in indoor cooking as a source mechanism.[139] Others have reported difficulty disseminating information when telecommunications were disrupted by the storm.[13]

CO detectors with an audible alarm have the potential to alert exposed individuals if appropriately installed and maintained.[140] One study concluded that detectors might prevent up to half of unintentional deaths.[141] The same study also found that 42% of those who were likely asleep at the time of fatal poisoning had alcohol in their system. This proportion was similar for victims whose blood alcohol level was either above or below 100 mg/dL.[141] In a report of unintentional nonfire-related CO poisonings following the December 2002 ice storm in North Carolina, researchers noted that the severity of poisonings in households with functioning alarms was much less than in those without them.[142]

Vehicle Incapacitation

The use of any vehicle carries with it the risk of mechanical breakdown or inability to negotiate winter terrain. When vehicles are incapacitated in noninclement weather or when help is readily accessible, it usually causes more frustration and aggravation than illness or injury. However, when driving in an inhospitable and dangerous environment, such as the aftermath of a severe winter storm, or when rescue is delayed by environmental conditions or shear EMS call volume, immobility could rapidly increase the risk to health.

Once stranded, an automobile's occupants must decide whether to remain with the vehicle or walk to better shelter. History suggests staying with the vehicle is the best course of action in most circumstances. Travel across terrain can be difficult due to snow and ice, especially with no knowledge of the area. Blowing snow can quickly cause disorientation. Land navigation is a learned skill, for which many motorists and emergency responders have no training. A detailed map or portable global positioning system device may help, but individuals may still be at risk from lack of sufficiently protective clothing. Remaining in a vehicle can retain some heat for a short period and will block any wind that can hasten the onset of frostbite and hypothermia. During any overland trek, a fall resulting in an injury to an ankle, knee, or back could incapacitate an individual and increase the risk from cold exposure. Unwittingly treading on thin ice over a body of water could lead to drowning or immersion injury.

Table 37.5: Suggested Items for a Winter Storm Survival Kit to Be Carried in Motor Vehicles for the Contingency of Being Stranded

- Blankets or sleeping bags
- Flashlight with extra batteries*
- First aid kit
- Knife
- High-calorie food that is nonperishable
- Extra clothing, hat, mittens or gloves, boots
- Large empty can and plastic cover with tissues/paper towels for sanitary purposes
- Smaller metal can and waterproof matches to melt snow for drinking water
- Sand or cat litter for tire traction
- Tire chains
- Shovel
- Windshield scraper and brush
- Tool kit
- Emergency tire repair equipment (canned compressed air and sealant)
- Tow rope
- Booster cables
- Water container
- Road maps and compass or global positioning system device
- Signal devices (e.g., flares, light-emitting diode lights, pylons)
- Cellular telephone with charger or citizens band (CB) radio with extra batteries*
- AM/FM and National Oceanic and Atmospheric Administration radios with extra batteries*

* *Lithium batteries have longer life and work better in cold temperatures.*

This information is in the public domain. It was modified from the CDC.[144]

The chances of being seen and rescued are much higher when staying with a vehicle, as passing cars may render aid in short order if the road is frequently traveled. If others familiar with the motorists' travel plans note that the stranded individuals are overdue, rescue assets will inevitably be dispatched. Attaching a brightly colored object to the antenna, putting up the hood, activating emergency flashers, and deploying road flares all signal distress. A dark unlit car on the edge of the road does not beckon help nearly as well as one with multiple active methods indicating the need for assistance. Care should be taken to prevent the buildup of snow against the exhaust system of the vehicle, which could cause CO poisoning without warning.[37]

Gasoline tanks should be kept near full to avoid ice formation inside the tank and fuel lines and to have enough fuel to idle the car 10 minutes each hour for heat if stranded. Motorists should not travel alone whenever possible, and someone should be made aware of their timetable and estimated routes of travel. The U.S. National Oceanic and Atmospheric Administration[143] and the CDC[144] suggest carrying a storm-survival kit when driving during the winter season (Table 37.5).

Other Injuries

The CDC has stated that "officials should consider the following recommendations during blizzards: 1) early in the storm, warn against nonessential driving; 2) announce publicly that persons who must drive should have extra clothes and food with them and remain in their vehicle if stranded; and 3) advise extreme caution if the heating system is used while the vehicle is stopped [even for short periods], because exhaust systems may become blocked with snow and ventilation adequacy is difficult to determine."[145]

Heavy snow can collapse the roofs of buildings not designed for the added weight. Family, friends, and the media often advise homeowners to clean snow from their roofs, but this can be a hazardous undertaking for people who do not have the agility and balance, strength and dexterity, or safety equipment to undertake the task.[146] Official broadcasts should warn the public about the potential dangers of clearing rooftop snow, and offer alternative resources for those who do not feel safe or capable of doing it. Media announcements regarding the cardiovascular risks of shoveling and the safe use of snowblowers and other power equipment might also be considered, but the potential impact on the epidemiology of injuries is unknown at this time. The same is true for mechanisms of injury related to winter recreational activities.

Fall prevention has been part of the geriatric medicine research agenda for some time.[147,148] With regard to slippery conditions caused by a winter storm, the elderly remain the population at highest risk.[33] Some prevention strategies may have application to other populations as well. Additional strategies may require development but none can be expected to have significant impacts on incidences and outcomes without ongoing surveillance programs to elucidate the epidemiology of winter slips and falls.

Perhaps the best public awareness campaigns involve simply extending existing community injury prevention and control measures. This would require continuous research efforts in injury epidemiology and clinical management to determine best practices for incidence reduction and improved outcomes.[149] Information on subpopulations related to winter storms might be extracted from larger population-based data collection and analysis programs.

RECOMMENDATIONS FOR FURTHER RESEARCH

As with many research questions in public health, it is difficult to measure prevention. Particularly in the field of disaster medicine, comparisons can often be made only to baseline rates of morbidity and mortality before a PICE. Evaluating any data between different events, even those caused by the same insult such as a winter storm, is made extremely difficult by the heterogeneity of multiple characteristics of the incident itself and the region affected. Determining the effectiveness of any change in medical interventions or response tactics, techniques, or procedures often lacks any valid cohort to which new data can be compared. Numbers are often small, especially when trying to examine subsets of populations that may derive the most benefit from any change in standard practices.

Although numerous disaster medicine centers have sprung up in the last decade, no nationally or internationally coordinated research agenda has been disseminated. The U.S. *National EMS Research Agenda*[150] made no specific call for outcomes research in disaster medicine. With specific regard to winter storms, no recommendation was made to study the potential occupational safety and health effects of driving in hazardous winter conditions or working in cold environments, better methods for managing cold-induced problems in the field, or out-of-hospital management of patients for prolonged periods of time.

Most disaster research must be multidisciplinary and collaborative,[151] with relationships made and responsibilities delineated before an event. Until more consistent data are collected for more events over a greater period of time, winter storm research will need to focus primarily on population effects. The goal is to develop better methods of rapidly identifying populations at risk for adverse health impacts caused by difficult outdoor movement, widespread power losses, and limited access to health care. Specific areas should include risk mitigation; system preparedness; out-of-hospital access, care, and evacuation; rapid needs assessments; and infrastructure recovery.

Risk Mitigation

No known force can stop a winter storm. However, the risks to potentially vulnerable populations are subject to mitigation. Research should focus on making society less susceptible to disruption. Developed solutions would necessarily require a cost/benefit analysis based on sound evidence. For instance, one method for potentially decreasing the incidence of accidental hypothermia and CO poisoning might be to equip every building at risk with a safe gasoline-powered generator and plenty of fuel. However, supplying millions of homes with this emergency capacity in order to save at most a few hundred lives every year might be too expensive. Perhaps a pre-event public education campaign would be more cost effective. Neither option, nor any of a myriad of other programs in the spectrum of cost versus benefit, should be implemented without research in one or more representative geographical regions or vulnerable populations.

One key feature to any pre-event risk mitigation policy is updating quantitative and qualitative data on vulnerable populations as often as practicable. Census data are useful, but so much more is necessary following a PICE. Are there buildings at higher risk for power loss than others? Which of those have safe alternate energy sources? Which households have infants, elderly, or disabled persons? Which have persons requiring home-health services such as oxygen, antibiotics, chemotherapy, or dialysis that could not be delivered over hazardous road conditions?

System Preparedness

Protection of the public safety and healthcare infrastructure against physical hazards (e.g., power loss, and inaccessibility) and system breakdown (e.g., victim needing unavailable resources) should also be researched. How can rescue capacity, EMS response, and hospital capabilities be preserved during and after a major winter storm? How fast can roads be cleared? How well can response vehicles move around the affected area? Other research priorities involve organization of the healthcare system. Should EMS personnel be more dispersed throughout the community prior to storm arrival? Should hospital staffing be bolstered before some storms to decrease absenteeism and allow for those on duty to maintain more normal work–rest cycles? Emergency management tactics, techniques, and procedures for planning, operations, safety, and overall effectiveness should also be scrutinized through research. To date, it is unknown whether these or any other interventions will improve medical or mental health outcomes after an event. Only proactive research will be able to answer these questions.

Human Access, Care, and Evacuation

True research into evidence-based best practices for out-of-hospital medical response to victims of a winter storm is virtually nonexistent. As such, there are many questions that require answers before significant funds should be invested in unproven equipment and technologies.

What balance of weather conditions and population needs make it unsafe to attempt or continue access efforts? What are the best search techniques for victims who cannot call for help? What types of vehicles or vehicle equipment should be used to access victims who are able to call for help? Which agencies are needed to facilitate access to a neighborhood with ice or snow cover, felled trees, and downed power lines? How best can rescue and EMS personnel be protected when working in cold environmental conditions? What are the caloric and fluid requirements of response personnel? Should work–rest cycles be different under cold stress?

In a mass casualty situation, what triage methodologies result in the best outcomes for populations affected by a winter storm? Preventing additional heat loss is most likely beneficial; however, should active-external, or even active-internal, rewarming be undertaken in the out-of-hospital setting or in an ambulance en route to the hospital? If so, what are the best methods of accomplishing this? How much rewarming should be achieved before hospital arrival? Is the care of a cold water immersion victim any different from that for a patient suffering from "dry" hypothermia? How does frostbite or hypothermia complicate other medical conditions for which EMS may have primarily been called? Should medic training include the diagnosis and treatment of advanced complications not commonly seen when healthcare access is not significantly delayed? Should medics be trained to manage patients for longer periods of time than they are accustomed when evacuation times are not limited by weather or road conditions? What balance of those conditions and patient medical requirements make it unsafe to attempt evacuation? Which patients should simply receive care but not be evacuated? Can protocols be used for these decisions or must medical control be consulted by radio or telephone to achieve safe dispositions for patients?

What types of vehicles or vehicle equipment should be used to evacuate victims? Is there any benefit to air versus ground versus water evacuation? Are field-expedient nonmedical vehicles safe for some patients? If so, which ones, and who makes the decision regarding vehicle selection? What is the best destination for a severely hypothermic or frostbitten patient? If it is a tertiary referral center, is there degradation of benefit over time? Should an intervening stop at a less-capable ED be made for immediate care before transfer to the referral center?

Rapid Needs Assessments

The CDC has posted suggestions for community studies in the early aftermath of any event that causes widespread property damage.[128] The first step would be to identify neighborhoods or other specific areas that are the most severely affected. This could be accomplished by satellite data, aerial overflights, or by reports from reliable observers within the distressed area. Once ground access is possible, surveyors would collect data (Table 37.3) from members of households, occupants of businesses and public buildings, and emergency responders. Disaster managers can use this information to determine: 1) the demographics of affected persons and families, 2) their physical and mental health; 3) their medical needs; and 4) their living conditions and additional resources required. Disaster response organizations should use the current information provided by the modified cluster sampling technique to target subsequent relief efforts, but even this method of data collection and analysis are worthy of study for accuracy and utility.

Repeated assessments throughout the response and recovery phases should be used to verify the effectiveness of measures taken. This last piece is frequently missed, which results in estimating the impact of the event but not the impact of various aspects of emergency management. Comparing prior community assessments within the same event would have more validity than comparing them with a different historical event. If relief efforts or other interventions are deemed unsuccessful, this could focus interevent research on new methods or technologies that may be more useful in similar circumstances following a future PICE.

Infrastructure Recovery

Although recovery should begin at the same time as the initial response, the latter will dominate early and the former will dominate late in the continuum of the disaster life cycle. Systematic and targeted data collection must be conducted throughout all four phases of the disaster (see Chapter 9). What worked and what did not, costs and benefits of different approaches, and proposed plans for the next event must be shared with other communities facing similar problems. As yet, there is no single repository for best practices in response and recovery, except in limited regional contexts.

Analysis of recovery data from the last event in a given region, or a critical review of past disasters in other regions, should produce better preparedness for the next occurrence. Not all PICEs are the same, but similar events cause similar challenges. By studying such incidents, knowledge can be learned and solutions proposed and tested before they are needed to save lives and protect property and systems. Implementation of these research priorities has the potential to significantly decrease morbidity and mortality from winter storms.

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38

Extreme Heat Events

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INTRODUCTION

This chapter addresses the medical and public health implications of extreme heat events (EHEs) and the associated mortality and morbidity. EHE conditions can be defined by summertime weather that is substantially hotter and/or more humid than average for a location during a comparable time period. History is filled with the failures of great civilizations caused by significant climate changes reacting with human adaptations. Examples include the collapse of the north African "Bread basket" for ancient Rome, the wind-swept droughts in Oklahoma's "Dust bowl" during the 1930s, the vast European droughts in the Middle Ages, and the severe 1921 drought in extensive areas of the former Soviet Union that resulted in millions of deaths.[2] Even the genocide in the Darfur region of west Sudan has a weather-related component. The ongoing drought has pit herders against farmers, with the added elements of race and religion exacerbating the situation.

There have been more than 20 serious EHEs across the world since 1901, including the deadly 2003 EHE in Europe that killed more than 35,000 people, with 15,000 dead in France alone.[3,3a] In the United States, up to 800 died of EHEs in Chicago and Milwaukee in 1995. Additional thousands have died in Philadelphia, St. Louis, Kansas City, and other major U.S. cities since the early 1990s. EHEs in U.S. mid-Atlantic and midwest cities can be accompanied by glaring sun with no cloud cover, temperatures in the 35°C–40°C range, and heat indexes (temperature and humidity) from 43°C to 51°C or more. This results in crowded hospital Emergency Departments (EDs) on diversion and media stories of the elderly found dead in tightly shut, overheated urban apartments.

EHEs are not determined by the absolute temperature alone, but are dependent on other conditions specific to each location. An EHE in sub-Saharan Africa in June, for example, will be much hotter in absolute temperature than an EHE in Minneapolis-St. Paul in a comparable period. In addition to overall temperatures, other environmental factors such as humidity, air circulation, building types, and nighttime temperatures can intensify the health effects of EHEs.

The first section of this chapter, "An Overview of Extreme Heat Events," provides a background to understanding EHEs as disasters. The second section of this chapter, "The State of the Art: Extreme Heat Event Risk Factors and Medical Response," is divided into five subheadings: 1) "Health Risk Factors from Extreme Heat Events," 2) "Urban Heat Islands as Risk Factors," 3) "Planning for Extreme Heat Events," 4) "The Chicago Heat Wave of 1995," and 5) "Extreme Heat Events in the Developing World." The third section of this chapter, "Recommendations to Prevent or Mitigate the Health Effects of Extreme Heat Events," includes recommendations for both policy change and future areas of research.

OVERVIEW OF EXTREME HEAT EVENTS

Health personnel are concerned with EHEs because rising temperatures result in rising heat-related mortality and morbidity. Global warming and climate change will only intensify this problem. Thermal trends between 1880 and 2005 show a clear upward movement in both land and ocean temperatures (Figure 38.1). Unless scientists determine a way to alter the weather, the best approach to protection of people around the globe will remain for the nations of the world to develop plans for improving weather prediction and for strengthening public health and medical system responses to EHEs. Most serious health effects of EHEs can be effectively prevented or addressed by providing timely warning to vulnerable populations, access to air conditioning, adequate potable water (in the developing world), and shelter from the sun. As will be discussed, these simple solutions can be hindered by complex physiological, environmental, medical system, and even political and sociocultural restrictions.

Increasing global warming, urbanization, and population numbers require improvement in effective EHE planning and response activities. This is true not only across the developed world, but more significantly in the sprawling cites and barren rural areas of the developing world. The fact that there are more than 1 billion people living without access to potable water complicates other EHE-related problems.[4] There is little likelihood

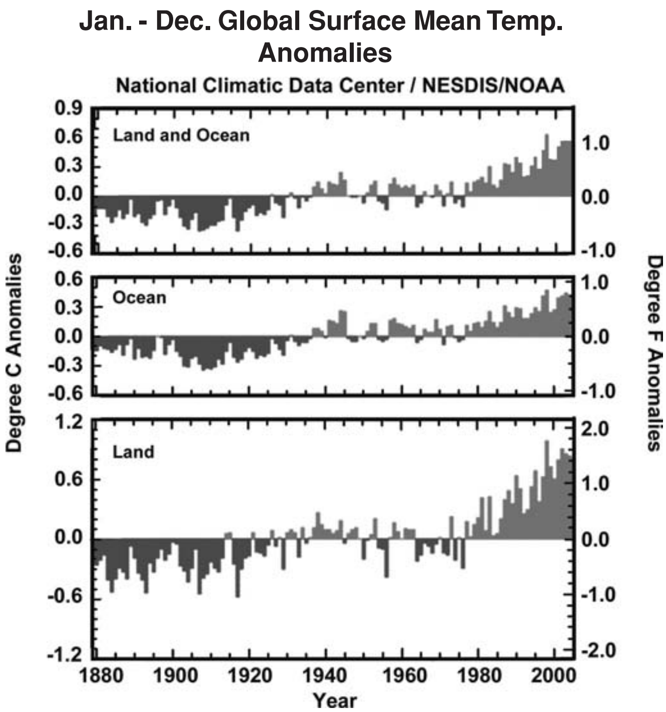


Figure 38.1. Annual average global surface temperature anomalies 1880–2005. *Source:* Environmental Protection Agency, http://www.epa.gov/climatechange/science/recenttc.html. Modified by Tom Javorcic, 2007.

of technological and engineering solutions to global warming in the near future. The political will to address global warming by strong and effective restrictions and planning programs (e.g., fuel-efficient automobiles, less burning of high-carbon fuels such as coal and wood, carbon taxes/exchange programs, and strong landuse regulations) has been variable. Until better mitigation strategies are in place to prevent EHEs, local and national governments need to address growing heat-related morbidity and mortality with effective planning and responses.

In most years, more people in the United States die of EHEs than of hurricanes, lightning, tornadoes, floods and earthquakes combined. During the period from 1979 to 1999, there were 8,015 heat-related deaths.[5] Despite this, EHEs have been among the most underrated of all deadly weather phenomena.[6] Figure 38.2 compares fatalities from EHEs documented by death certificates to fatalities from other weather-related disasters over a 25-year period. EHE deaths often exceed those from all other weather-related sources.[7]

Mortality documented by death certificates will often be dwarfed by the number of actual heat-related deaths occurring during an EHE. Estimating the number of individuals who have died of temperature-related causes during an EHE is difficult. A traditional method has been to estimate "excess mortality," defined as the difference between the number of deaths observed and the number expected, based on the crude death rates for the same geographical area, during the same period when no heat wave or other unusual circumstances were present.[8] Substantial inconsistencies often exist between the "excess deaths" that are calculated for the period of an EHE and the exact number of deaths that have been certified as heat-related by a medical examiner or a coroner. For example, the average annual rate of heat-related deaths increased during EHEs in each age group, except for children aged 14 years and younger. This was particularly true for persons 55 years and older. Because other causes of death (e.g., cardiovascular and respiratory diseases) also increase during heat waves, heat-related deaths due to weather conditions represent only a portion of heat-related mortality.[10–12]

In 1980, when U.S. summer temperatures reached all-time high levels, there were 5,000 deaths above the expected number, with more than the 1,700 cases documented as having been caused by heat.[8] In contrast to violent weather events, an EHE is a "silent killer" that is dramatically less apparent than other hazards, especially at the outset.[7] There are credible estimates as high as 160,000 deaths annually across the world from EHEs and

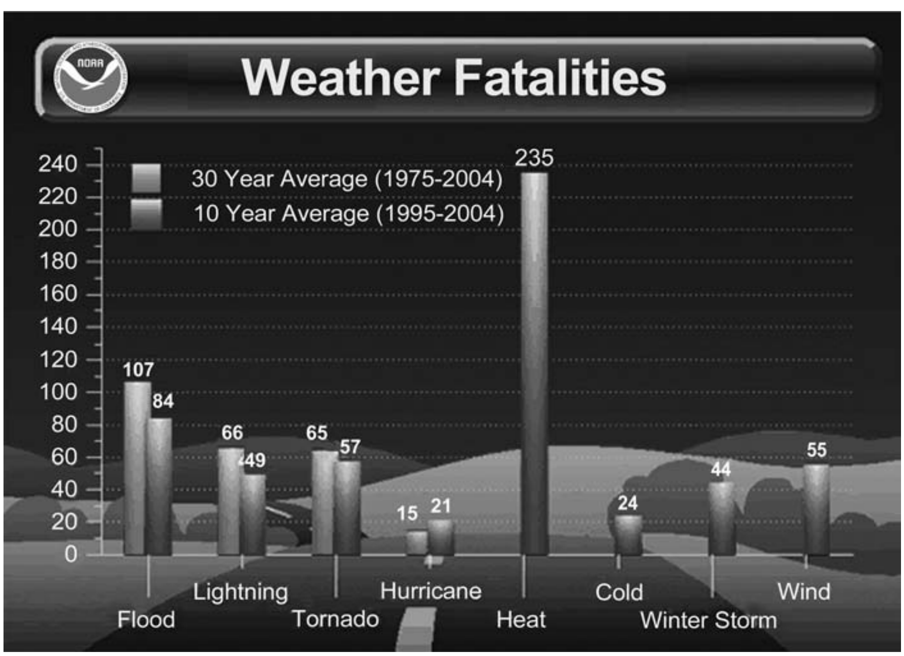


Figure 38.2. Weather Fatalities. *Source:* NOAA, summer 2006.

other weather disasters, with most of these deaths occurring in developing nations.[12,13]

Even advanced nations are not immune to what might otherwise appear to be a problem of teeming urban areas in poorer countries that lack adequate supplies of potable water, decent shelter for their populations, and a clear recognition of the dangers posed by EHEs. Kalkstein, using data from his study of 44 large American cities, estimates that 1,840 excess deaths occur annually due to the presence of high-risk air masses during a "present-day typical summer."[14] This estimate is consistent with studies demonstrating that only a portion of the increase in mortality during EHEs is documented on death certificates.[8,9,15] Previous studies have estimated the combined EHE-attributable summertime mortality (excess deaths) for several vulnerable U.S. metropolitan areas is well above 1,000 deaths per year.[1,16,17] The U.S. Centers for Disease Control and Prevention (CDC) has found that the diagnoses of heat-related deaths have been underestimated by 22%–100%.[8,10,18] Although similar research on EHE-attributable mortality in rural areas has not been completed, some studies found evidence of such an impact.[19]

Public awareness of potentially deadly EHEs has generally lagged behind the reality. In Europe, for example, despite cataclysmic, heat-related death tolls in recent years, the Europeans have had a difficult time in changing their basically benign, "friendly to people" view of the summer's heat.[20] Global warming/climate change data may change these perceptions.

Global warming/climate change is likely to result in progressively more serious and frequent EHEs across the developed and developing world.[21] Urban populations in nonindustrialized countries continue to be particularly vulnerable to the direct effects of climate change.[22] The world political community has generally accepted the human involvement paradigm that the burning of carbon-based fossil fuels to a great degree causes the verified fact of continued global warming.[23] At the 2005 United Nations (UN) Summit on Global Warming, Janez Dromvsek called for integrated worldwide planning, a search for solutions, and the raising of politicians' and the public's consciousness.[24] Worldwide efforts to mitigate the effects of EHEs in developing nations generally have been neither extensive nor successful.

THE STATE OF THE ART: EXTREME HEAT EVENT RISK FACTORS AND MEDICAL RESPONSE

Health Risk Factors from Extreme Heat Events

Physics, Physiological, and Meteorological Effects of Heat Exposure

Increasing heat and humidity affect the body's ability to maintain its homeostatic balance, but similar heat indexes (temperatures and humidity) will affect individuals differently based on personal, geographical, sheltering, and other aspects of the miniclimates in which they live. The temperature of the air, its humidity and motion, and the amount of radiant heat energy to which an individual is exposed are the most important factors in human heat stress. Of these, air temperature can have the greatest impact.[25] Although there may be intense temperature fluctuations on the outer surfaces and extremities of the human body, thermal homeostatic mechanisms attempt to maintain a relatively stable core temperature. There are four aspects to this homeostatic process: 1) metabolic heat gain, 2) heat loss from perspiration/evaporation, 3) conductive and invective heat loss or gain, and 4) the effects of radiant energy.[8] When air temperature is low, heat generated metabolically is more easily lost from the body to the air. As air temperature increases, convective heat loss is no longer possible, and heat can be gained from the air. High humidity limits the cooling effects of perspiration evaporation.[8]

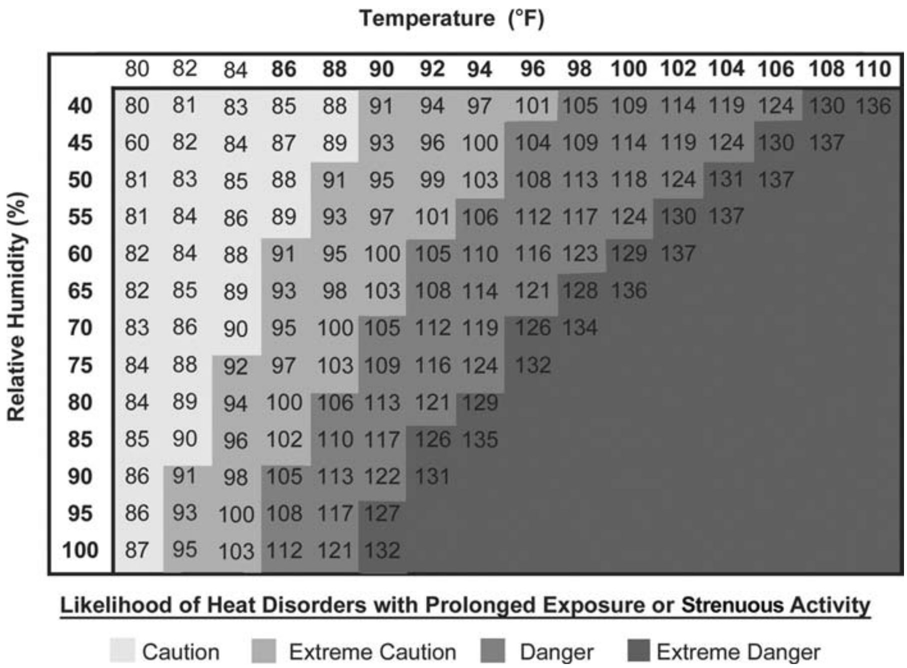
The interpretation of any heat index value will be affected by differences in an individual's age, medications, clothing, and body habitus. In addition, these numbers will fluctuate significantly when compared with other values obtained if one could measure the various microclimates to which individuals are exposed.[8] For example, those older than age 52 tend to produce significantly less perspiration than those who are younger.[26] Differences in hydration patterns can complicate the application of general heat indices to individuals or groups. Elderly populations with little shelter from the sun's direct rays, or those shuttered tightly within steaming, unventilated brick buildings in inner-cities will experience drastically different reactions to the heat than middle class, middle-aged suburbanites who can escape to air-conditioned homes.

Increasing temperatures, humidity, and direct exposure to the sun can increase the heat stress that individuals will experience during EHEs. Heat index tables often assume that temperatures are taken in a shaded area, with little wind. In addition, most heat index tables note that direct sunlight can increase heat index figures by up to approximately 8°C and that exposure to dry winds can further increase health risks by promoting rapid dehydration (Figure 38.3).[27] Ultimately, any meteorological conditions that increase heat indexes will increase heat stress and health risk. All else being equal, the shock effect of the increased heat is greater the earlier in the summer the EHE occurs.[28,28a] In a similar fashion, health risks increase with the duration of the EHE, the amount of time spent above minimum temperature thresholds, and the rapidity of the rise in the heat index.[1,29–33] Residents become increasingly acclimated to the heat as the season progresses. It is not absolute temperature, but rather the extent of upward deviation from usual local summer temperatures that seems to be the key variable affecting mortality.[32] As Table 38.1 demonstrates, there is striking similarity across the continents (with the exception of Antarctica) in the array of the highest ever recorded temperatures.

Diagnosis and Treatment of Heat Stress Illnesses

There are several clinical syndromes that comprise heat stress illnesses or conditions: 1) heat cramps, 2) heat edema, 3) heat syncope, 4) heat exhaustion, and 5) heat stroke. They represent variations and overlap in a continuum of heat illness, from minor complaints to overwhelming heat stress that can lead to death.[33]

Heat cramps present as pain and spasm in heavily exercised muscles. Their presentation can vary, from the parade marcher who complains of abdominal pain, to the athlete with cramping in the calves. The mechanism is thought to result from an imbalance in water and sodium intake, leading to hyponatremia, either measurably or locally at the cellular level. Clinically the body temperature is normal, with little evidence of frank dehydration. Measurement of electrolytes may reveal hypokalemia, hyponatremia, respiratory alkalosis, hypomagnesemia, and hypophosphatemia. On the scale of severity, this is usually a nonthreatening condition, treatable with rest, removal from the heat source, and oral or parenteral fluid and electrolyte replacement. Pitfalls that may occur include the attribution of abdominal cramping to heat cramps, when in fact the patient has an alternate diagnosis, such as infectious peritonitis or internal bleeding from a ruptured



RH (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	60	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Figure 38.3. *Source:* National Oceanic & Atmospheric Administration, http://www.srh.noaa.gov/ssd/html/heatwv.htm. Modified by Tom Javorcic, 2007.

viscus or hemorrhagic ovarian cyst. Additionally, rhabdomyolysis can occur in the setting of severe exertion or repetitive muscular contraction, leading to myoglobinuric renal failure and life-threatening hyperkalemia with its attendant effects on cardiac conduction. Thus, a reasonable evaluation in the setting of significant muscle pain will involve laboratory studies that can detect these conditions.

Heat edema is a mild condition resulting in swelling of the hands or feet, related to prolonged peripheral vasodilation followed by orthostatic pooling of blood in the extremities. It is usually responsive to elevation of the legs. It must be differentiated from renal failure or congestive heart failure in susceptible populations.

Heat syncope is characterized by sudden loss of consciousness and is also related to peripheral venous blood pooling with subsequent orthostatic hypotension. It occurs with prolonged standing, or rising quickly from a sitting position. Such persons should not be "held up" or supported, but rather gradually lowered to the ground. First aid treatment consists of laying the patient on the ground and lifting the legs up slightly to restore blood flow to the head. Maintaining the patient in an upright position may prolong the period of poor cerebral perfusion. Rehydration should ensue, and a cardiac rhythm strip should be obtained to ensure no heart blocks or other cardiac conduction abnormalities are occurring.

Heat exhaustion occurs in the setting of excess diaphoresis in a hot, humid environment, leading to volume depletion. Core body temperature will be elevated above normal, but will remain less than 40.5°C, which usually defines the level for heat stroke. Symptoms are profuse sweating, malaise, fatigue,

Table 38.1: Highest Temperature Extremes

Locator #	*Continent*	*Highest) Temp (°C)*	*Place*	*Elevation (m)*	*Date*
1	Africa	58	El Azizia, Libya	112	13 Sep 1922
2	N. America	57	Death Valley, CA (Greenland Ranch)	–54	10 Jul 1913
3	Asia	54	Tirat Tsvi, Israel	–220	22 Jun 1942
4	Australia	53*	Cloncurry, Queensland	190	16 Jan 1889
5	Europe	50	Seville, Spain	8	4 Aug 1881
6	S. America	49	Rivadavia, Argentina	206	11 Dec 1905
7	Oceania	42	Tuguegarao, Philippines	22	29 Apr 1912
8	Antarctica	15	Vanda Station, Scott Coast	15	5 Jan 1974

* *Note:* This temperature was measured using the techniques available at the time of recording, which are different from the standard techniques currently used in Australia. The most likely Australian high-temperature record using standard equipment is an observation of 50.7°C recorded at Oodnadatta in 1960.

headache, dizziness, nausea, and vomiting. If left untreated, the condition will likely progress to classic heat stroke. Tachycardia and hypotension may be present, but major neurological dysfunction does not occur. Treatment consists of cooling, oral rehydration, or intravenous rehydration in someone who is hypotensive or fails to respond to oral fluid replacement within a few hours.

Heat stroke is the most life-threatening condition related to heat stress. It is defined as an elevated core body temperature usually equal to or greater than 40.5°C in association with significant acute mental status or behavioral changes. Mental status changes can consist of confusion, bizarre behavior, hallucinations, delirium, unresponsiveness, seizures, posturing, or coma. The observation that sweating ceases is found in only 50% of cases, and those patients with exertion-related hyperthermia are more likely to be sweating. Loss of sweating as a mechanism for body cooling is a late finding. This true medical emergency occurs when heat production exceeds physiological cooling capacity such that heat dissipation is no longer occurring. Hyperthermia is characteristically differentiated from fever, in that fever occurs due to an upward adjustment of the temperature set point in the hypothalamus. In hyperthermia, the hypothalamus set point is normal, but the body is unable to eliminate acquired heat, leading to excessive body temperature.

With the onset of heat stroke, widespread cellular and organ damage ensues, characterized initially by tachycardia, increased cardiac index, and central venous dilation. Critical deterioration continues, progressing to hypotension and cardiovascular collapse. Manifestations include coagulopathy in association with hepatic and cardiac failure. Hemostatic disturbances are marked by drops in platelet count and fibrinogen and consumption of clotting factors.

Classic heat stroke is described during EHEs, particularly in the elderly. Exertional heat stroke may also occur in young, fit populations such as athletes and military recruits undergoing training. Several high-profile deaths in professional athletes were reported by the media in recent years, demonstrating the importance of prevention when weather conditions increase the risk of such heat stress. In that setting, marked rhabdomyolysis and myoglobinuric renal failure are often observed along with acute hepatic failure and disseminated intravascular coagulation. Mortality ranges from 10% to 70% in series of heatstroke patients, with higher mortality rates found when treatment is delayed more than 2 hours.[34] Predictors of multiorgan dysfunction include respiratory failure, metabolic acidosis, elevated creatinine phosphokinase, and liver function elevations greater than twice normal.[35]

Treatment requires rapid cooling to avoid further cellular and organ damage by extreme hyperpyrexia. In the field or upon arrival in the ED, ice or cold liquids should be placed in contact with the patient especially in the axillae and groin, and additional cooling measures instituted as available, while airway, breathing, and circulation are assessed and managed. Airway management may include endotracheal intubation for control of the airway. If severe hyperpyrexia is suspected, use of a rapid sequence paralytic agent that does not induce hyperkalemia is indicated. Due to altered mental status, an immediate glucose determination is needed to allow rapid diagnosis and treatment of hypoglycemia. Breathing assessment should include oxygen saturation monitoring. Circulatory support includes cardiac monitoring and fluid resuscitation when indicated to support blood pressure, perfusion, and urine output. Caution is necessary when dealing with the geriatric population that may have antecedent cardiac, pulmonary, and/or renal disease. In addition to ice packing, when fans are available, cooling can be accomplished by spraying the undressed patient with tepid (not cold) water while blowing air from large fans across the body surface to maximize evaporative heat loss. More invasive methods such as ice water lavage of the stomach through a nasogastric tube or the peritoneum through a peritoneal lavage catheter, and even cardiopulmonary bypass have had reported anecdotal success. These aggressive treatments have limited evidence of benefit, however, and may actually be harmful and are therefore not recommended by some experts.[36,37] A newer modality of using intravenous catheters containing cooling coils offers an additional treatment option. Frequent monitoring of the core body temperature is essential to avoid overshooting and creation of further problems due to hypothermia. It is not necessary to reduce body temperature to normal, but only to the level thought not to produce cellular injury; a goal of 38.9°C is reasonable. Risks and benefits of each of these techniques have been reviewed.[38]

In addition, the number of fatal cocaine overdoses appears to correlate with higher ambient temperatures. In a New York City study, the mean daily number of cocaine overdose deaths increased by 33% on days with a maximum temperature of 31.1°C or higher, in comparison to days when the mean temperature was below this point.[39]

The Emergency Department and Extreme Heat Events

In nations with well-developed emergency services, the ED plays a significant role during EHEs. EDs are the major point of entry for most victims suffering heat-related illnesses and therefore have a large role in preventing escalating morbidity and mortality. EDs should certainly be prepared to manage surges of EHE patients with adequate cooling equipment. Thus, ED managers must ensure sufficient supplies of water spray bottles, cooling packs, fans, cooling catheters, and ice during EHEs. Informational handouts can be printed as part of discharge instructions in advance of such emergencies as well as during the events. This should become part of the general community educational program, much as is done for other types of safety issues. Increased visits to the EDs in affected areas should be expected.

Using a wide variety of measures to predict EHEs is a complex process that can involve the National Weather Service, local health departments and emergency management agencies, first response emergency medical services agencies, hospitals, medical examiners/coroners' offices, and many other local agencies and community organizations. No matter how effective the ED may be as a heat mortality sentinel, it cannot provide sufficient warning to reduce the impact of these emergencies. Systems designed to predict EHEs in a timely manner should augment and in no way substitute for the longer-range prediction times that air mass monitoring systems allow. The EHE has already started by the time patients begin presenting to EDs.

EHEs tend to generate so many patients so quickly that, in systems where it is permitted, many EDs implement diversion status. As three recent Institute of Medicine (IOM) reports delineate, the U.S. emergency medical care system "is woefully inadequate and unprepared for a pandemic, bioterrorist attack, natural disaster or other national crisis."[40] The IOM found the U.S. emergency care system to be underfunded, too fragmented to communicate and cooperate effectively across levels and geographical areas, and possessing little surge capacity to manage a disaster. The IOM also found that emergency care staff members are often inadequately trained to respond to large-scale disasters or to care for pediatric patients.

During Chicago's July 1995 EHE, there were 1,072 more hospital admissions than average for comparative weeks, with 838 (35%) more patients aged 65 years and older being admitted than expected. There was also strong anecdotal evidence of increased ED visits. An analysis of excess hospital admissions during the heat wave defines who was admitted and why. The primary reasons for a hospital visit were dehydration, heat stroke, or heat exhaustion. The susceptible population at risk for admission had comorbid cardiovascular illnesses, endocrine disorders, liver and kidney diseases, or nervous system disorders. Within this population, the elderly were disproportionately represented, in large part due to their altered thirst perception and related conditions.[41] On the second day of the EHE, only a few Chicago EDs were on diversion and directing ambulances to other hospitals. By the fourth day, however, 18 city EDs were diverting patients to other facilities.[7] A study of the 1993 heat wave in Philadelphia found a 26% increase in total mortality and a 98% increase in cardiovascular mortality associated with the EHE. In adjacent counties, the risk for dying of cardiovascular disease rose significantly for people older than 65 years, for both sexes and all races.[42]

During the European Heat Wave of 2003, heat-related deaths in a Parisian hospital occurred mostly in elderly patients (mean age 84), and 69% were women. Patients who died differed from those who survived.[43] The former were characterized by greater levels of dependency and by a more abnormal initial clinical presentation (such as elevated temperature, lower blood pressure, and altered mental states). They were also more likely to have existing ischemic cardiomyopathies and to be taking psychotropic medications.[43] In London, during the same period, 2,091 deaths occurred (17% more than for the same period in earlier years). Twenty-three percent of the deaths were among those 75 years of age or older.[44] Similar findings come from Australia, where high environmental temperatures are common, although it is rare that these exceptional conditions produce elevated levels of heat-related morbidity and mortality. In four major teaching hospitals in Adelaide, most patients presenting with heat-related conditions (85%) were 60 years or older, with 20% coming from institutional care, and 30% with poor mobility. Peak presentation followed high daily temperatures for four consecutive days. Severity was related to existing cognitive impairment, diuretic use, presenting temperature, heart rate, blood pressure, plasma sodium, and plasma creatinine. The mortality rate was 12%. Seventeen percent required a more dependent level of residential care upon discharge.[45] Similar findings came from a 1999 study in Wisconsin where heat-related illnesses led to 21 deaths. Death rates were highest among the elderly; particularly those aged 65–84 years (2.2/100,000). Heat was the underlying cause of death for 12 of the 21 victims. Cardiovascular conditions resulted in another eight deaths and were a contributing cause for an additional seven.[46]

Hospital/Emergency Department Surge Capacity and Extreme Heat Events

For years, medical disaster planners have considered "surge capacity" in their catastrophic planning (see Chapter 3). Although an EHE would severely test the in-house surge capacity of existing hospitals and EDs, it is unlikely that most EHEs would last long enough and generate enough patients to necessitate the use of external surge facilities. A quick review of surge capacity, however, is helpful to the extent that the same forces that will expand external surge capacity can be used to support and extend services internally.

U.S. hurricanes in 2004 and 2005 provide an example of the devastating health and medical effects of weather disasters. Hurricanes Katrina and Rita and subsequent flooding caused the same types of damage to many local care facilities as they did to other types of building. Many hospitals and federal and state medical support agencies were forced to establish operations in temporary locations such as shuttered retail stores and veterinary hospitals.[47] Freestanding or support/augmentation facilities were also constructed at airports, sports complexes, and adjacent to existing institutions. These "surge" hospitals addressed the increase in demand for medical care and contained triage, treatment, and sometimes surgical capacities.[47] Advice, guidance, and funding to state health departments and hospital systems for surge planning is available from the U. S. Department of Health and Humans Services' Hospital Preparedness Program, as well as from the integrated, all-hazard medical system planning within the Federal Emergency Management Agency's Metropolitan Medical Response System program.

Using the U.S. emergency management organization as an example, federal disaster support to hospitals is only a small part of the national emergency management system. This system is a complex network of public, private, and nonprofit organizations (ranging from the American Red Cross to professional organizations such as the American Hospital Association, local hospital councils, and even local community groups in the vicinity of hospitals) and individual benefactors. It also includes federal, state, and local government agencies, special districts and quasigovernmental bodies, nonprofit service and charitable organizations, ad hoc volunteer groups and individuals, and private sector firms that provide governmental services by contract.[48] Dealing with this huge array of emergency preparedness agencies and entities in a coordinated and effective manner requires hospital preparedness staff whose perspectives are broader than just the individual hospital's concerns. They must also be knowledgeable about the complex and rapidly growing scientific evidence base related to disasters.

When U.S. hospitals implement surge planning, they enter an integrated, but complicated web that includes Joint Commission requirements for: 1) establishing hospital incident command systems as the chain of command for disasters; 2) all-hazard emergency response plans; 3) mutual aid agreements and processes with other hospitals, systems, and local, state, and federal agencies; 4) coordination with local emergency management agencies; and 5) the requirement to maintain comprehensive documentation on decision making, victim destinations, patient tracking, and reimbursement.[49] Existing rules and waivers under the federal Medicare program can also have significant effects on a hospital's ability to address surge conditions (Table 38.2). Other recommendations that address surge planning appear in the publication *Medical Surge Capacity and Capability: A Management System for Integrating Medical and Health Resources during Large-Scale Emergencies.*[50] Those that have the most relevance to EHEs include

- Redundancy. Developing redundancy in hospital operations systems to ensure backup capability during an emergency. Backup systems should be evaluated for their vulnerability to hazards, particularly those most likely to affect primary systems

- Testing of backup and support systems. Establishing programs for testing, inspection, and preventive maintenance of backup systems and facility safety features

The National Foundation for Trauma Care has made a number of key recommendations for improving the capacity of trauma centers to provide care to victims of a terrorist event.[51] Those relevant to EHE surge planning include

- Fund disaster medical care at cost and develop sustainable funding because existing federal programs (predisaster and postdisaster) do not provide enough fiscal support
- Sustainment (e.g., staff and supplies) for more than 3 days is required
- Fund statewide (and multistate) resource monitoring systems
- Provide adequate funding to train staff, based on the proximity and the threat of the hazard
- Provide aftercare for the chronically ill and displaced persons
- Mutual aid agreements and memoranda of understanding must be developed

Auf der Heide published response strategies for hospitals during disasters. Those that are directly applicable to EHEs are

- Establish EMS/hospital radio networks to rapidly collect hospital status information and direct the flow of those casualties who are transported by ambulance. Since a truly interoperable system that is effective, affordable, and easy to use does not currently exist, overall communications redundancy is desirable
- Ensure that hospitals/EMS radio systems are established to facilitate early warning to hospitals from responders in the field. A number of sophisticated systems exist that report hospital bed status availability, hospitals on diversion, and other key information

The Joint Commission found that legal and reimbursement issues are among the most critical, nonpatient care–related problems that hospitals face when developing surge capacity.[47] During surge conditions, state and federal waivers can protect emergency medical workers. During Hurricane Katrina, for example, the Governor of Louisiana waived state licensure restrictions for those licensed out of state. The Department of Health and Human Services afforded liability protection to healthcare workers who volunteered, and waived the *Emergency Medical Treatment and Active Labor Act*. A number of recent U.S. laws and agreements (the Emergency System for Advanced Registration of Volunteer Health Professionals) as well as a proposed hospital-based credentialing system have made it potentially easier to use volunteers who respond to a disaster.

Other U.S. federal and state programs that can provide healthcare staff resources during surge conditions include the National Disaster Medical System, the U.S. Public Health Service Commissioned Corps, and the Medical Reserve Corps. The Emergency Management Assistance Compact, administered by the National Emergency Management Association, can also provide volunteers. Individuals recruited by this program (31,000 for Hurricanes Katrina and Rita alone) played important roles in the responses to the four hurricanes in 2004 and to Katrina and Rita the next year. It must be stressed that all of these are "borrowed" resources to the extent that the nation does not have a standing pool of available healthcare personnel. Each individual has an existing job, so the problem of mobilizing personnel with existing commitments is one that occurs in every major disaster.[47,52]

Table 38.2: External Support for Hospital Emergency Departments before/during EHEs

- Longer shifts, intra- and interhospital agreements
- Mutual aid (provided by state/local agencies, groups, or through FEMA's Emergency Medical Assistance Compact – EMAC)
- State/Local Departments of Public Health Assets, e.g., The Illinois Mobile Emergency Response Team (IMERT), or the Special Operations Response Team (SORT) in North Carolina
- The National Disaster Medical System (described earlier)
- The Medical Reserve Corps (situated in the Office of the U.S. Surgeon General)

Mortality and Morbidity from Heat Exposure

There is a relatively consistent correlation between mortality and increases in heat measured by temperatures, heat index (a measure of temperature and humidity), or by air-mass conditions.[12,14,53–55] Using sophisticated air-mass models, researchers have demonstrated a clear relationship between heat-related mortality and EHEs in 44 major U.S. metropolitan areas.[14] In a study of 28 metropolitan areas within the United States, heat-related deaths during EHEs significantly exceeded the expected totals for time of year and were in substantial agreement with the previous findings.[17] Overall, however, heat-related mortality trends have declined between 1964 and 1998, as temperatures and heat stress conditions have risen. This suggests that a relative "desensitization" of the U.S. metropolitan population to weather-related heat stress has occurred. Such desensitization can be attributed to a variety of factors, including improved medical care, increased utilization of air conditioning, better public awareness programs, and both human physiological and urban medical/emergency response systems adaptations. The irony is clear: traditionally hotter metropolitan areas have lower heat-related mortality.

EHEs also increase morbidity, although the data are less compelling. The majority of studies emphasize the most serious incidents that result in ED or hospital admissions. Nonetheless, the general trend of research examining all conditions is clear.[56] Semenza studied 1,072 hospital admissions during the 1995 Chicago EHE and found the majority of excess admissions were due to dehydration, heat stroke, and heat exhaustion among people with existing, underlying conditions.[41] Rydman also studied intense heat-related morbidity from the same event through an analysis of ED visits and found that heat-related morbidity was an antecedent of mortality.[57] Kilbourne searched for the most effective responses to heat-related illnesses and determined that universal access to air conditioning may be the most effective intervention, even with the relatively steep costs of providing this service to the poor.[32] More recent studies found that basic behavioral changes and adaptations (e.g., use of air conditioning, adequate hydration, heat emergency plans, warning systems, and illness management plans) could significantly affect heat-related outcomes.[58]

The most precise definition of mortality related to heat waves is that given by a medical examiner or a coroner in the formal determination of death. After serious EHEs in Chicago in 1995,

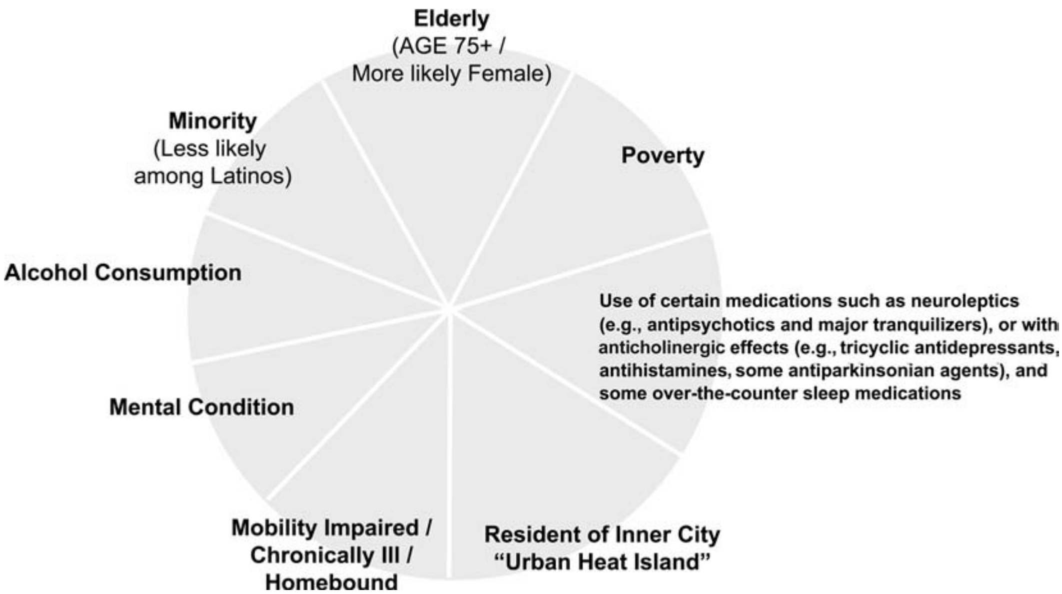


Figure 38.4. The demographic and individual risk factors of heat-related mortality.

and in Philadelphia in 1993, the National Association of Medical Examiners recommended the following definition of heat-related death: "a death in which exposure to high ambient temperature either caused the death or significantly contributed to it." The committee also recommended that the diagnosis of heat-related death be based on a history of exposure to high ambient temperature and the reasonable exclusion of other causes of hyperthermia. The diagnosis may be established from the circumstances surrounding the death, investigative reports concerning environmental temperature, or measured antemortem body temperatures at the time of collapse being at least 40.6°C. Under those conditions, the cause of death should be certified as heatstroke or hyperthermia. In cases in which the antemortem body temperature cannot be established, but the environmental temperature at the time of collapse was high, appropriate heat-related diagnosis should be listed as the cause of death or as a significant contributing condition.[59]

Demographic and Individual Factors in Heat Exposure

Those individuals at the highest risk of becoming ill or dying during EHEs are the very young, the elderly (socially isolated, without access to air conditioning, bedridden, and with ischemic heart disease or other chronic conditions), the poor, minorities, and those taking certain medications such as neuroleptics or antiparkinson agents.[8,26,45,55,57,60–65] Behaviors that can result in heat stroke from dehydration and impaired judgment include strenuous exercise in hot or humid weather (even by the young and physically fit), alcohol consumption, and the use of some nonprescription drugs (e.g., antihistamines and sleeping pills).[8,66] Cocaine overdose, which is associated with hypertension, tachycardia, coronary vasospasm, arrhythmias, and increased core temperature, was linked with a significant increase in mortality in Marzuk's 1998 study of New York City.[39,64]

Use of cooling centers by individuals was not shown to be significantly protective, probably because so few visited them.[60] Walking down flights of stairs, with the mobility limitations often accompanying older age, and crossing potentially unsafe streets to attend cooling centers are unlikely options for many of the at-risk elderly.[60] European mortality patterns in the August 2003 heat wave mirrored those seen in the United States, with 70% of those dying from heat-related causes being 75 years or older.[67] Accurate demographic estimates and projections of those sickened or dying from heat-related causes are complicated because susceptible groups often remain in the city, creating a bias in predicted excess deaths.[68] Most often, there are more females affected by adverse heat-related conditions. When stratifying by age group, there is probably some residual confounding related to sex, because the increase in mortality seems to be greater among women. This probably reflects the higher proportion of women in the elderly population, their possible higher susceptibility, and their higher rates of living alone (Figure 38.4).[68]

During Chicago's heat wave of 1995, hospital admissions were up 11% for the week of the heat event, with a 35% increase for patients 65 years of age and older. The majority of the excess admissions (59%) represented patients requiring treatments for dehydration, heat stroke, and heat exhaustion. With the exception of acute renal failure, no other primary discharge diagnoses were significantly elevated. In contrast, analysis of comorbid conditions revealed 23% excess admissions of underlying cardiovascular diseases, 30% for diabetes, 52% with renal diseases, and 20% excess admissions related to nervous system disorders. Patient admissions for emphysema and epilepsy were also significantly elevated during the heat event.[41]

Geographical Factors in Heat Exposure

Average summer temperatures appear to have no effect on heat deaths. Kilbourne observes that it is not the absolute temperature value, but rather the extent of upward deviation from the usual summer temperature that seems to be the key variable affecting mortality.[32] For example, southwestern cities such as Phoenix have fewer heat-related deaths but have higher average temperatures than midwestern cities such as St. Louis or Chicago, which have experienced high mortality from heat waves. Neither excess mortality nor prominent heat-related health effects were noted in Phoenix in July 1980 despite temperatures that averaged

Table 38.3: Threshold Heat Temperatures that Result in an Increased Local Mortality Rate

Location	*Threshold Temperature (°C)*
Atlanta, Georgia	34
Chicago, Illinois	33
Cincinnati, Ohio	33
Dallas, Texas	39
Denver, Colorado	32
Detroit, Michigan	32
Kansas City, Kansas	37
Los Angeles, California	27
Memphis, Tennessee	37
Miami, Florida	32
Minneapolis, Minnesota	34
New York City, New York	33
Philadelphia, Pennsylvania	33
St. Louis, Missouri	36
Salt Lake City, Utah	35
San Francisco, California	29
Seattle, Washington	31

2.4°C above normal and a highest monthly temperature of 46°C. As expected, based on reports in the international literature, cities that normally have a cool climate (those located in the north) reported the highest excess mortality.[69] Reasons for these differences have not been studied extensively. Possible explanations include differences in population age/acclimatization, architectural style/building materials, and air conditioning use. Research done at the University of Delaware resulted in a list of the temperature levels that affect mortality and morbidity in select, large American cities whose populations have been subjected to various degrees of heat stress (Table 38.3).

There is some evidence of a geographical and physiological basis for the lower death rates in urban areas that have higher average temperatures. Kilbourne makes the same observation that heat seems to cause fewer health problems in characteristically warm areas than in those that are more variable in climate; the temperature level required to increase mortality is actually higher in hotter climates.[14,32,71] DiMaio has observed that when individuals live in a temperate zone, many of the sweat glands with which they were born become permanently inactive during childhood.[72] If, however, the individual lives in the tropics, the glands remain functional throughout life. Other adaptations include reduction in sodium loss from sweat to 3–5 g/day, after 4–6 weeks of acclimatization. A person who sweats profusely may lose as much as 15–30 g/day of sodium chloride until becoming acclimated.

Chestnut demonstrated geographical patterns in heat-related mortality.[73] The highest hot weather–related mortality rates are in northern metropolitan areas of the U.S., even though average summer temperatures are higher in southern metropolitan areas. This suggests that biological/behavioral adaptations occur in areas that are consistently hot, but not where minimum daily temperature variability is great. The availability of air conditioning, standards of living, and housing quality contribute to differences in mortality, but these explain a much smaller share of the fatalities than does variability in minimum daily temperatures.[73] Kalkstein found that consecutive days of hot, oppressive weather caused a continued rise in mortality.[74] Chestnut also reported that areas with higher average temperatures and more frequent hot weather episodes do not necessarily experience more hot weather–related mortality during summer months.[73] Several southern metropolitan areas with very hot, humid summer weather experience much lower or no statistically significant hot weather–related-mortality. It remains unclear how many of these data apply to the degree of mortality or morbidity from increases in the temperature, duration, and frequency of hot weather episodes in the tropics.[2]

Death rates related to EHEs do not occur on the days with the highest average temperatures. In a study of heat-related mortality from the September 1970 heat wave in New York and other eastern seaboard cities, the highest mortality levels occurred on the third day, when the temperatures were less than those on the first 2 days (Figure 38.5).[8,75,75a] In Chicago's 1995 EHE, a slightly different pattern manifested itself, with the number of deaths peaking 2 days after the maximum heat-index recording.[76] This is consistent with previous studies demonstrating that during EHEs, the maximum number of heat deaths tends to lag behind the days with the highest temperatures.[77,78] It has also been suggested that EHE-related mortality may reflect the tendency of heat stress to precipitate death in persons who are already ill from a wide variety of chronic diseases and would die in the near future anyway.[8] Evidence of this potential effect has been sought but not found. For example, no decrement in the number of deaths was reported following the EHE in New York in 1972.[8,75,75a]

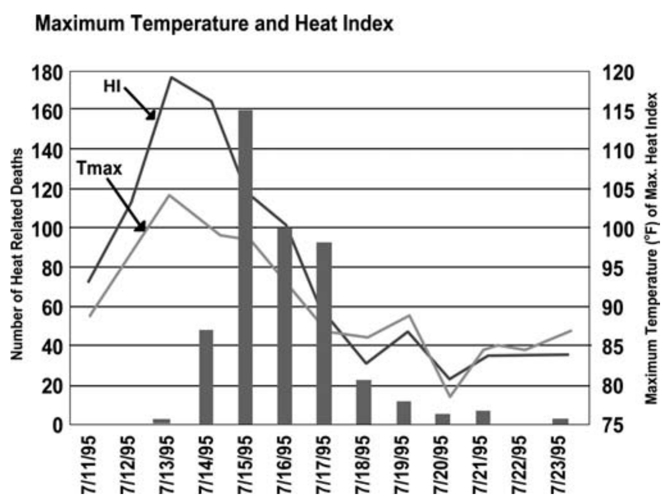


Figure 38.5. Heat-related deaths – Chicago, July, 1995. This graph tracks maximum temperature (Tmax), heat index (HI), and heat-related deaths in Chicago each day from July 11–23, 1995. The light gray line shows maximum daily temperature, the dark gray line shows the heat index, and the bars indicate the number of deaths for the day. *Source:* By the National Synthesis Team. U.S. Global Change Research Program, published in 2000.

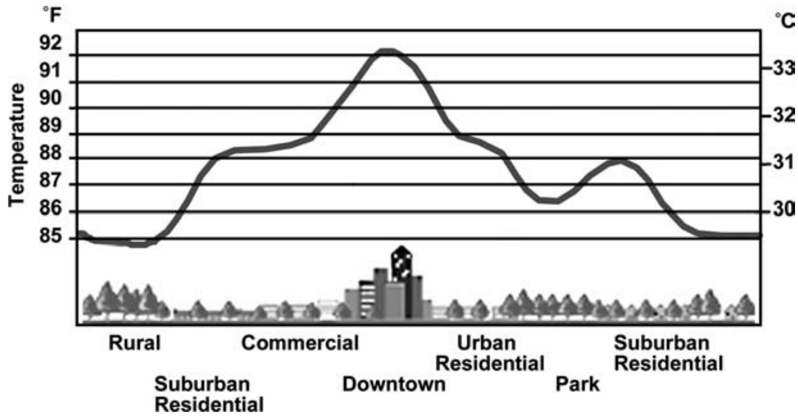


Figure 38.6. Urban heat island profile. *Source:* Environmental Protection Agency, http://www.epa.gov/heatisland/about/. Modified by Tom Javorcic, 2007.

Urban Heat Islands as Risk Factors

The Urban Heat Island and Bioclimates

The long-established concept of the "Urban Heat Island" is pervasive in the American and the European literature on EHEs, and applies, to a lesser extent, to urban areas in developing countries.[79,79a] This phenomenon describes urban and suburban temperatures that are 1°C–6°C hotter than nearby rural areas. Elevated temperatures can impact communities by increasing peak energy demand, air conditioning costs, air pollution levels, and heat-related illness and mortality.[80] A typical urban heat island profile is shown in Figure 38.6. Important aspects of the urban heat island literature include themes regarding poverty, social isolation, social class, race/minority status, crime, poor housing, inadequate healthcare, and mobility problems. Ultimately, most of these factors are related to poverty and unemployment. Studies of heat islands do not generally indicate bioclimate aspects (effects of weather and climate on life forms, including humans) and are therefore of limited use to urban planning.[81]

Urban areas tend to be warmer because of their "masses of stone, brick, concrete, asphalt, and cement."[25] Their darker surfaces, which absorb more solar heat during the day, radiate this energy into the environment at night.[70] All of these factors including diminished wind and cooling air currents create the heat storing and absorbing "Urban Heat Island." The Atlanta Metropolitan Area Heat Profile appears in Figure 38.7 with dark and light gray denoting hotter and colder areas. Heat wave response planning is of interest in intensely developed urban areas that are large enough, dense enough, and often old enough to have potentially damaging urban heat islands. U.S. studies analyzing data from the last 100 years confirm this insight and recognize clear associations among 1) large masses of cityscape (e.g., cement, asphalt, and high percentages of multiple unit dwellings), 2) a relative lack of trees and other vegetation, and 3) poor wind and air circulation patterns. These areas have experienced relatively high EHE-related morbidity and mortality.[8,31,70,73] Klinenberg has called urban heat islands "Urban Loneliness Islands," referring to the physical and social isolation that affects many elderly heat victims.[82]

Figure 38.7. *Source:* Environmental Protection Agency, http://www.epa.gov/heatisland/about/measurement.html. Modified by Tom Javorcic, 2007.

After the deadly Chicago heat wave of 1995, the National Oceanic and Atmospheric Administration observed[7]

> There is sufficient circumstantial evidence to conclude that the urban heat island was at least partially responsible for . . . conditions in Chicago's south side . . . the elderly and infirm . . . in urban areas are in the greatest danger during heat waves.

During EHEs, these effects can magnify health risks by increasing both the potential maximum temperature to which residents are exposed and the duration of time in which this exposure occurs.[3]

Urban populations in nonindustrialized countries are likely to be particularly vulnerable to such effects when compounded by climate change.[83] Worsening economic conditions will only exacerbate this impact. A recent statement by Lord May, President of the (British) Royal Society, makes clear that climate change and its related and unexpected costs could ruin efforts to elevate Africa out of poverty.[4] Vulnerable populations can, however, be spared many of the effects of EHEs through relatively uncomplicated human interventions, including the use of advanced early warning systems and providing access to water, shelter, appropriate emergency medical care, and air conditioning – if available.[1]

Concentrations of asphalt, concrete, stone, and brick are relatively new, and make up relatively smaller parts of urban areas in the developing nations. Poor immigrants to the city, and even the emerging middle class, usually live in a different environment. These areas are characterized by quasitraditional, owner-constructed, single- or extended-family housing, frequently densely packed, and usually with dirt rather than asphalt or cement roads. These typically large barrios, favellas, kampungs, or townships are not really heat islands, due to their lack of a genuine urban infrastructure, and they vary widely as to their degree of criminality. Yet these communities are where almost all deaths and illnesses from EHE events will occur.

Heat in the Indoor Environment

Kovats and Jendritzky have found that there are three main factors associated with indoor heat exposure.[84]

1) *Thermal capacity of the building* – A heavy building will warm up more slowly in a heat wave, particularly if it is well insulated.
2) *Position of apartment* – The upper floors of a building will generally be hotter than the lower floors because the roof provides inadequate insulation and warmer air tends to rise.
3) *Behavior and ventilation* – Occupants will adapt as best they can to hot environments using fans (which can actually cause harm at higher temperatures) and opening windows to let in cool evening air. The fact that many people tend to wear the same clothing regardless of season or temperature demonstrates the complexity of decision processes and determinants of behavior.

Givoni has categorized the variables that influence the inner bioclimate.[81,85,86]

- The geometrical configuration of the building
- The orientation of the building
- The size and location of the windows
- The properties of the building materials
- The colors of the external surfaces

Givoni has also categorized the aspects of external design that affect urban climate.

- Size and density of the built up area:
  - The microclimate in the immediate vicinity of green spaces differs from that prevalent in unplanted areas
  - Vegetation has lower heat capacity than building materials
  - Solar radiation is absorbed so that reflected radiation is very small (low albedo)
  - Green spaces have higher evapotranspiration rates than unplanted areas
  - Plant leaves can filter dust out of the air
- Layout and width of streets and their orientation to prevailing winds
- The height, shape, and relative location of buildings
- Shading conditions along streets and parking areas
- Ensuring short distances for walking

There is a need for further health research on the relationship between housing types and heat effects. In addition, there is little information about how people behave in their homes. When do they use their air conditioners? What is the effect of electrical costs on the poor? When do they open their windows for cooling or when do they close them to keep out pollution or noise?

Air Conditioning

Air conditioning is a "special case" in Europe, which relies much less on air conditioning than the United States, even in many healthcare institutions. The European research on air conditioning is far from definitive, but supports the use of unit-wide, central air conditioning as opposed to single room air conditioning. The latter has been found to be minimally, if at all protective, unless the housing unit has enough window air conditioners to approximate the coverage of central air conditioning.[87] Although the Europeans recognize the protective nature of air conditioning in EHEs, they stress that air conditioning requires sealed buildings that create stagnant, polluted air issues, and that air conditioning itself uses energy that contributes to global warming. When power grids fail, people are often left in relatively airtight buildings.[81] In Europe, air conditioning is advised only in cases in which ill health is present.[84]

Planning for Extreme Heat Events

The Extreme Heat Event Planning Process

Despite the many examples of deadly EHEs, a recent review of plans from 18 U.S. cities at risk for heat-related mortality found that many had inadequate plans or no plans at all.[88] Another study of the nation's 120 largest cities found that only 29 had developed single-purpose response plans of varying quality and scope.[89,90] Although there is no mechanism for coordinated U.S. EHE response planning, this decade has seen significant federal activity. These efforts include the development and mass circulation of a comprehensive, interagency extreme heat event guide (2006), the federally sponsored Heat Wave Workshop in 1996, the National Weather Service's growing use of sophisticated air mass prediction systems, the CDC's coverage of EHEs in its *Morbidity and Mortality Weekly Reports*, and the studies found on multiple web pages by the CDC, Environmental Protection Agency, and National Oceanic and Atmospheric Administration.

Urban EHE response planning has developed into a unique policy area with its own literature that is scattered among larger disciplines. It is supported by a growing public awareness constantly reinforced by heat wave alerts. During recent decades, a modestly growing number of urban governments in the United States, Canada, and Europe have reacted to EHEs by developing EHE response plans. These include alert/watch/warning systems based on an analysis of deadly air masses that provide more "early warning time" than previous systems. In addition to such strategies, existing urban EHE response plans have included the following: 1) public utility bill forgiveness or modified bill payment, 2) free air conditioner distributions, 3) public cooling centers, 4) hotlines, 5) public education and information systems, 6) registries for the elderly and other at-risk populations, and 7) aggressive outreach programs. Such policies could be adopted in developing countries, although international donors may need to supply the necessary resources. The most plausible cooling sites are usually government offices and elite hotels, places often reluctant to admit poor people.

Khogali and Rosenfeld break down response strategies into primary, secondary, and tertiary levels. Their recommendations are specific and proactive in reducing heat-related disease in the workplace and sports venues.[91]

Primary prevention addresses adequate and effective building design to maximize comfortable cooling, good ventilation, and reduction of radiant and convective heat with mechanical aids.

Secondary prevention includes a wide variety of workplace and sports-related preventative measures that are placed in two groups. The first is referred to as selection and acclimation. These interventions include pre-event employment and placement medical examination in occupational settings and pre-event participation medical examination for sports activities. The second measure is appropriate administrative personnel behavior. This emphasizes modification of the work-rest cycle or the exercise–rest cycle and provision of cool rest areas with fluids.

Tertiary prevention strategies aim at diagnosing heat illness syndromes as early as possible. Khogali and Rosenfeld stress workplace and organized athletic participation.

Certain characteristics are associated with individual municipalities that have developed an EHE response plan. A logistic regression analysis of the 29 cities with such documents showed that cities with larger populations, higher percentages of multiple unit dwellings, fewer residents age 25 or older with bachelor degrees, higher violent crime rates, and a member of a heat wave advocacy coalition working or living within the jurisdiction were more likely to have developed a plan. Violent crime was a significant predictor. If such correlations are not spurious, they offer further evidence of widespread perceptions that heat waves are law-and-order problems. Cities with a political rather than a professional administration are more likely to have a plan, suggesting "political" solutions as more plausible than purely "technocratic" ones.

Well-designed EHE plans can be cost effective. Semenza, for example, concluded that those at greatest risk of dying during Chicago's heat wave of 1995 were people with medical illnesses, socially isolated, and without air conditioning. Such groups could clearly benefit from simple interventions.[55]

In both Chicago and Milwaukee during the 1995 events, the National Weather Service issued warnings of the developing heat wave several days in advance, which were quickly broadcast by the local media. Given this advance warning, many of the heat-related deaths associated with this event were preventable.[93] Despite these timely warnings and effective media coverage, this information either failed to reach or was not used effectively by the people who could have prevented heat-related deaths. This included the victims themselves as well as members of the healthcare community who did not always understand the scope of the impending calamity.[7] Much more than effective media announcements are needed to avoid serious heat wave mortality and morbidity.[55,57,94–97] The development of pre-event plans that integrate public and private assets are necessary to coordinate and effectively deploy life-saving resources.

It is difficult to use scientific evidence to judge the post facto efficiency of EHE response plans because no two heat waves are the same, and because of the large number of interrelated variables. Researchers have analyzed the 1995 EHEs in St. Louis and Chicago and compared them to the 1999 EHEs in those same cities. Although noting differences, they saw more effective and faster responses in 1999 that appeared to save lives that would have been lost in 1995. These cities learned from prior experiences and crafted effective EHE response plans.

The only intervention that was not widely reflected in the content of existing plans was equipment grant subsidies (e.g., for air conditioners) for poor residents. Not surprisingly, bill forgiveness, bill postponement, and related programs involve real losses for utility companies. Such programs, as they exist, reflect a confluence of creativity, resources, cooperation, and public spirit. In developing countries, air conditioners would rank low among priorities for the poor as compared with receiving advanced notice of the impending increase in temperature, better education, potable water, decent shelters, and healthcare. In addition, a large number of air conditioners would likely cause local circuits to fail or create a demand that electricity-generating facilities could not fulfill.

Community Prevention and Mitigation Plans for Extreme Heat Events

The U.S. National Center for Environmental Health within the CDC conducted a nationwide survey of local heat wave preparedness plans in an effort to develop guidelines for cities.[6,98] CDC's National Center for Environmental Health reviewed EHE preparedness plans from 12 U.S. cities at risk for heat wave–related morbidity. Cities were selected based on location and population. Examination of their respective plans focused on assessing key facets. These included 1) the inclusion of community organizations, 2) plans for early information dissemination, 3) targeting of high-risk populations, 4) heat monitoring methods and plan activation, 5) interventions, and 6) evaluation. The important elements of these plans are discussed.

Community Participation

Effective heat wave response plans require collaboration between a wide variety of government agencies including departments of public health, emergency management agencies, urban and regional planning departments, agencies for the elderly, and community and volunteer organizations. Community organizations can lend and donate equipment or supplies, provide air-conditioned cooling sites, and assist with membership lists to conduct outreach for high-risk populations. Although the departments of health and community organizations were generally included in plans, incorporation of the police, media, hospitals, utility companies, and local businesses varied. Communications systems between organizations appeared in all plans, but only six provided complete and updated contact information.

Early Information Dissemination

Heat-related illnesses can be prevented by the dissemination of early public information, and such educational endeavors are essential to successful prevention efforts. These should include recognition of health threats posed by high heat and humidity, appropriate precautionary and response measures, and encouragement to check on family members and neighbors in high-risk groups. Eight of 12 plans included early educational messages to city residents.

High-risk Populations

Although eight of the 12 surveyed plans targeted educational messages and interventions toward the elderly populations, only four developed specific methods to reach socially isolated individuals. Furthermore, only one plan addressed individuals with chronic illnesses, and two addressed those on medications affecting thermoregulation. Three focused on the disabled and two on the homeless. Clinics, pharmacies, physicians, visiting nurses, and home health workers can help with public education, but were not included in many plans.

Heat Monitoring Methods and Plan Activation

Each plan involved methods for monitoring heat. Typically, monitoring was done by the local office of the National Weather

Table 38.4: Elements of Effective EHE Plans

- Ensuring prediction of EHE conditions 1–5 days in advance
- Quantitative links between temperature and health effects
- EHE notification and effective governmental responses: hotlines, public information, at-risk registry, direct action
- Active mitigation by urban builders and urban governmental regulators

Service. Six plans included the medical examiner's office and EDs for evaluating heat-related mortality and morbidity. Ten plans used a three-level public warning system for advisory, watch, and warning levels. Only three described criteria for deactivation.

Interventions

All 12 cities surveyed had plans to provide air-conditioned shelters. Ten municipalities used hotlines, and six provided transportation to the shelters. Two provided air conditioners and "check-in" services for the elderly, and two could procure emergency funds for cooling packs, beverages, and transportation services. Four provided water, suspension of utility disconnection, and extension of community swimming pool hours. Two cities provided translation services and four provided telecommunication devices for the deaf.

Evaluation

Only one proposal outlined a method of evaluating the plan following its implementation. After the EHE and the response conclude, the lead organization should conduct an evaluation of the city's efforts and document the results in an After Action Report. This evaluation should include data/input from participating organizations and from the public. This will help improve future responses to heat wave emergencies.

Elements of Effective Extreme Heat Event Plans

Effective EHE preparedness and response plans vary, based on different local circumstances. The EHE experts who developed the *Excessive Heat Events Guidebook* reviewed multiple information sources, including the preparedness and response literature, the views of other experts in the field, and the best examples of existing plans.[1] They selected a number of elements key to the development of effective EHE preparedness and response plans (Table 38.4).

Extreme Heat Event Prediction: Ensure Prediction of Extreme Heat Event Conditions 1–5 Days in Advance

Adequate advanced warning is probably the most important factor in preventing EHE related morbidity and mortality. EDs need time to augment staffing and hospitals must adjust to summer vacations, staff rotations, and the suspension of elective procedures. Ambulance services require similar preparation and coordination. If importing medical support from other jurisdictions is necessary, pre-event planning is critical. Since the pool of paramedics and emergency medical technicians is a relatively inelastic group, the practice of assigning individuals to serve in a variety of capacities will likely be ineffective and only highlight existing shortages and limited staff availability.

Forecasting the development and characteristics of an EHE is critical to both EHE risk assessment and implementation of notification and response systems. The National Weather Service provides this information across the U.S. and is moving toward the use of more sophisticated air mass models that provide improved notification. Toronto and a growing number of U.S. cities use this sophisticated air mass–based prediction system that incorporates local factors. The system was originally developed by Kalkstein at the Center for Climatic Research at the University of Delaware. Air mass occurrences can be predicted up to 48 hours in advance with the use of model output statistics guidance forecast systems.[99]

Extreme Heat Event Risk Assessment of Potential Health Impacts from Rising Temperatures

Whichever agency coordinates the response to EHEs, it must develop quantitative estimates of potential health impacts from the rising temperatures. These impacts will range from effects on EDs and hospitals to populations whose special needs and circumstances make them more vulnerable. Emergency managers can access records of facilities and locations with significant concentrations of high-risk individuals to use as the basis for health needs projections. Estimating resource needs based on the risk assessment will result in outreach activities to those most likely to be affected.

Extreme Heat Event Notification and Effective Response Actions

Coordinating public broadcasts of information about the anticipated timing, severity, and direction of EHE conditions as well as information regarding implementation of various protective measures is important. Emergency facilities, healthcare providers, and hospitals require notification regarding the timing of EHEs so that emergency staffing plans can be invoked. Emergency phone lines must be created as soon as early weather warnings are issued.

Mutual aid plans are necessary so that staff and facility shortages can be managed effectively. In addition to mutual aid assistance, in the U.S., a variety of state and federal programs may provide staffing during EHEs, including the National Disaster Medical System, the Emergency Management Assistance Compact, and the Medical Reserve Corps. At the time of this writing, some of these federal response assets are coordinated through the staff of the Assistant Secretary for Preparedness and Response. Local hospital councils and hospital networks may also provide mutual support.

Outreach activities for high-risk groups including the elderly and homeless must be undertaken as soon as possible after early weather warnings are issued. Utility shutoffs should be suspended during the period of the EHE and the recovery phase. Cooling shelters must be staffed and operational, with transportation and security measures taken. Rescheduling of some public events may be required.

Extreme Heat Event Mitigation

Strategies currently exist that can reduce the effects of urban heat islands and general EHE conditions. City managers can develop and publicize urban garden and vegetation programs. Contractors can construct buildings using lighter colors (particularly on roofs) and use the reflective quality of certain building materials, particularly in public structures, to reduce EHE effects. A summary of basic strategies that various levels of government

Table 38.5: Effective Urban Strategies to Reduce Heat Island Effects

- Cities foster urban gardens/roof gardens
- Builders use light colors (especially on roofs or any reflective surfaces)
- Cities support tree and shrub intensity
- Cooling airways planned

can follow to reduce the risks of heat-related mortality from EHEs are shown in Table 38.5.[1]

The Philadelphia Extreme Heat Event Response Plan

In response to a deadly EHE in 1993, a multiagency task force developed an integrated EHE preparedness and response plan. As the *Excessive Heat Events Guidebook* observes, the Philadelphia plan is often described as the "Benchmark" Plan. The Philadelphia Plan includes[1]

- Public announcements associated with intense education and preparation of the media
- Buddy system advocacy for checking on local high-risk residents throughout the event (includes block captains)
- Heatline activation
- Home visits by health department staff
- Halt to service shutoff during high heat warning periods
- Increased emergency medical service staffing
- Increased outreach for the homeless
- Cooling shelter/senior refuge
- Outreach by public posting of key numbers on local landmark buildings

Basic strategies for reducing heat-related mortality based on a review of the EHE response literature and several model city plans are presented in Table 38.5.

The Chicago Heat Wave of 1995

The Chicago Heat Wave of 1995 was a relatively short, but intense event that resulted in deaths within vulnerable populations and damaged the reputation of the political system that was slow in recognizing and coping with its consequences. The effects of heat-related emergency extend beyond morbidity and mortality and include intensely emotional and political components. During the Chicago heat wave, a short but intense confrontation between the medical examiner and the city's mayor ensued regarding the definition of heat-related deaths. By varying accounts, Chicago experienced approximately 500–700 excess deaths, most of which were classified as heat-related during the roughly 5-day heat wave period.[55] The African-American community had the highest rate of heat-related mortality of all minority groups.[100] In Chicago's case, there was an existing heat wave emergency plan, but it was not as detailed or as extensive as the one that was developed after the event. The plan in effect during the heat wave was very brief and not comprehensive. It was the focus of an intense media debate regarding its value, the lack of urgency of the city's initial response, and the definition and numbers of "excess" heat-related deaths. In the midst of a growing controversy, two reporters for the *Chicago Sun Times* wrote

> Chicago's 1½ page heat plan is thin on details about getting relief to the people who need it most. And during last week's heat emergency, they failed to follow that plan until the death toll started rising.[101]

During the first days of the heat wave, the mayor was under attack for his response to the deadly event, and, like most Chicagoans, he did not anticipate the problem. The Cook County medical examiner reported more than 370 heat-related deaths, and accurately predicted that the final count would be more than 400. The newspapers reported that when confronted with such numbers, the mayor responded to the medical examiner by saying, "Every day people die of natural causes . . . You can't put everything as heat-related." The nightly news aired images of the crowded funeral homes and the refrigerated trucks outside the county morgue.[102] The medical examiner's figures and methods were supported by later research.[63] Once the magnitude of the crisis became clear, an improved plan was quickly developed. In the interim, community groups called for the resignation of top cabinet members involved in the heat crisis.[103]

Extreme Heat Events in the Developing World

A scientific consensus has developed regarding the belief that global temperatures are warming and that there is an association with humankind's growing use of carbon-based fuels. In 1988, under the guidance and auspices of the United Nations (UN), scientists and government officials from around the world inaugurated the Intergovernmental Panel on Climate Change. This body has produced massive world assessment reports in 1990, 1995, 2001, and most recently, in 2007, further refining and corroborating the global warming paradigm as both anecdotal and scientifically validated evidence continues to grow.[104] A meta-analysis was reported in the journal *Science* in 2004, stating that of 928 papers presented, "none of the papers" disagreed with the thesis that global warming exists and that human activity is a cause. A significant amount of planning and analysis has emerged from the United States and Europe in response to deadly heat waves. Given that 2007 had the highest January temperatures on record to that date, planning for EHEs across the world will likely intensify (Figure 38.8).[1,8,105,105a,105b] Planning related to global warming has its limitations. Robert J. Samuelson has said, "we don't know enough to relieve global warming, and – barring major technological breakthroughs – we can't do much about it." He cites projections from the International Energy Agency demonstrating that "unless we condemn the world's poor to their present poverty – and freeze everyone else's living standards, greenhouse gases will double by 2050. No government will adopt the draconian restrictions on economic growth and personal freedom that might curb global warming." World population growth and development will likely proceed as expected exemplified by China's construction of one new coal-fired power plant each week.[106] The urban megacities of the developing world are subject to the interlocking problems of shortages of potable water, weak government services, lack of access to air-conditioned structures, and crowded shelters (Table 38.6).

Despite the history of EHEs, there is consensus that many adverse outcomes are preventable.[1,107] Reducing future undesirable outcomes requires improving the awareness of public health officials and the general public regarding the associated health risks while continuing to develop and implement effective

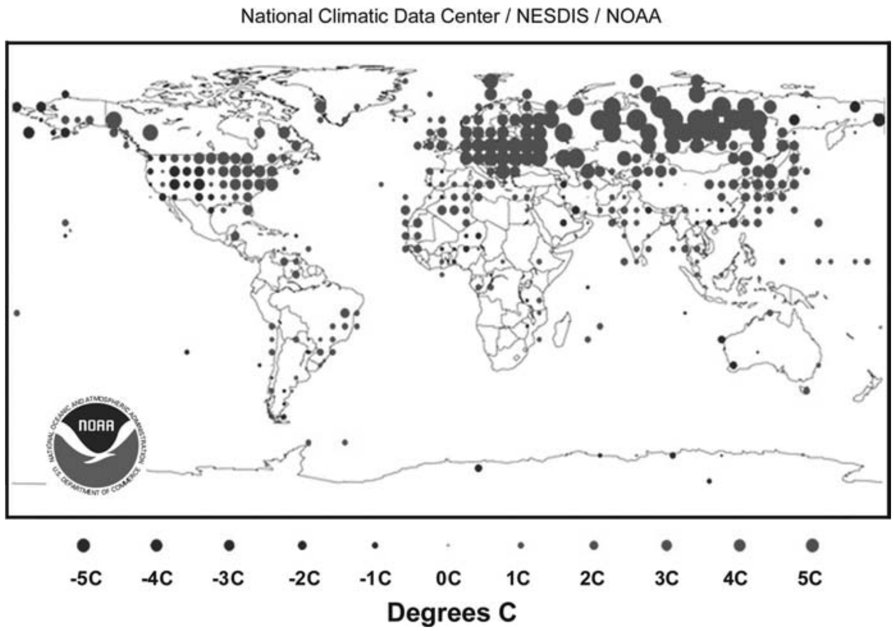


Figure 38.8. Temperature anomalies january 2007 (with respect to a 1961–1990 base period). *Source:* National Oceanic & Atmospheric Association, http://www.noaa.gov. Modified by Tom Javorcic, 2007.

EHE notification and response programs.[106] EHEs are public health threats because they often increase the number of daily deaths and other nonfatal adverse health outcomes in affected populations. The most vulnerable groups can be found living in urban heat islands and EHEs can increase mortality and morbidity in these vulnerable populations.[92,106,108] Future unfavorable health impacts could be reduced through early forecasting of EHEs and subsequent implementation of low-cost and effective responses.

The effects of global warming are intensified by two crucial issues: population growth and the shift to living in cities. For those residing in developing countries, the cities often provide only rudimentary infrastructure and poverty significantly impacts quality of life.[109] At the end of 2008, the world's population reached more than 6.87 billion and it is expected to reach 7.5 billion by 2015. Two-thirds of these individuals will live in cities by 2020 with estimates of up to 1 billion now living as squatters in informal housing, mainly across the developing world.[110,111] In 2015, there are predicted to be 23 "megacities" (>10 million inhabitants each), with 19 of these in the developing world. This does not imply, however, that urban density is necessarily negative. London's stylish Kensington and Chelsea have densities three times those of poorer boroughs.[108]

The available support from international organizations is insufficient to ameliorate EHE disasters in meaningful ways, so a search for solutions to these growing public health problems is a pressing global need. Industrialized nations can play a significant role as informed leaders of public opinion, selecting the best domestic and international policies. The situation in several cities will be highlighted to illustrate the problems.

Table 38.6: Interlocking EHE Problems in Urban Megacities of the Developing World

- Shortages of potable water
- Weak government services
- Lack of access to air conditioned structures
- Crowded shelters
- Unplanned, tightly packed neighborhoods with casual structures

The following discussion will focus on two cities from South America (Caracas, Venezuela and Rio de Janeiro, Brazil), Africa (Cairo, Egypt and Nairobi, Kenya); and southeast Asia (Jakarta, Indonesia and Kuala Lumpur, Malaysia). There are many interesting differences among these cities, but the cities' surprising similarities will be discussed. Because political and economic constraints on adequate preparations for EHEs are significant, these will be addressed for developing nations.

Each of the cities mentioned previously has the following characteristics: 1) a gleaming high-rise commercial center representing a heat island that is smaller in relation to the city's total surface area than in the west, 2) spacious elite residential areas occupied by foreigners and ethnic minorities whose success can stir resentment among the poor, 3) huge residential areas occupied by lower socioeconomic status individuals in search of employment (often recent migrants from rural areas), and 4) a better-educated, emerging middle class that cannot afford elite residences. The areas where the poor reside are called barrios, favellas, alleys, townships, or kampungs. There, the physical infrastructure, roads, electricity, sewage facilities, potable water, communication networks, schools, clinics, and hospitals range from grossly overstretched to virtually nonexistent. For example, in some regions, extreme, monsoon-like rains cause sewage-laden flooding that does not drain because the open ditches built by local residents do not connect to each other.[112] Also lacking are social safety nets and bureaucratic competence. Individuals have few net benefits from citizenship. This exacerbates problems with any response to EHEs. While military and security institutions do exist, these powerful resources are not generally available to address EHEs.

Each vulnerability exacerbates the others and compounds the impact of disasters, ensuring persistent malnutrition, insecure residential status, and deteriorating public safety.[113] Traditional coping techniques are ineffective in these urban areas. Personal savings do not exist so people cannot afford to replace their homes when destroyed by disasters.[108] The poor are essentially segregated from mainstream markets and the economic opportunities these markets offer, as well as from basic education and healthcare. Even under conservative assumptions about population growth, landuse, and industrial production in developing countries, computer models predict serious health consequences from a warmer world.[115]

High levels of air and water pollution in these cities will exacerbate the deleterious effects of EHEs for the majority who cannot afford any mitigating interventions, even bottled drinking water. Breathing the air of Jakarta (population 14 million) has the estimated health effect of smoking two packs of cigarettes a day. This impact is magnified because many Jakartans do smoke two or more packs of cigarettes a day as well. On a hot day, the collective struggle for breath is palpable. Carbon dioxide concentrations and diesel exhausts contribute to high levels of asthma and other respiratory problems. The absence of any interconnected sewer drains means a greatly increased risk of hepatitis, gastroenteritis, cholera, meningitis, typhoid, and even polio – especially for children.[116]

It is extremely difficult for the poor to help themselves, or compel the authorities to provide assistance. There are few if any realistically available "cooling centers" in these six cities. The main venues – government offices and elite hotels – will not welcome temporary occupation by the poor. It might be thought that tax incentives would prompt corporations to occasionally open their cooled offices to those living in poverty, but some corporations have already made arrangements to avoid paying taxes, and others do not provide such shelter for practical or security-related reasons. Some of the poor can attempt to seek shelter in the badly polluted underground car parks or similar structures, but will likely be deterred by inhospitable police. The prevalence of rice paddies in the suburbs of Asian cities offers some cooling, as does the prevalence of Australian eucalyptus trees, but their deep roots lower the water table.

Elitism, or rule by a small and powerful politically insulated group, is more frequent, even in ostensibly democratic countries in the developing world. The six cities and countries discussed have varying degrees and types of democracy. Elitism is far from absent in western politics, but there are countervailing powers and pressures on elitism in the west, so it does not always determine political outcomes. Analogous powers and pressures have yet to emerge in most developing countries. In the cities/countries under discussion, elitism simply correlates with increasing inequality and a resistance to reform.[117] In these cities, one of the only recourses to for the poor is to engage in political demonstrations or civil unrest. These tactics usually do not improve their situation to any great degree. This is a major reason why elites, and the police and military forces they support, treat EHEs primarily as law-and-order problems.

The state of administration in most developing countries is also problematic. In the west, disaster planning and implementation is the province of trained and motivated professionals. In contrast, there is little bureaucratic altruism in most developing countries and little evidence of professionally trained management. Elite interests are typically far removed from EHEs. Attempts to plan and implement EHE policies are thwarted by low levels of administrative competence, especially at the municipal level, and public mistrust, because few benefits are conferred by this bureaucracy. It is impractical for a bureaucrat to specialize in healthcare planning, because these administrators are regularly transferred for reasons unrelated to their expertise or the public's needs. Low bureaucratic salaries and sometimes a culture of corruption often mean that actual management decisions run contrary to any reasoned elaborations of the public interest. Persons imbued with an ethos of professionalism will be less likely to exhibit such behavior.[118]

All problems cannot be attributed to political and administrative underdevelopment. Even the best of intentions are stymied by an acute shortage of resources. The western mix of clinics, hospitals, and specialty service providers is in short supply. The few services that exist are mostly dedicated to elite use. Emergency responses are usually directed toward regime stability, and often involve the military and police rather than public health. Because overall elite fortunes are also tied to issues such as severe acute respiratory syndrome and avian influenza, there can be public health responses in these areas. Ideally, UN agencies, western governments, and nongovernmental organizations (NGOs) such as Oxfam could, and no doubt will, coordinate efforts in future events.

Egypt (Cairo), Kenya (Nairobi), and Indonesia (Jakarta) are acutely dependent on aid from multilateral donors. Organizations such as the International Monetary Fund, the World Trade Organization, the World Bank, and the U.S. Agency for International Development provide EHE resources and expertise. They could demand implementation of effective policies as conditions for providing assistance; however, this is unlikely to occur. Many of the best intentioned NGOs and international aid organizations are not sensitive enough to EHE-related needs at their highest administrative levels. At present, donors are unlikely to consider extreme weather before other types of development projects, although growing worldwide awareness of global warming may change this.[112]

Could international organizations improve on extreme-weather preparedness for developing countries? Will they develop a regional or global warning system for EHEs and a strategy for more effective city planning before an extreme-weather equivalent of the 2004 tsunami occurs? This is what Anna Tibaijuka, the head of UN Habitat, calls "the biggest problem confronting humanity in the 21st Century."[110] The background paper for the 3rd World Urban Forum recommends that cities form new partnership networks with multilateral institutions and donors, national and provincial governments, the private sector, and the urban poor to create resource commitments for planning, implementation, and upgrading of slums.[119] As the Hyogo Framework for Action, 2005–2015 notes[120]

> Disaster loss is on the rise with grave consequences for the survival, dignity and livelihood of individuals, particularly the poor . . . [since this loss interacts with] changing demographic and socio-economic conditions, unplanned urbanization . . . environmental degradation, climate variability and change [including El Niño/La Niña], . . . competition for scarce resources, and the impact of epidemics such as HIV/AIDS.
>
> Events of hydrometeorological origin [i.e., floods, droughts, landslides, tropical cyclones, hurricanes and typhoons] constitute the large majority of disasters.

> The Yokohama Strategy . . . [of 1994, addressed] disaster risks in the context of sustainable development [and identified gaps and challenges that still remain unfilled and unmet] in five main areas. (a) Governance: organizational, legal and policy frameworks; (b) Risk identification, assessment, monitoring and early warning; (c) knowledge management and education; (d) Reducing underlying risk factors; (e) Preparedness for effective response and recovery.

The World Health Organization seems ideally placed to undertake these actions, especially because it already collaborates effectively with similar organizations such as the UN Habitat and the UN Environmental Program on other issues. Additional plausible coordinators are the World Bank, which has recently augmented its mission to take account of global warming, or the International Monetary Fund. Regardless of what organization takes the lead, the same stumbling blocks are likely to remain: a scarcity of resources and political/ bureaucratic entanglements.

International leadership is just one issue. The question also arises as to which level of government is most appropriate for managing EHEs in developing countries? In Europe, citizens look toward national ministries or even the national chief executive. Responsibility in the U.S. falls almost exclusively on the municipal level by default. In developing countries, mayors or regional governors are frequently unskilled and lack leadership training. Instead, they are usually people who have performed well in elite patron–client networks and are given their positions as a reward by prominent national politicians. It is these latter politicians that the public will hold responsible. Therefore, one solution is to assign formal authority for EHE response planning to these individuals.

Ideally, such a plan would be technocratic in its creation and supported by sufficient political power and legitimacy to enhance implementation. Matters are frequently complicated, however, as the concept of elitism and the lack of a technocracy in developing countries illustrate. One potential innovation that can partially circumvent uncooperative administrations and supply needed technocracy is use of an Advocacy Coalition. These entities are groups of respected politically independent professionals who work together to identify a problem and to develop solutions. Often these groups are composed of weather professionals, government officials, public health personnel, and medical and emergency management experts who advocate for EHE planning.[121] Such groups exist in the United States and in Europe. With a legitimacy based on their nonprofit volunteerism, such advocates could collaborate directly with interested municipalities and national NGOs.

Factors that correlate highly with injury and death from EHEs in the U.S. are also associated with death from these events in the developing world. These factors include poverty and social isolation, race, age older than 75 years, the percentage of people living in multiunit dwellings, population density, and high rates of violent crime. Many of these are often combined into the single variable identified as the urban heat island, described previously. Other than poverty, however, many of these factors are absent from the cities under discussion. For example, levels of violent crime are low in Cairo, Jakarta, and Kuala Lumpur. The additional factors relevant to developing countries remain unclear. Ideal research projects designed to answer such questions will encompass large populations. The relative scarcity of resources and the wider scope of competing needs in developing countries suggest that smaller, less sophisticated evaluations are more relevant.

In contrast, Europeans demonstrate a broader, more integrated approach that better links building codes, wetlands/ shoreline protections, landuse regulations, controls over rates of urbanization and deforestation, and control over industry locations. Some extreme-weather events are so new to Europe that the tailoring of responses to a specific event remains insufficient, as illustrated by the lack of sufficient numbers of air-conditioned hospitals and cooling centers. Developing countries are can select between adaptable U.S. and European approaches to create a strategy that meets local needs.

The generally modest external support available to developing nations for solving EHE-related health problems is less problematic than it appears. Developing nations, generally with sophisticated external support, have implemented cost-effective interventions and accomplished major public health successes even under conditions of extreme poverty, weak or nonexistent healthcare infrastructure, and civil war or unrest. For example, as recently as 1988, 125 countries were endemic for polio; however, by the end of 2003, just six countries were reporting polio cases. Efforts were launched in 1974 to kill the black fly that spreads disease and blindness. By 2002, these interventions prevented up to 600,000 cases of blindness.[122] Nevertheless, the challenges associated with EHEs requires a much more rapid response (a matter of days) than that for traditional health problems resulting from infectious diseases.

RECOMMENDATIONS TO PREVENT OR MITIGATE THE HEALTH EFFECTS OF EXCESSIVE HEAT EVENTS

Hospitals/Emergency Departments in the U.S.

EDs Can and Should Be Used to Predict the Healthcare Burden and Epidemiological Consequences of Environmental Disasters

Computerized networks of ED databases should be developed and incorporated into existing reporting mechanisms.[57] These networks would report the prevalence of heat-related conditions treated in the ED in real time. Although ED data create an accurate picture of the EHEs current impact, they will not provide the 1–5-day lead time for area-wide EHE preparations and response. Air mass monitoring systems are necessary to supply this advanced warning.[123]

Individual Hospitals and Medical Systems Should Arrange for Extra Medical Staffing in Support of Emergency Department Services

The rising demand for medical care associated with EHEs will place additional burdens on individual hospitals and medical systems to increase emergency services capacity.[1] Increased staffing of EDs, individual hospitals, and hospital systems in response to a forecasted EHE can prevent the emergency medical system from becoming overwhelmed. This enhances the opportunity to avert negative outcomes or at least address them at an earlier and less severe stage.[1] EDs must be aware that many of the additional support staff needed in emergency situations have multiple commitments. They are often members of the local, state, and federal emergency teams, as well as the National Guard and other organizations.

Local Emergency Medical Systems Need Fiscal and Institutional Support at the Regional, State, and Federal Levels

It is likely that the onset of EHE conditions will result in significant increases in demand for emergency care in the form of emergency medical services calls and visits to EDs. Existing local and state resources supported by mutual aid agreements, state emergency medical assistance compacts, as well as the resources of the federal government may provide the necessary additional medical support that individual hospitals or hospital systems require. Evaluation of the applicability and availability of these resources must occur before the onset of EHE conditions.[1]

Studies published by the U.S. Institute of Medicine emphasize that although demands on emergency and trauma care have grown dramatically, the capacity of the system has not kept pace.[124] Meeting the need for medical care in the face of increasing patient volume and limited resources remains challenging. Balancing existing system utilization with the huge demands that EHEs could place on EDs requires extensive area-wide planning coupled with an effective integration of existing response assets and systems.

Hospitals Should Employ a Full- or Part-time/Shared Medical Disaster Manager

The increasing probability of EHEs as well as other disaster events makes such positions a wise investment. In some cases, federal and state funds may be available to support hiring emergency managers. For smaller facilities, a single individual may be employed by a number of institutions or by a hospital trade group. These disaster experts can conduct hazard vulnerability analyses for the areas surrounding local facilities as well as perform evidence-based disaster research and analysis.

Local and Regional Governments

Urban Areas at Substantial Risk for Extreme Heat Events Should Develop Listings of Vulnerable Individuals, Especially Those Older than 60 Years of Age

Detailed registries are difficult to develop and can be costly. In their absence, however, the municipal government's ability to conduct effective outreach to those vulnerable to EHEs is extremely limited. Information for compiling such lists can be obtained from religious and social organizations. Another option is requiring owners of dwellings in which the elderly are residents to report essential data to local health and welfare agencies. City departments of urban and regional planning and Administration on Aging offices can also be very helpful in supporting the development of registries.

Research Exploring the Effectiveness of Extreme Heat Event Preparedness and Response Strategies as well as the Association Between Extreme Heat Events and Morbidity Is Necessary to Aid in the Development of Evidenced-based Plans

McGeehin and Mirabelli have discussed the need for broad-based research into EHEs, including further investigations of critical weather parameters as they relate to EHEs and urban design.[58]

International Endeavors

An International Institute Is Needed to Coordinate the Various Aspects of Extreme Heat Wave Preparedness and Response, Focusing on Emergency Management and Planning Efforts Related to Weather, Public Health, Medical, Structural, Environmental, and Urban and Regional Planning Issues

A number of federal, state, and municipal organizations as well as universities have served as focal points for research and development activities for EHEs. To continue and intensify the growing interest in EHE response planning and the related areas of medical, weather, and emergency management research, a single-purpose institute dedicated to the study of EHEs should be developed.

Proposed Solutions to the Problems of Extreme Heat Events in the Cities of the Developing World

What should response organizations, administrators, and politicians *do* about EHEs in developing countries? The U.S. and, to some extent, European experiences yield a long list of EHE preparedness and response items for developing countries to consider. In practical terms, these are more likely to be addressed by international NGOs and be coordinated by entities such as the World Health Organization.

Weather Prediction Based on Air Mass Modeling from Entities Such as the National Oceanic and Atmospheric Administration and the European Union Should be Used as the Basis for Alert/Watch/Warning Systems

These air mass monitoring systems can provide an additional 1–5 days of early warning regarding EHEs. They are already in place in a growing number of urban areas across the world and are being instituted in the U.S. by the National Oceanic and Atmospheric Administration's National Weather Service.

Education and Communication with the Residents of Urban Areas Is Necessary. These Efforts Must Anticipate Cultural and Religious Diversity and be Externally Funded

EHE preparedness and response efforts must be extremely sensitive to local religious and cultural practices. As in most proposals discussed in this section, external funding from NGOs and international aid coordinated by organizations such as the World Health Organization are required. These efforts may be complicated by local practices and the general lack of governmental and political support.

Targeted Funding for Specific Public Health Measures Is a Practical Necessity

The underfunded status of emergency medical and public health systems in most developing nations is likely to continue, as is the lack of governmental resources and political determination to address EHEs. Therefore, financial support for specific public health measures is required. Otherwise, assistance will continue to come from international NGOs and other external sources of international aid.

Utilization of Police and Military to Improve Disaster Response

This is a resource and political choice issue that can best be addressed by the developing nations' themselves. External pressures to appropriately utilize these resources can be helpful. However, addressing EHE-related issues without confronting larger medical and public health systems shortfalls may not be realistic.

Implement More Effective Urban and Regional Planning in Cities that Feature Extensive Areas of Slum Housing

Unless these EHE infrastructure issues can be addressed along with other medical and public health systems needs, there is little chance of addressing existing resource shortfalls.

Distribution of Bottled Water and Portable Water Systems Can be Effective Short-term Solutions to Extreme Heat Events

Although initially effective, these interventions do not address the long-term needs of developing nations regarding adequate supplies of potable water. It highlights the traditional approach of meeting short-term disaster needs as opposed to addressing the much larger, long-term resource and political/governmental problems that are the root cause of most medical and public health problems.

FUTURE RESEARCH DIRECTIONS FOR EXTREME HEAT EVENT PREPAREDNESS AND RESPONSE

The following examples illustrate the types of research endeavors that could improve the effectiveness of EHE preparedness and response plans. These areas of research have been generally underinvestigated by public health and medical planners. The research selections that appear reflect significant aspects of the urban reality from which EHEs have developed. Unlike most public health and medical research, it is not primarily empirically derived. Rather, it is process driven, and recognizes that good plans will not automatically result in good outcomes unless time and thought are spent on the implementation aspects. In fact, a whole research literature in political science and public administration has been dedicated to how laws, plans, and concepts are implemented.[125]

Experts in the field of urban and regional planning have spent decades studying how plans are implemented into effective methods of solving specific problems. Implicit in this research is how the public, the urban governance leadership (public and private), and other groups are brought together to turn plans into reality. The types of responses that various U.S. or European cities crafted cannot be directly transferred to cities in the developing world without some modification. There is, however, much to be learned from most aspects of these strategies. Although it will not be possible to implement some systems that depend on effective and relatively well-equipped bureaucracies, potentially useful technologies can be applied successfully if the particular political, ethnic, sociocultural, and other urban-based realities are understood. The projects can be grouped in eight categories.

1) *Remote sensing.*[126] Such techniques could have an important role in refining and quantifying the widely accepted effects of urban heat islands. These procedures are not referenced in any of the plans reviewed in this chapter, although the weather prediction and heat island literatures are becoming more incorporated into related areas of investigation. For example, the U.S. National Aeronautics and Space Administration Landsat space imaging shows a clear correlation between demographic changes and physical landscape changes. Future international coordination efforts, taken in conjunction with such prediction innovations as air mass modeling, can be expected to predict localized risks for heat-related morbidity and mortality.
2) *The effects of information on participants in the problem-solving process.*[127] Information has a transformative function that can alter perceptions of those participating in urban issues. Consensus building requires broad information access. Urban and regional planning research constantly recognizes the value of information and that it is part of the problem-solving process. Simply stated, consensus building with accurate and pertinent information among agencies or constituents cannot be undervalued. A good example is the widespread and effective public information campaign that educated citizens about the buddy system in Philadelphia. This plan had a positive and life-saving impact as people evaluated each other's state of health during EHE events.
3) *Rational arguments and irrational audiences.*[128] When institutions are involved in technological issues such as power plant locations, they often confront hostile and apparently irrational audiences. Sometimes frustrated technocrats will turn to behavioral science for solutions. Whether or not the audience is really "irrational" depends on understanding their perceptions of the problem. In the developing world, belief systems and social and class orientations may dissuade people from what appears to be the most prudent technological solutions. An example would be resistance to the brief use of large, air-conditioned spaces in tourist hotels to prevent heat-related deaths.
4) *Consensus building: mistaken interests in the discourse model of planning.*[129] Researchers have demonstrated that mistaken judgments about individual and group self-interest could be addressed by structured rational discourse; however, more work is needed. In the complicated ethnic and political milieus of modern urban areas, mistaken motives still lead to failure. For example, many urban EHE plans include cooling centers that require individuals to use public transportation, travel through dangerous areas, and overcome personal mobility issues. In this case, the planners either need to modify their consensus to ensure the public can easily access the sites or abandon the concept.
5) *Planning through consensus building.*[130] In an investigation of eight case studies, consensus building with stakeholders was an effective planning strategy. This research proved that those whose interests are directly impacted will actively participate if they are approached. Borrowed from the urban development experience, the author followed eight projects and found that arriving at a consensus involving the major stakeholders is normally required if a plan is to be effectively implemented. In U.S. cities, this means that EHE interventions such as cooling centers must be tested among urban elderly poor, as well as with the utility companies and major government agencies. In developing nations, it means arriving at consensus will require participation by NGOs, local and/or world advocacy groups, impoverished citizens, and the local elite, whose acquiescence is required.
6) *Discussion and rationality.*[131] Researchers found some indication that discussion enhanced rationality among the participants; however, increased rationality among the participants may not be sufficient to foster the outcomes that are desired by planners.

7) *Confronting a fractured public interest.*[132] The researcher reviewed models addressing urban ethnic conflict in Johannesburg, Belfast, and Jerusalem. In Johannesburg, government planners confronted racism, poverty, and vast cultural gaps as they improved services to the squatter-shack areas in Alexandria Township. They concentrated their efforts on addressing the poor quality of water, sanitation, housing, and public health services. The planners balanced the need to reduce apartheid patterns and provide access to the more affluent white areas for blacks while serving as mediators for the interest of all groups. Addressing urban and regional planning problems required that political, social, and racial problems were also resolved. This type of organizational research on the political and ethnic environments in the developing world also applies to the increasingly diverse urban and rural areas in the U.S.
8) *Planning and chaos theory.*[133] Some of the ideas about randomness or chaos emerging in various fields of the natural, social, and applied sciences have major implications for EHE planning. Research suggests that the world may be both easier and more difficult to understand than previously believed and that untidy cities may not be as dysfunctional as is assumed. This is another way of saying that just because an order is not perceived, does not mean there is none. This knowledge is very important in the cultures of urban areas in developing nations as emergency management professionals work with supportive local networks to advocate for implementation of EHE plans.

In summary, the technologic aspects of EHE planning are far less complicated than are the influences of political, sociocultural, and ethnic issues. Only through the application of coordinated transdisciplinary approaches to research will the morbidity and mortality of EHEs be reduced.

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39

Volcanoes

Peter J. Baxter

OVERVIEW

Introduction

An understanding of how people are killed and injured in volcanic eruptions is essential for advancing disaster mitigation measures as well as for managing casualties in actual events (Table 39.1).[1] The main aim of disaster medicine is the prevention of direct human deaths and injuries and reducing economic losses that can indirectly affect health through increasing poverty and inequality. A surprisingly large number of lethal phenomena are associated with eruptions, and health hazards can arise even when volcanoes are in a state of apparent repose. Compared with other types of disasters such as floods, wind storms, and earthquakes, volcanic eruptions occur much less frequently. In recent decades there were on average only two–four events worldwide per year that involved fatalities and people living near an active volcano have only a low statistical risk of a serious event happening in their lifetimes.

The reactivation of a volcano in a densely populated area should trigger a state of emergency, like a warning for an approaching hurricane or storm surge. Forecasting an eruption in a state of unrest requires a team of experienced volcanologists equipped with the latest monitoring technology who can make a rapid appraisal based on what is known about the particular volcano and by drawing analogies from similar volcanoes and how they behave. Although most of these potential crises do not lead to a major eruption and states of unrest can remain in place for years, the uncertainty of forecasting eruptive behavior and the possibility that a serious eruption can happen with little to no warning means that evacuation decisions may have to be made very quickly.[2] As the development of emergency planning at most volcanoes is still in its infancy, a state of unrest at a volcano usually arises in a community with a poor state of disaster preparedness. This chapter describes the key elements of volcanic disaster planning for health sector workers.

Recent Historical Record of Volcanic Eruptions

The most comprehensive database for global volcanic disasters and incidents in the 20th century (Tables 39.2 and 39.3) shows how the numbers of dead, injured, homeless and evacuated, or otherwise affected persons are attributable to a relatively small number of large events.[3] A typical crisis at the end of the century developed at Guagua Pichincha volcano, which lies close to Quito, the capital city of Ecuador, and the densely populated Inter-Andean valley. Its resumption of activity in 1998 raised widespread concerns about a repetition of its last major eruption in 1660. Heavy ash falls affected Quito's city center, and lahars (mud flows), triggered by heavy rain on the ash deposits, devastated the slopes of the volcano complex, which today are an integral part of the city. In the event, this "worst-case" eruption failed to materialize, and evacuation or other mitigation measures were not needed; however, the uncertainty affected the city population of over 1 million (Table 39.2) and its economy for several years.

The historical record is not a good guide to present-day volcanic risk. By the end of the 20th century approximately 10% of the world's population was living in areas of active volcanism, with a significant proportion in megacities whose inhabitants were largely oblivious to the hazard, as shown in the example of Quito and the Inter-Andean valley, which is flanked on both sides by active volcanoes.

Vulnerability of Cities to Volcanic Disasters

What could happen to a city or any other inhabited area in the worst-case volcanic crisis was brought to world attention by the cataclysmic explosive eruption of Mount St. Helens in a wilderness area of the Cascade Range of the western United States on May 18, 1980. Despite scientists close monitoring of the volcano for 2 months after a state of unrest began, the devastating blast occurred without any immediate warning. The forest was devastated by a directed lateral blast and pyroclastic surge that destroyed trees as far away as 28 km and killed 58 of the more than 100 people who were in the area at the time. What if, in the place of the 10 million downed trees, there had been buildings and people?[4] The world was shocked by the horrific scenes at Nevado del Ruiz volcano, Colombia, in 1984 when 23,000 people died buried in massive volcanic mud flows, known as lahars, which had been triggered by a sudden summit eruption

Table 39.1: Main Injury Agents in Volcanic Eruptions

Hazard	*Injury Agent*	*Impact*
Flow Processes		
Pyroclastic flows and surges	Heat	Skin and inhalation burns
	Dynamic pressure	Body displacement
	Hot particles	Asphyxia
	Missiles	Multiple trauma
Lahars	Lateral loading and crushing	Multiple trauma
		Traumatic asphyxia
	Slurry	Asphyxia, infected wounds
Lava	Radiant heat	Skin burns
Fall Processes		
Tephra	Collapsed roofs	Multiple trauma
	Roofs with ash infill	Asphyxia
	Respirable particles	Asthma
	Crystalline silica	Silicosis (chronic effect)
	Ballistic projectiles	Multiple trauma
	Pumice/lava fragments	Multiple trauma
Other		
Gases	Irritant acid gases and aerosols	Asthma, bronchitis
Earthquakes	Collapsing houses	Multiple trauma

that partially melted the glacier and sent torrents of melt water and pyroclastic debris toward the town of Armero. A warning system was in place, but it was inadequate, and there was no evacuation plan.[5] The blindness of the responsible authorities in preventing this entirely foreseeable and largely avoidable disaster was an important stimulus for the United Nations declaration of the 1990s as the International Decade for Natural Disaster Reduction, the main goal of which was to transfer technology and know-how to developing countries to enable them to improve their preparedness and mitigation measures for reducing disaster risks.

Mitigation measures need to be directed toward reducing this global failure of sustainability, which is beginning to have huge societal impacts in most countries with active volcanoes. One famous example is Vesuvius, Italy, which encapsulates the sociopolitical challenge of evacuating large populations at risk when the size, timing, and duration of a foreseeable devastating eruption cannot be predicted with any certainty, while the consequences of inaction could lead to the loss of thousands of lives.

Table 39.2: Best Estimates of the Human Impacts of 20th Century Volcanic Events[3,46]

Human Consequence	*Number of Events*	*Number of People*
Killed	260	91,724
Injured	133	16,013
Homeless	81	291,457
Evacuated/affected	248	5,281,906

Even if only a small (or no eruption) occurred, the disruption caused by the threat of a major eruption and the evacuation of over 600,000 people for possibly months would have unprecedented politicoeconomic implications.

There have been other notable volcanic crises that have left their marks, either because of devastating eruptions or because the threat failed to materialize (Table 39.1). These have included El Chichon, Mexico, in 1984 when more than 2,000 people died in pyroclastic flows, and Mt. Pinatubo, Philippines, in 1991, in which more than 300 people died in the ash fallout that collapsed roofs;[6] however, more than 50,000 people were evacuated in time from the paths of lethal pyroclastic flows and surges.[2] At some other volcanoes, such as Galeras, Colombia and the city of Pasto (200,000 people) or Tungarahua, Ecuador and the small city of Banõs (25,000 people), crises have continued for some years and up to the time of this writing, with thousands of people enduring elevated levels of risk on a daily basis. Thus, although many eruptions can be small and short-lived or occur in remote places some volcanic crises and eruptions can continue for years and lead to severe socioeconomic consequences. This distinguishes most volcanic eruptions from sudden-onset events such as floods and earthquakes with which they are often misleadingly linked by disaster planners.

CURRENT STATE OF THE ART

Types of Volcanoes and their Eruptions

A simplified way to approach volcanoes and their hazards is to learn whether they are mainly explosive or effusive (a nonexplosive outpouring of fluid lava) in behavior.[7] An essential guide to

Table 39.3: Top 10 Volcanic Events in the 20th Century by Impact[3,47]

	Killed		*Injured*		*Homeless*		*Evacuated/Affected*	
Rank	*Event*	*No. People*	*Event*	*No. People*	*Event*	*No. People*	*Event*	*No. People*
1	Pelée, 1902	29,000	Nevado del Ruiz, 1985	4,470	Pinatubo, 1991	53,000	Guagua Pichincha, 1999	1,200,400
2	Nevado del Ruiz, 1985	23,080	Awu, 1966	2,000	Kelut, 1919	45,000	Pinatubo, 1991	967,443
3	Santa Maria, 1902	8,750	Ambrym, 1979	1,000	Galunggung, 1982	22,000	Pinatubo, 1992	787,042
4	Kelut, 1919	5,110	Dieng, 1979	1,000	Pinatubo, 1992	15,700	Agung, 1963	332,234
5	Santa Maria, 1929	5,000	Lake Nyos, 1986	845	Tokachi, 1926	15,000	Vesuvius, 1906	100,000
6	Lamington, 1951	2,942	Taal, 1965	785	El Chichón, 1982	15,000	Popocatépetl, 1994	75,000
7	El Chichón, 1982	2,000	El Chichón, 1982	500	Merapi, 1930	13,000	Soufrière Guadeloupe, 1976	73,500
8	Lake Nyos, 1986	1,746	Merapi, 1994	500	Merapi, 1961	8,000	Mayon, 1984	73,000
9	Soufrière St. Vincent, 1902	1,565	Merapi, 1998	314	Soufrière Hills, 1995	7,500	Arenal, 1976	70,000
10	Merapi, 1930	1,369	Vesuvius, 1906	300	Colo (Una Una), 1983	7,101	Galunggung, 1982	62,755
Total		80,562		11,714		201,301		3,741,374

this is the stratigraphic (geological) record, which provides the evidence from past eruptions. Explosive eruptions involve rapid energy changes whereby magma, or molten rock, is so violently expelled from a deeper environment that it turns into pyroclastic fragments. The silica-rich composition of the magma lends it a high viscosity and these volcanoes are found in subduction zones, an example of which is the Ring of Fire around the Pacific Ocean. Mount St. Helens belongs to this category. The most hazardous products of explosive eruptions are pyroclastic flows and surges, and tephra (ash and glass) fallout, including ash and pumice blocks, as well as expelled ejecta. Fragmentation may also be produced by steam explosions and the thermal shock when magma comes into contact with water below the earth's surface or when it erupts into surface water, ice, or wet sediments. Explosive eruptions are often accompanied by small, viscous lava flows.

At the other end of the spectrum, volcanoes with silica-poor rocks mainly occur at midocean ridges, and more commonly have fluid lava eruptions. The most well known volcanoes with effusive eruptions are on the Big Island of Hawaii. Volcanoes of intermediate magmas can have features of both types. Mount Etna, Italy, is an example of a mainly effusive volcano whose hazard is mostly lava flows, but spectacular eruptions in 2001 and 2002 reminded people that it also had explosive potential.

Explosiveness is also governed by the percentage of volatile components, or dissolved gases, in the magma. Viscous magmas are more resistant to deformation from the action of forces and mechanical stress, and so the gases do not so readily escape, and this leads to increased gas pressure. Typically, only low levels of pressure develop in eruptions involving more fluid magmas. The main volatiles are water, carbon dioxide, and sulphur dioxide. Only a small percentage of emissions consist of other gases and these include hydrogen chloride (hydrochloric acid) and hydrogen sulphide, and trace gases including hydrogen, carbon monoxide, and methane.[7] Volcanic gas emissions and gas bursts are human hazards in populated areas.

Location of Volcanoes

Volcanoes are not found everywhere on earth. Volcanoes and their gas emissions were responsible for the formation of the earth's atmosphere and today plate tectonics and the volcanism arising from it are essential for maintaining the atmosphere in a state that enables life to continue on earth. Eruptions and earthquakes are the deleterious events that maintain this planetary homeostasis. Eighty percent of volcanoes are in subduction zones at convergent plate boundaries, which include the Ring of Fire around the Pacific Ocean (including the Cascades and Mount St. Helens in the United States), and island arcs, such as Indonesia and the islands of the Caribbean; these are explosive. In contrast, approximately 10% of volcanoes occur at midocean ridges and are effusive.[7] There are approximately 700 subaerial volcanoes in the world, of which 170 are currently active.

Scale of Eruptions

The most devastating eruptions are explosive in nature; large eruptions are uncommon in comparison to small events. Volcanoes that erupt the most frequently are likely to be the best studied, for obvious reasons; scientists regularly monitor a proportion of these, especially if they are in densely inhabited areas. All of the most frequently active volcanoes in Italy and Japan are closely monitored, whereas a lack of resources makes it possible to focus attention on only a handful of the dozens of volcanoes in Indonesia. When a volcano that has been dormant for many years shows signs of activity, scientists will be needed to install monitoring devices or intensify current monitoring efforts to keep the volcano under close surveillance. If experts determine that a volcano is moving toward an eruption, they will advise authorities to declare a state of unrest.

The *size* of an eruption relates to the *magnitude* of the eruption (mass of material discharged, or *tephra volume*) and the *intensity* or rate of discharge *(mass flow rate)*. A *volcanic explosive* *index* is a measure of both of these parameters.[7] The largest eruptions are in the supervolcano league, such as Yellowstone, whose eruptions are at average intervals of 100,000 years; an event at Yellowstone would impact most of the U.S. and produce a global catastrophe through persistent atmospheric effects lasting several years after the event. None of these tremendous eruptions have been witnessed in recent history. Eruptions on the scale of Tambora, Indonesia, in 1815, which temporarily lowered global temperatures and triggered crop failures, occur once every 1,000 years on average. A Krakatau-type (Java, 1883) occurs approximately twice every 100 years, and one the size of Mount St. Helens (1980) once every 10 years somewhere in the world. Types of explosive eruptions include the largest and most energetic and destructive – the plinian and subplinian, which have major ash falls and pyroclastic flow activity – to the smaller strombolian and vulcanian, which do not. Plinian eruptions produce high ash and gas-laden atmospheric columns that penetrate into the stratosphere and can interfere with climate and weather on a global scale.[8]

The main eruptive hazards can be divided into fall and flow processes. Air falls of tephra – airborne fragments of rock and lava of any size or shape expelled during explosive eruptions – are the most common and most hazardous fall processes.

Pyroclastic flows and surges, lahars and debris flows, and lava flows can, for emergency planning purposes, be envisaged by "thinking visually" or intuitively, but their behavior belongs to the world of flow, or fluid dynamics, on which the understanding of the blood circulation, meteorology, and aeronautics is based. The concepts that describe the motions of fluids – viscosity, vorticity, waves, instability, and turbulence – apply to the complex behavior of pyroclastic flows and surges, which move along the ground and over obstacles with features of both gases and liquids. Fluid dynamics underlies the computer modeling of such phenomena, as will be described later.

Human Impacts of Pyroclastic Flows and Surges

Pyroclastic flows and surges are the most hazardous eruptive phenomena. They are hot mixtures of particles and gases that flow as density currents and are the most devastating phenomena, associated mainly with explosive volcanic eruptions. Their hazard is related to their unsurvivable high temperatures and high overpressures (higher-than-hydrostatic pressures), or a lateral loading effect akin to blast waves from nuclear or conventional weapons, and the high speeds with which they move and overcome topographical obstacles in their paths.[9] They comprise fine magma fragments ("ash"); pulverized rock and air become entrained and heated as they move.

Pyroclastic surges form more dilute and turbulent suspension clouds than pyroclastic flows, which settle when they stop moving into a thin layer of well-sorted and fine-grained deposits. Pyroclastic flows are very dense with high particle concentrations and therefore have much more potential for destruction; they are more topographically controlled in that they readily follow valley bottoms, and settle as a massive, poorly sorted deposit.[7,8]

These so-called pyroclastic density currents can be formed in several different ways. Among the most dangerous are lateral blasts, as occurred at Mount St. Helens, when the side of the volcano suddenly gave way after 2 months of volcanic unrest and the surge obliterated a 180° sector as far as 28 km from the crater.[4] The Soufrière Hills volcano on Montserrat has been erupting since 1995 with its most significant events being caused by the growth and collapse of large domes of heaped-up, viscous lava, extruded like toothpaste from its tube, with the material in each major collapse forming a flow or surge into low-lying areas. Large explosive eruptions often begin with vertical eruption columns, which can last several hours or even 1 or 2 days, but at some stage parts of the column may lose their buoyancy and descend down the flank of the volcano, as occurred in the famous eruption of Vesuvius in AD 79 that destroyed Pompeii. Toward the end of such eruptions dense flows can be formed by a process known as "boiling over" the crater rim. In all instances the hazards in the areas affected by the surges or flows are similar. Whether they form surges or flows can be unpredictable, but an important feature of pyroclastic flows is that surges can detach from them and extend much further than the pyroclastic flow would normally travel. All the phenomena are driven by gravity and some will have the extra impetus from explosions.

For emergency planning purposes, the event that typifies the risk scenario in terms of likelihood and severity is the violent surge of a small volume (covering areas <10 km^3).[9] This type of event has been modeled for the next eruption of Vesuvius and considered to be the most likely.[9] A plausible emergency scenario is one in which people have returned to an exclusion zone around an explosive volcano against scientific advice, or evacuation has been incomplete prior to the eruption, such as when many people refuse to move despite warnings from the authorities. A surge should be regarded as unsurvivable in the open, with the effects of high temperature (>200°C), dense and irrespirable concentrations of ash, and lateral loading (dynamic pressure) forming a lethal combined impact. At ordinary temperatures, the minimum concentration of inhalable dust ($<100\ \mu$) capable of causing asphyxia is reported to be 0.1 kg/m^3, but this figure is not well founded.[10] Autopsies of victims at Mount St. Helens in 1980 showed ash occluding the tracheas of victims found in locations close to the volcano where this concentration was undoubtedly greatly exceeded.[11]

Exposure to dry, motionless air at 200°C–230°C can reportedly be survived by a lightly clad person for 2–5 minutes, but in the open and in the absence of protective clothing the convective heat transfer from a fast moving flow at this temperature quickly causes severe thermal injury and rapid death. Inhaling dry air free from hot particles at this temperature is also tolerable for only a few minutes, but the presence of steam, or water vapor, or inhalable amounts of hot, fine ash will reduce the temperature that can be tolerated to below 100°C, because of the risk of thermal injury to the airways in the absence of respiratory protection.[10] In a dome collapse – generated flow on Montserrat in 1997, 19 people died in the open when they were caught in the surge that detached from the flow running along a valley. They were killed instantly by the surge temperature, which was as high as 400°C and ignited their clothing.[12]

At a similar eruptive event at Mount Unzen in Japan in 1991, 41 people, including two volcanologists, were killed, and seven survivors in the open developed severe laryngeal edema within 25 minutes of exposure, but they were rescued in time to undergo life-saving tracheostomy at the hospital. Laryngeal obstruction is therefore likely to be an important cause of death in victims whose rescue is delayed. The seven survivors and 10 other victims subsequently died from acute respiratory distress syndrome as a result of their inhalation injuries and extensive skin burns, as did two badly burned loggers at the Mount St. Helens eruption in 1980.[13]

Some surges can also be saturated with water vapor, which will increase the amount of heat delivered to the respiratory tract and skin. Humans cannot survive long breathing saturated air over approximately 60°C. At 50°C the heat transfer to the deep lung could be comparable with that of dry air at 200°C, while at 80°C the oxygen concentration of saturated air would be 10%–11%, a critically low level not even allowing for the presence of ash particles.[10] Thus, inhalation of saturated air that also contains an abundance of inhalable ash particles at temperatures between 50°C and 100°C could be very hazardous, giving rise to acute bronchoconstriction, pulmonary injury, and hypoxia and could explain the sudden deaths recorded in people sheltering in houses who otherwise appear externally unharmed. A base surge from a steam explosion due to magma–water interaction would also present this hazard. Irritant volcanic gases such as sulphur dioxide might also be present in the surge cloud mixed with the entrained air.

Direct contact of the skin with the hot ash in the surge will cause partial and full thickness burns. In the outdoors, clothing may offer little protection and become combusted in the heat of the surge, or be torn off the body by the violence of the surge impact. Indoors or outside under some protection against the hot current in the periphery of a surge, the heat transfer would be much briefer so that even light clothing could limit the total body surface area (TBSA) affected. Thus a person wearing a suit would receive 20% TBSA burns if the hot ash was in contact with the unprotected exposed skin, whereas for someone with a t-shirt and shorts the figure would be approximately 40% TBSA; these patterns have been observed, for example, in the fatal Unzen eruption in 1991.

A provisional burns scale that predicts mortality risk in volcanic eruptions has been devised by the author for mass casualties in a pyroclastic surge striking an urban area. Many victims would be killed outright, including most of those caught outdoors, as already explained. In locations sheltered by topography or other buildings, burns to the skin and lung would be the main cause of injury

Level 1. Minor effects of heat, such as singed hair, superficial burns to uncovered skin. Low mortality.
Level 2. Burns to 20%–40% TBSA; moderate inhalational lung injury. Mortality dependent on treatment resources, patient age, and existing illnesses. Without early treatment in a large-scale disaster most would die.
Level 3. Burns greater than 40% TBSA; severe inhalation injury. Mortality greater than 90% in a disaster.
Level 4. Rapid death from heat or asphyxia. Mortality 100%.

Other injuries can be expected, such as lacerations from broken glass when windows are imploded by the pressure impact of the surge, and smoke inhalation from fires ignited by the hot ash in contact with combustible materials in streets and inside dwellings.

No published data on survival in a large series of volcanic eruption victims exist, but some (unpublished) evidence was obtained after an eruption of Merapi, Indonesia, in 1994, when approximately 30 people were killed outright and 86 survivors (52 males and 29 females) were admitted to four hospitals in Yogyakarta after exposure to a pyroclastic surge. They had been attending a wedding at a spot with a view of the volcano's summit. This event was totally unexpected and occurred when the lava dome collapsed, as it did at times, sending a pyroclastic flow along a different valley from its usual course. The mean TBSA burned of those hospitalized was 44% (as recorded in the hospital records and probably overestimated) and the overall mortality was 78%. Most of those who died were very badly burned – all had TBSA burns of over 50% – and must be assumed to have had inhalation injury as well.

The Baux index is a long-recognized guide for triaging burn casualties in an event on a mass scale, as would be envisaged here. The index is calculated by adding the age of an adult (>17 years) to the TBSA burned. This sum is the probability of mortality. This index does not account for inhalation injury from hot ash particles, which is likely to be severe in individuals with greater than 40% TBSA burns and would greatly increase their mortality risk.

More than a small number of casualties with 20%–40% TBSA burns would exceed the national burn unit capacity of most countries, yet this group could comprise a large number of the volcano victims and their survival would be largely dependent on the speed of search and rescue operations and time taken until they received definitive treatment. National and international burn centers would need to be available to receive patients in transfer when local facilities were overwhelmed (see Chapter 3).

At the time of this writing, no events of mass burn casualties on this scale have previously occurred, with the exceptions of the Los Alfaques camping ground explosion in Spain in 1978[14] and the Ufa gas explosion in the Soviet Union in 1989.[15] The scenario in a volcanic eruption would be altogether different. Rescue attempts would be hampered by the continuing eruption, with previous ash falls and resuspended ash preventing access. A thick deposit of hot ash on the ground would prevent immediate entry to the disaster area by road (tires can catch fire and shoes ignite on contact with thick pyroclastic deposits before they have cooled). Concern over an additional pyroclastic surge would keep rescuers away for hours until it was believed that the activity had subsided. Helicopters would be needed for rapid movement of rescuers and patients, but these might not fly if too much ash were in the air because this could interfere with the engines.

Explosion Hazards to Scientists and Tourists

Although certain eruptions and volcanoes are referred to as explosive, the release of energy is much slower and in a different form than with nuclear weapons or conventional explosives. In a "blast wave" in a typical pyroclastic surge the dynamic pressure is solely from the lateral loading of the gravity current and there is no peak overpressure as produced in a supersonic wave. Minor explosions from volcanoes can be steam driven, or phreatic, with rocks being hurled without warning from fumaroles or craters, killing those within range. Six scientists and three tourists were killed in an explosion in the crater at Galeras, Columbia, in 1994 due to multiple trauma resulting from flying rocks blasted from the lava dome.[16]

In most explosive eruptions shock or blast waves do not present hazards far from the eruptive vent and instead it is the dynamic pressure and heat of a pyroclastic surge or flow, together with the kinetic energy of entrained loose materials and projectiles that cause the injurious impacts. Velocity measurements of projectiles have been estimated for explosions at the craters in the 1968 eruption at Arenal Volcano (300–400 m/s) and at Ngauruhoe in 1975 (220–260 m/s).[17] Although loud sound waves can rattle or even break windows, supersonic blast waves are uncommon and their direct effects will mostly be limited to the vicinity of the crater.

The Impacts of Lava Flows

Lava flows from most volcanoes are slow moving and so, in contrast to pyroclastic flows and surges, usually cause few deaths and injuries because people are able to move out of the lava path in time. The main hazards are from their high temperature (800°C –900°C), which can cause combustion of buildings by their direct contact or just by radiant heat. Lava flows are especially mechanically destructive and can cause collapse of buildings in their paths. It is for their destructiveness that they are most feared, although some success has been achieved with diverting lavas, the best example being the intervention of the Italian Civil Protection in the flow from the eruption of Mount Etna in 2003. Fifty-one lateral vent eruptions have occurred at Mount Etna in the last 330 years, but these have been of minimal threat to human life. Volcanogenic earthquakes arise when fissures open and these can weaken and destroy buildings and occasionally kill people from their cumulative shaking effect.

Secondary hazards from lava flows can arise in several different ways. Lava flows entering the sea will generate clouds of steam and hydrogen chloride gas. Occasionally people close to lava flows can be asphyxiated in heavy rain because of trapped rainwater suddenly flashing to form a jet of steam. Lava flowing over densely vegetated areas can trap pockets of methane and organics, which can then explode and scatter lethal projectiles of lava.[18] More rarely, a lava flow moving down a slope can disintegrate on meeting a sudden incline and form a small but potentially lethal pyroclastic flow.

A few volcanoes in the world can erupt very fluid and fast moving lava and their lava flows can be highly hazardous. An example of this type of volcano is Nyiragongo, located near the city of Goma in the Eastern Democratic Republic of Congo and in the midst of an humanitarian crises. More than 4 million lives have been lost as a result of conflict and its consequences since 1998.[19] In 1977, 500 people living high up on the flanks of the volcano died in a sudden rifting eruption, which drained the crater lava lake. Then, in January 18 and 19, 2002, the rifting suddenly extended further down the flank toward Goma, trapping 170 villagers in flows moving as fast as 60 km/hour. Two main flows reached Goma, by which time they were moving much more slowly, the largest arriving at approximately 1800 hours on the first day. More than 300,000 people escaped from the advancing lava as it drove its way through the center of the city, destroying the main commercial areas and more than 120,000 homes before the end of the day.[20,21]

The chaotic self-evacuation of the population and then their rapid return within 2 days before the main lava flow had even ceased flowing raised many concerns about the health hazards they would face. The most important was the risk of outbreaks of endemic cholera and dysentery from the consumption of unchlorinated water from Lake Kivu. International aid agencies flew workers to the disaster zone and helped to erect emergency chlorination stations and water tankers along the side of the lake. The loss of food supplies and charcoal for cooking would have led to hunger very quickly in a population with an already high prevalence of acute malnutrition, but aid workers averted a food crisis. Crowding increased the risk of infectious disease outbreaks and responders rapidly initiated an immunization campaign. Most people had to escape from the lava flows with relatively little warning and left all their possessions behind. The psychological stress of losing all their property and livelihoods to the lava flows was one of the most significant factors for the population. Only approximately 13,000 people had to be accommodated in relief camps, the remainder being taken in by relatives or others from the same ethnic group.[20]

The absence of governmental organizations due to the existing complex health emergency meant that the population was entirely dependent on a swift and effective response by the international agencies and without this, the loss of life from epidemics and other secondary consequences of the eruption would have been much greater.

The Impacts of Lahars

Lahars, or volcanic mud flows, are slurries of water and sediment (60% or more by volume), which can flow at speeds of a few tens of kilometers per hour to more than 100 km/hour on the steep slopes of a volcano. They can flow and set like concrete. In the disaster caused by the Nevado del Ruiz volcano in which 23,000 people died, as much as 85% of the town of Armero was left covered in 3–4 m of hardened mud. In the rescue operation over the following 5 days 1,244 survivors, mainly from Armero, were admitted to hospitals and 138 of these subsequently died. The lahar struck the town at approximately 1130 hours and was preceded by a river of water that flowed along the streets that was fast and deep enough in places to overturn cars and sweep away people.[5] When the lahar arrived it was traveling at an estimated velocity of 12 m/second and flowed for 10–20 minutes, during which time most of the town was devastated as buildings collapsed under the load of the moving flow. Survivors clung to moving pieces of debris or were swept along on top of the mud. Overall, the several inundations of mud lasted approximately 2 hours, with two slower moving major pulses being accompanied by several smaller pulses over this time period.

The head of the lahar would have been turbulent and contained all manner of debris, including large boulders. The slurry mass would have likely buried victims or hurled them against stationary objects, or they would have been contorted and crushed by debris such as trees and collapsed parts of buildings. Stones and other sharp objects would have caused deep lacerations. The slurry would have forced its way into the mouth, and into the eyes, ears and open wounds. The pressure against the chest would have inhibited breathing in those buried up to the neck as they were swept along in the flow resulting in death by traumatic asphyxia.

The main injuries sustained by the hospitalized patients were severe crush injury with open fractures, hemorrhagic, hypovolemic or traumatic shock, chest trauma (flail chest, pneumothorax, mud aspiration, and wound sepsis). More than two-thirds of the in-hospital deaths were ascribed to overwhelming infection, such as gas gangrene, ischemic gangrene, tetanus, and generalized sepsis or septic shock. Some patients had limbs amputated for the treatment of wound infections.[22]

An important cause of wound sepsis was primary suturing of infected or deep or extensive wounds after inadequate debridement, instead of leaving them open for 5 days before closing them (delayed primary closure).

A small number of victims who were rescued after being immersed in mud for at least 3 days developed life-threatening necrotizing fasciitis caused by anaerobic and aerobic organisms in synergistic combinations. Zygomycetic organisms were identified in patients with more severe and rapidly progressing lesions. This dreaded complication was due to normally nonpathogenic soil organisms replicating in wounds in the absence of oxygen and is notoriously resistant to medical treatment.[23]

The reason for so many people surviving when trapped in the slurry was due to its granular or sandy consistency. Lahars diluted by water in this way are called noncohesive, because they contain relatively little clay, in contrast to the much denser cohesive types, which contain much clay derived from chemically altered rocks. The sandy consistency made access to the injured difficult and many had to be air lifted from the slurry by helicopters. The lahar was originally hot and scalded some victims, and many parts must have retained heat over several days otherwise the trapped victims would have died from hypothermia before they were rescued.

Mount Rainier in the U.S. state of Washington is the most hazardous volcano in the Cascade range because of its potential for forming massive lahars, which can travel long distances into areas that have become heavily populated.[24] Mount Rainier – at 4,393 m – is the highest peak in the Cascade range and its load of glacier ice exceeds that of any mountain in the conterminous United States.

Emergency planning and land utilization in the volcano's footprint are based on the lahar hazard, which according to volcanologists dominates the risk scenario above all other eruptive phenomena as based on its history and potential hazards. More fluid, noncohesive lahars can form in future volcanic activity if huge quantities of melt water are produced from glacier melt water (as in the Nevado del Ruiz tragedy), but cohesive lahars can also form with little, if any warning, or in the early stages of activity when magma is forcing its way to the surface. This can occur because the flanks are formed by substantial volumes of unstable, water-rich hydrothermally altered rock that can collapse in the form of a dry debris flow or a dense lahar.[24]

In Ecuador, a vast, fast-moving lahar developed at Cotopaxi (5,897 m high) from the melting of the summit ice in its last eruption in 1877. At the time of this writing, the worst expected volcanic disaster in the country is a new eruption of this volcano that would lead to a repeat of this event in the Chillos valley, which has become much more populated since the 19th century, with the town of Lattacunga (population 80,000) only 50–70 minutes travel time for the lahar along its path. The damage to property and infrastructure, as well as the potential for extreme loss of life, would dwarf the losses suffered in the Nevado del Ruiz disaster given the greater economic development that has occurred in this high-risk zone.

Even small, noncohesive lahars can be very dangerous, and they arise commonly when thick ash deposits produced by eruptive activity become mobilized by heavy rains almost anywhere on a volcano. A serious complication in an eruption is the triggering of lahar formation when heavy rainfall is produced as large quantities of fine ash particles mix with rain clouds. Lahars can present lethal hazards for several years after large eruptions, which leave thick ash deposits on flanks, as was seen following the Mount Pinatubo eruption in 1991, with resultant deaths and other very disruptive consequences for thousands of people living along the far end of the slopes of the volcano.

Tephra Fall Impacts

Tephra is the ash and glass material emitted in the atmosphere during a volcanic eruption. The temperature of the erupted material and the mass eruption rate determine the height of the eruption column, which along with wind strength and direction, are the principal controls on the long-distance transport and fallout of the tephra. Ash typically is finer grained and forms thinner deposits with increasing distance downwind from the eruptive vent.[7,8]

Ash falls can affect very wide areas downwind of an erupting volcano as far as hundreds of kilometers away and can have many different impacts on health and human activity over these long distances. The mixture of ash, gases, and aerosols that are injected into the atmosphere can circle the earth and have temporary effects on global weather and climate.[7,8] The most important aspects for disaster medicine are the immediate health and safety hazards that arise in a typical heavy ash fall, including those created by damage to infrastructure. A large conurbation would be most vulnerable to many of these, such as disruption to transport, breakdown of utilities, and the injuries and loss of life from weaker structures collapsing under the accumulated weight of ash. The experience at the eruption of Mount St. Helens in 1980 is a good model for disaster planning for ash falls at most explosive volcanoes that have moved into a state of unrest.[25]

The first experience downwind of an eruption of this size is the cloud passing overhead and darkness growing as ash starts to fall. In some instances, pumice and other clast material in the fallout can be large enough to smash windshields and cause head injuries, so people should rapidly seek shelter. When fine ash settles on windshields it soon leaves smears if the windshield wipers are turned on; when the spare wiper fluid is depleted, the driver can no longer see out of the windshield. If the ash fall is heavy, visibility can become zero. When ash has settled motor vehicles resuspend it in the air and visibility becomes severely limited. Rain accompanying an ash fall can make the roads very slippery, resulting in collisions. Even without rain, steep inclines can become hazardous as car wheels lose their grip on the road. Ash soon clogs engine air filters and can bring vehicles to a halt. All transport, including planes and trains, will grind to a halt if visibility becomes bad, a situation that lasted for 5 days in central Washington State after the eruption of Mount St. Helens on May 18, 1980, until an unseasonable rainfall in a normally arid area cleared the air of ash that was being constantly resuspended by winds. Volcanic ash severely damages jet engines and airplanes' superstructure, so airports will close after even a light deposit of ash on the runway.

Ash settling on unprotected electrical insulators at substations can lead to outages from short circuits as it is a good conductor of electricity when it is wet. These outages in turn can stop water supplies that depend on pumping. Drains and sewage systems can become blocked with the mass of ash when it is mobilized by rain. Electronic equipment and computers are readily penetrated by fine ash (laptops depend on a small inside fan for cooling) and can be rendered useless. Hospital systems and equipment can fail. Falling ash and lightening strikes (frequent in some eruptions) can lead to serious communications disruptions, including the lack of availability of wireless phones, television, radio, and any other technology requiring transmitters or repeaters.

Rates of accumulation of ash on horizontal surfaces can be as high as 10–20 cm/hour and weak roofs begin to collapse with an accumulated depth of wet ash of only 10 cm. The type of roof and its condition will determine the extent of damage. A collapsing roof can kill or injure the building's occupants by striking them with roof members and by burial in the onrushing ash, causing asphyxia.[26]

Ash particles in explosive eruptions can be very fine and of respirable size. The high inhalable particulate matter concentrations can irritate the airways and trigger asthma attacks in people with asthma and asthmatic bronchitis. The ash from silica-rich lava dome eruptions can contain very elevated levels of crystalline silica (cristobalite, quartz), and long-term exposure to repeated ash falls over many years has the potential to cause silicosis. This risk is apparent on Montserrat and long-term health checks and chest x-ray surveys are needed to confirm the effectiveness of the measures for preventing the disease in the general and working populations.[27]

Ballistic projectiles do not usually travel farther than 5 km from the crater. They are an important reason for evacuating a population living close to a crater, even though other more important hazards may dominate the risk scenario. Hot ballistics even of small size can smash through corrugated metal roofs leaving small holes of entry but then explode their hot fragments over furniture inside and trigger fires. Obviously, direct impact can cause serious injury as well. Blocks a meter or more in size can leave large impact craters. Experiencing a shower of ballistics is very frightening and can leave an area with damaged or burnt-out houses, roads, and infrastructure such as, downed power lines.[28]

Hazards of Volcanic Gases

A few volcanoes emit substantial amounts of gases in the plumes from their craters for years without showing any other activity. The summits of most volcanoes are so elevated that the plume does not result in any hazardous concentrations in the ambient air. At a few low-lying volcanoes (e.g., Masaya, Nicaragua; Poas, Costa Rica) gas plume emissions can present health hazards for kilometers downwind of a volcano's vent due to the effects of sulphur dioxide on the airways, while soluble acid gases damage vegetation by direct fumigation or by making rain water intensely acid. Volcanologists entering crater areas to take samples are at risk of being overcome by carbon dioxide and hydrogen sulphide.[29]

Soil gases can permeate into the atmosphere from the slopes of volcanoes in repose and their concentrations can accumulate in the indoor air of buildings with gas permeable foundations.[30,31] Carbon dioxide is the main hazard, and the gas can also act as a carrier of the radioactive gas radon, which is known to be a causal factor for lung cancer and can accrue inside poorly ventilated houses.

A change in the composition of plume or soil gas and an increase in emission rate from a volcano can be the first sign of magma on the move, so these gases are routinely monitored for evidence of a renewal of volcanic activity.

A rare but important hazard in volcanic areas is an accumulation of carbon dioxide in solution in a pressurized hydrothermal system of a volcano or the build up of huge amounts of carbon dioxide dissolved under the hydrostatic pressure of deep lakes. An event that triggers the sudden release of the carbon dioxide can lead to the formation of a lethal, denser than air cloud of asphyxiating gas. In the Dieng Plateau, Java, in 1979, carbon dioxide was suddenly released and flowed down a slope and killed 149 villagers fleeing from an incipient minor eruption.[32] Two thousand people died when a cloud of carbon dioxide was released late at night from Lake Nyos in 1986, with victims lying unconscious on the ground for hours before dying or regaining consciousness when the gas dispersed in the early morning.[33] Many deep lakes in volcanic areas around the world have been studied for carbon dioxide accumulation since that time, but only Lake Kivu in the Eastern Democratic Republic of Congo and Lake Albano near Rome have been identified so far as potential candidates for such releases. In a future eruption of Nyiragongo, the fissuring could extend into Goma and Lake Kivu, which is a highly stratified and deep lake (maximum depth 485 m) containing a huge quantity of carbon dioxide and methane dissolved in its deeper waters. These gases, derived from volcanic sources under the lake and from biodegradation of organic matter, have accumulated over the centuries and would be highly dangerous if suddenly released in a cloud that was blown over the populated shore. While the technology for degassing lakes before they become saturated with gas and highly hazardous (as occurred with Lake Nyos) is available, the technology does not exist for identifying hydrothermal systems that are waiting to explode when disturbed by the onset of volcanic activity.

Table 39.4: Volcanic Crises and Cities since 1980

Campi Flegrei, Italy	1982–1984	Naples
Galeras, Colombia	1989–ongoing	Pasto
Popocatapetl, Mexico	1994	Mexico City, Puebla
Colima, Mexico	1994	Colima
Guagua Pichincha, Ecuador	1998–2001	Quito
Tungurahua, Ecuador	1999–ongoing	Banõs
Reventador, Ecuador	2002	Quito
Nyiragongo, Dem. Rep. Congo	2002–ongoing	Goma

Emergency Planning for Cities and Islands

As with many other hazards, densely populated areas increase vulnerability to volcanic eruptions. The key infrastructure of cities is very vulnerable to volcanic activity. This, coupled with the large numbers of people, leads to a challenge for health officials responsible for making timely evacuation decisions as the consequences of a judgment error could be large human or economic losses. At the time of this writing, there have been no recent major eruption impacts on a city or megacity, but there are cities in proximity to volcanoes where the potential for major disaster exists (Table 39.4). A glimpse of what could happen can be seen by analyzing the worst volcanic disaster of the 20th century that occurred in 1902 when the city of St. Pierre on the French Caribbean island of Martinique was struck by a pyroclastic surge, killing 28,000 people within minutes and leaving only two survivors in the city itself.[9] At least half a million in a megacity of 4 million people in the Bay of Naples area are at risk from pyroclastic surges and flows in a future eruption of Vesuvius. Lava flows have not entered a modern city, but the invasion of Goma by two lava flows in 2002 described previously shows how the destruction can be severe and in a complex emergency threaten large loss of life from ethnic conflict and expose thousands to infectious disease epidemics and the risk of starvation. At Mount Rainier, the horrors of Armero in 1984 could be visited on the large population in the Puget Sound lowland area, but monitoring and warning systems and emergency planning are in place to help prevent such a disaster.[24] Although actual experience is limited in terms of the direct and indirect impacts of ash on the health and safety of an urban population (and what mitigation measures will be feasible to offset the immediate risks), a large ash fall with a depth of 0.5–1 m on a city would most likely lead to a complete paralysis of the city's functioning. Massive and costly clearance operations to remove the vast quantities of ash would be required to restore the city's infrastructure.

Very similar considerations apply to islands, where lack of space means that people may live in proximity to an erupting volcano or leave the island to live elsewhere because of safety concerns or to find remunerative work. The island of Montserrat is only 17 × 10 km and half of the island around the volcano has become an exclusion zone.[34] Of an original population of 12,000 people, only 4,500 remained in 2007 when the volcano was still erupting.

Until recently, volcanologists have been using a hazard-based approach to decision making in volcanic crises, which means advising authorities on the most likely maximum event (maximum expected eruption),[35] rather than using the evidence from past eruptions to determine all the main eruption possibilities and their probabilities. Thus, at Vesuvius the maximum expected event is on the scale of the largest eruption of the last 1,000 years; the 1631 eruption is the reference eruption, with the likelihood of pyroclastic surges and a heavy ash fall across the breadth of Italy, which dominate the risk scenario for emergency planning. The drawback to the hazard-based approach is that it is all or nothing, and the authorities will lose the confidence of large numbers of people having to be evacuated from their homes for more than 1 or 2 months if a large eruption fails to occur. Recognition that smaller-scale eruptive events are much more probable is needed in a long drawn out crisis, as has been demonstrated repeatedly in the eruption of the Soufrière Hills volcano, Montserrat, since it began erupting in 1995.[34]

This problem of scientific uncertainty and evacuation decision making is embodied in the 1976 Guadeloupe crisis. More than 70,000 people were evacuated from the Basse Terre area in Guadeloupe for up to 9 months because the Soufrière volcano threatened a major eruption. The foreseen eruption did not occur, which led to intense recriminations among the scientists involved, as well as huge economic and political consequences.[2] The Tungurahua volcano, Ecuador, renewed its activity on September 14, 1999 and the President of Ecuador ordered a hurried evacuation of the town 3 days later. There were no preparations in place for an evacuation of 25,000 people and by the end of December the people had forced their way back into their homes despite the risk of death from pyroclastic flows that had been widely predicted by volcanologists. At the time of this writing, the disaster risk is high because the eruptive activity continues with approximately 17,000 people living in the city.

RECOMMENDATIONS FOR FURTHER RESEARCH

A more risk-based approach for volcanoes is under development that assigns probabilities to all the reasonably foreseeable eruptive events and their emergency scenarios. The full range of eruptions and their impacts can be codified in a decision tree whose branches can be populated with conditional probabilities through a process of elicitation and expert judgment. This approach was first applied to a volcanic crisis in Montserrat in 1997[34] and is analogous to the evidence-based methods that are used in medicine in diagnosis or treatment in the face of clinicians' uncertainty.[36] This methodology is beginning to be more widely used as a powerful way to quantify risk and to identify the most important eruptive scenarios for emergency planning purposes.

An evidence-based approach to volcanic crises is becoming possible through the development of numerical simulation modeling in recent years to predict probabilistically the impacts and consequences of pyroclastic flows and surges and ash falls in developed areas. The extent of lahar run-out can also be modeled. Models are not absolutely predictive but they are useful for beginning to quantify risk assessment, as long as their uncertainties and limitations are understood. They are also beginning to be used to support decision making in crises. The MESIMEX exercise in the fall of 2006 in Naples was the first "real-time" exercise to simulate a state of unrest lasting 5 days and escalating toward an eruption. The exercise incorporated models for forecasting the direction of the wind and the building damage footprint under the plume, as well as the limits of a pyroclastic surge and the extent of disruption and damages caused by houses collapsing from volcanogenic earthquakes.

Computer simulations of volcanic hazards[37] and their impacts, together with casualty types and estimated numbers, provide the opportunity for probabilistic risk modeling and research into mitigation measures, a quantum leap compared with past approaches. Thus, models to predict casualties from tephra fallout[37–39] and pyroclastic surges[40–42] based on the vulnerability of buildings and their occupants to impacts quantified by numerical simulation modeling are now being developed. For the first time, three-dimensional numerical simulation modeling of pyroclastic surges by using supercomputer technology[43] opens up the future possibility of quantifying risk for disaster planning in cities and a much greater interaction between volcanologists and decision makers. At present, these tools are helping to define the limits of uncertainty in decision making, but one day they will become essential adjuncts for developing proportionate approaches in volcanic crises. This work needs to be based on an improved understanding of the causes of death and injury in eruptions as well as collecting data on the range of impacts to the built environment and infrastructure in actual events.

Probabilistic-based methods are also being applied to evacuation decision making in cities where the political and economic consequences of false alarms and relocating large numbers of people can be enormous, especially if an eruption fails to materialize. On the other hand, an evacuation decision that is too late will expose the same population to large losses of life. This dilemma was illustrated in the delayed call by the Mayor of New Orleans in the face of Hurricane Katrina resulting in thousands of trapped people in the flooded city.

Conclusion

Volcanic eruptions are infrequent compared with other hazards. They do not attract the same high level of general attention as earthquakes, floods, and windstorms, at least until a dangerous volcano moves out of a state of repose and threatens to erupt and devastate a populated area. Despite this, a threatened or actual volcanic eruption is of much higher complexity compared with these typically short-lived events, and the emergency management of a volcanic crisis, which can last months or years, is a unique challenge to all those involved, including the population at risk.

Although mitigation of human casualties by timely evacuation is the main goal in emergency management of volcanic threats, disaster planners must also be familiar with rescue and emergency treatment measures and prepare for unique conditions associated with volcanic eruptions. Complete or partial evacuations may last months and measures to support displaced persons are essential, or people may soon prefer to accept a high risk and return to their homes against the advice of scientists and the authorities. In a prolonged crisis in which a forecasted major eruption fails to occur, public perceptions can quickly become highly distorted as a disillusioned population becomes habituated to risk taking and starts to ignore official warnings. With the limited ability of scientists to accurately forecast the timing and size of most future eruptions,[44] the potential for events with mass casualties is always present and remains throughout the duration of most volcanic crises, not just when an eruption begins.[45]

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46. Used with permission from Elsevier.
47. Used with permission from Elsevier.

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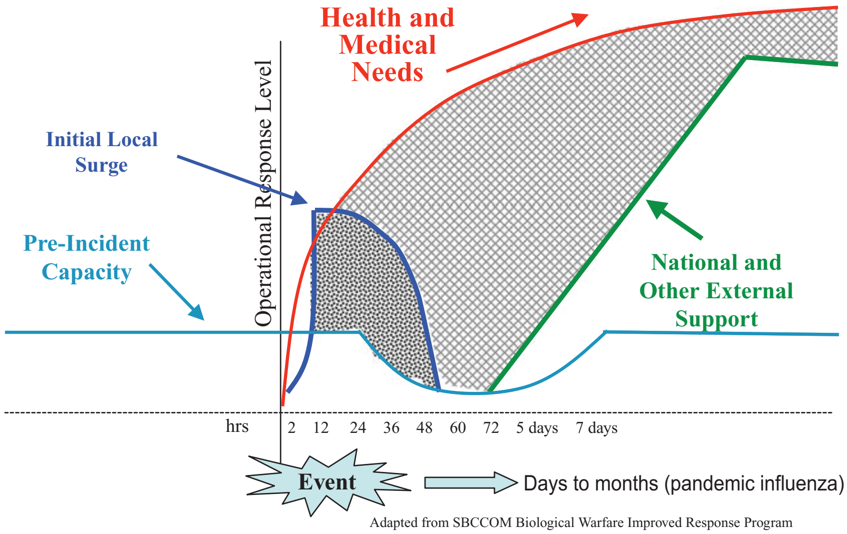


Plate 3.1. Medical surge.

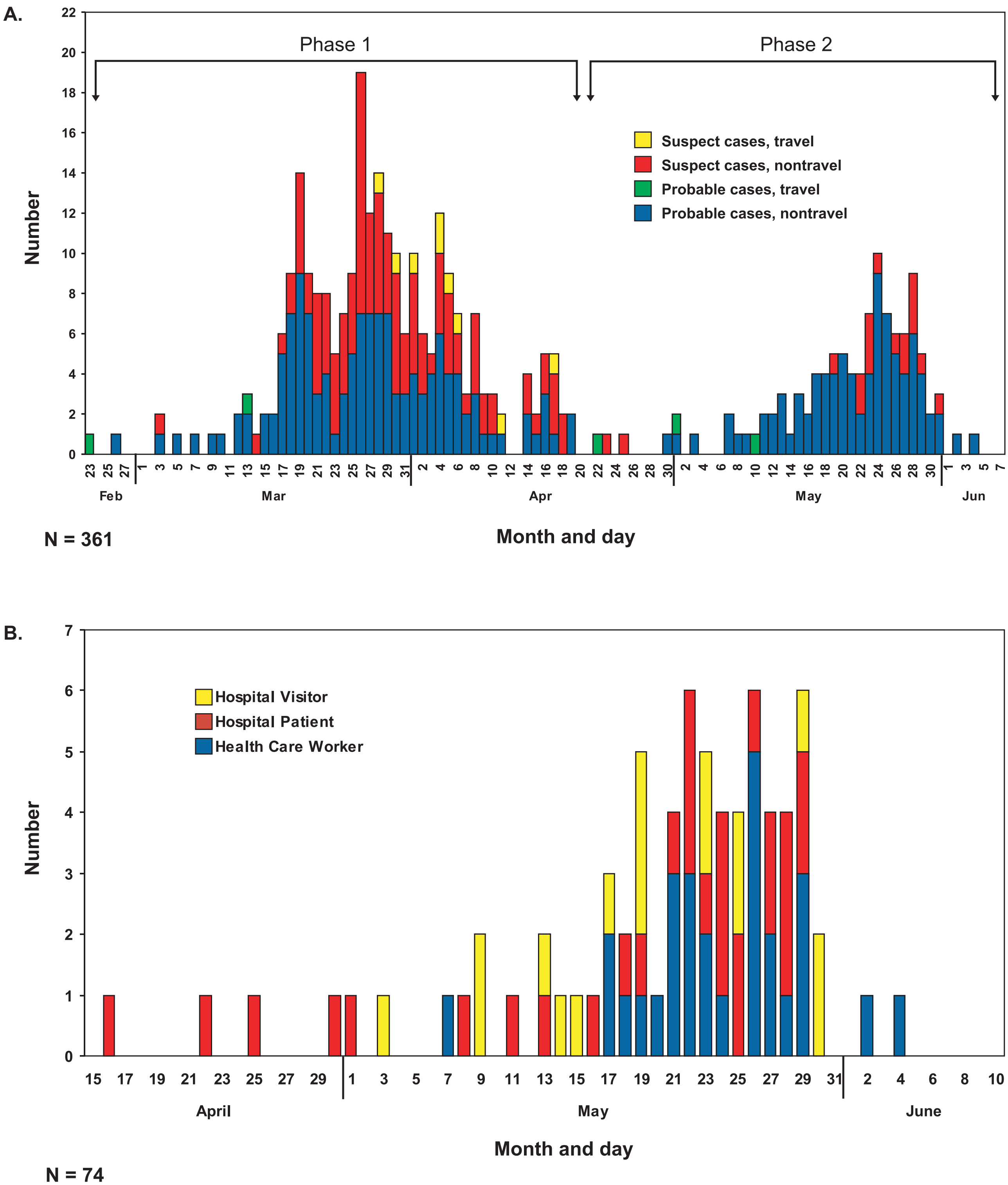


Plate 6.3. Reported SARS cases in Ontario, Canada in 2003 demonstrating the two phases of the epidemic. **A**) Number of reported cases of SARS by classification and date of illness onset – Ontario, Canada, February 23 – June 7, 2003. **B**) Number of reported cases of SARS in the second phase of the epidemic by source of infection and date of illness onset – Toronto, Canada, April 15 – June 9, 2003. Adapted from U.S. CDC.

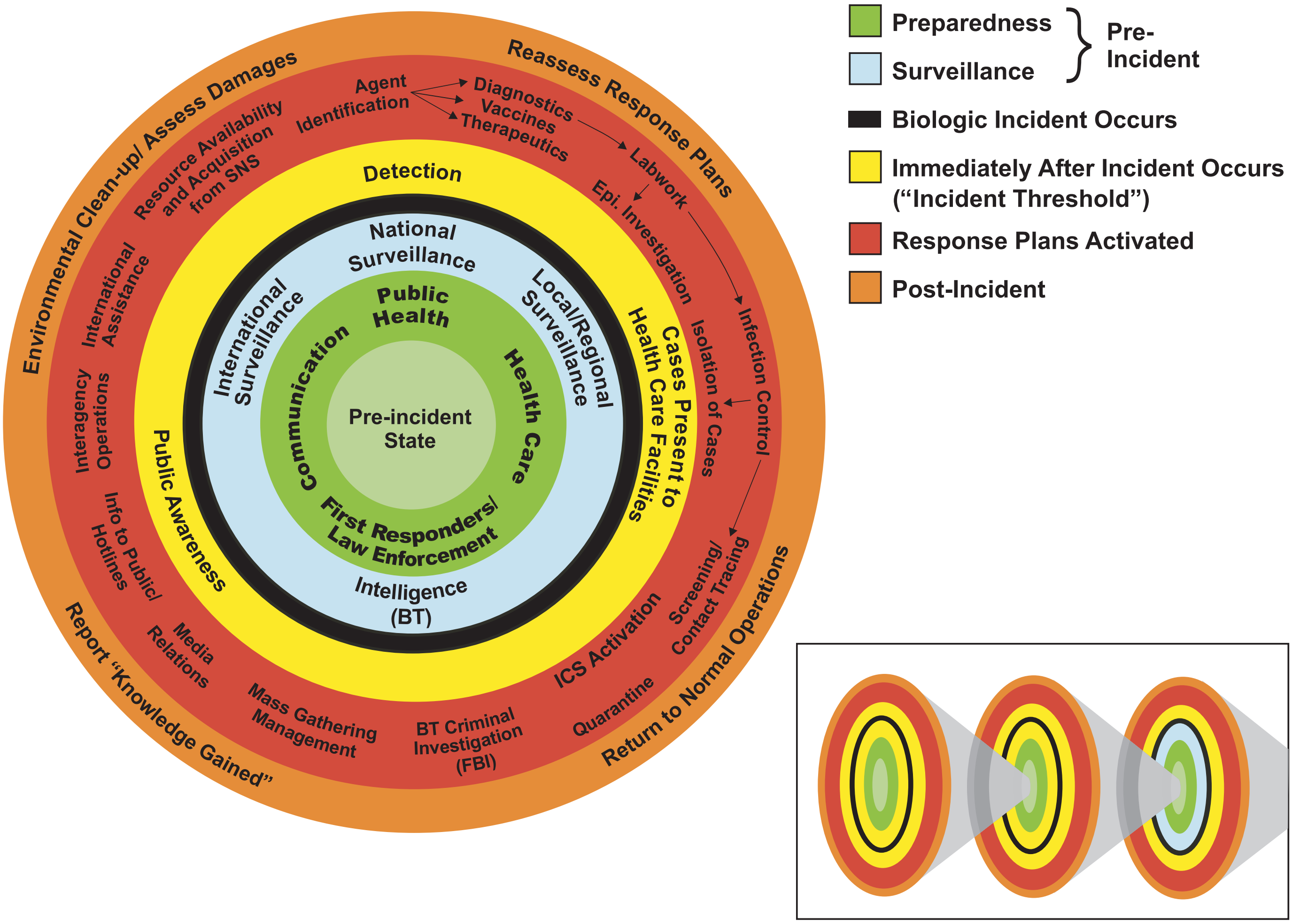


Plate 6.4. Schematic of events before and after a biological incident. "Incident" refers to the exposure of a population to a newly emerging disease (e.g., SARS), to an infectious disease with the potential for extensive casualties and/or public fear (e.g., *Neisseria meningitidis*), or to an act of bioterrorism. Represented are examples of the factors that need to be considered before, during, and after an incident. Increased size of the concentric circles generally corresponds with the progression of time; however, events in larger circles may "feed back" on smaller circles. The use of circles symbolizes the interconnectedness of entities and events within each ring.

The center of the diagram ("Preincident State") represents the situation prior to a biological incident; during this phase, the various response stakeholders (e.g., Public Health, Healthcare, First Responders/Law Enforcement and Communications) enhance preparedness by, for example, improving response plans and participating in practice exercises. This aims to fortify comprehensive preparedness plans (second ring labeled "Preparedness") and surveillance activities (third ring labeled "Surveillance"). The heavy black line represents the occurrence of an actual biological incident. After this happens, a period of time ensues when response stakeholders should become aware of the incident (fourth ring labeled "Incident Threshold"), either by active detection through surveillance efforts or passively by presentation of cases to healthcare personnel. Depending on the agent, the incident may not be initially apparent. This time between the occurrence and detection of an incident is the "incident threshold." Response plans are activated (fifth ring labeled "Response Plans Activated") when the incident is recognized. Some elements of the response are shown to illustrate the types of actions the preparedness stakeholders may need to take. This includes agent identification and development of diagnostics/vaccines/therapeutics, activities that will not be timely for an EID unless solid scientific programs are in place in the Pre-incident State. The events in the final circle (sixth ring labeled "Post-Incident") largely occur in the post-incident phase when disease transmission has been controlled and no new cases are detected. Some actions such as the clean up of environmental contamination may initiate sooner to prevent disease transmission. Disaster mitigation efforts are analyzed in the post-incident phase. "Knowledge Gained" is used to optimize preparedness plans for the next potential biological incident (this flow of information is symbolized in the inset). Effective planning and surveillance in the circles before an incident occurs can reduce the incident threshold time and make the events of the subsequent circles easier to manage.

Plate 8.1. Corpus Christi, Texas, September 9, 2008 – Firefighter assists nursing home evacuees prior to the arrival of Hurricane Ike. Patsy Lynch/FEMA News Photo.

Plate 8.2. Caddo County, Oklahoma, August 20, 2007 – Damage to a nursing home as a result of a tropical storm. There were no injuries. Patricia Brach/FEMA News Photo.

Plate 8.3. Biloxi, Mississippi, September 27, 2005 – Vietnamese residents of Biloxi, Mississippi are assisted by a FEMA community relations representative. Mark Wolfe/FEMA News Photo.

Plate 13.1. APR and PAPR with hood.

Plate 13.3. NIOSH-approved N95 respirator.

Plate 13.4. NIOSH respirator with HEPA filters.

Plate 17.5. Slane Castle 2001: U2 concert.

Plate 18.2. The Concorde's last flight in the year 2000. A piece of metal on the runway caused a tire explosion. Debris from the tire punctured the wing fuel tank and the fuel caught fire. Photo from Associated Press. Available at: http://www.airdisaster.com/photos/afsst/2.shtml.

Plate 18.3. The 1991 MD-81 crash in Stockholm was caused by engine failure at low altitude when clear ice from the wings was sucked into the engines. During the emergency landing, the aircraft's momentum was reduced by hitting a number of trees before crashing on a snowy field. The snow probably prevented a postcrash fire.

Plate 18.6. Telescoping. Illustrator: Gunilla Guldbrand.

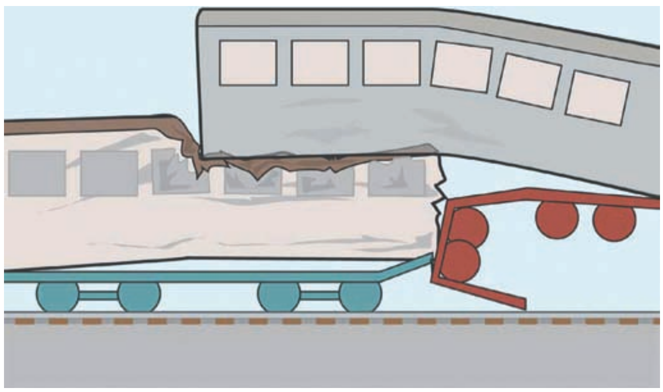


Plate 18.7. Overriding. Illustrator: Gunilla Guldbrand.

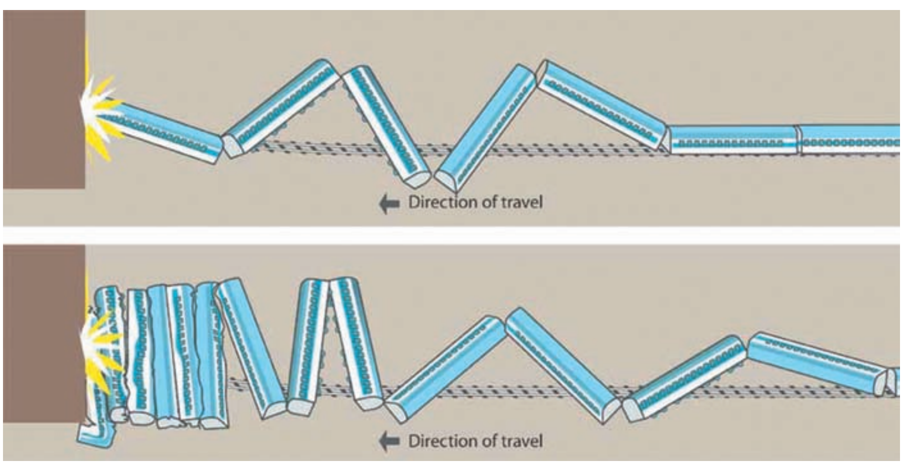


Plate 18.8. Jack-knifing/Lateral buckling. Illustrator: Gunilla Guldbrand.

Plate 18.9. The Eschede, Germany, train disaster is one of the world's worst high-speed train disasters. The train disintegrated in the crash and the disaster claimed 101 lives and injured 103.

Plate 18.11. A Japan Railway express train derailed in 2005, and jack-knifed against a parking garage in an urban area of Amagasaki, Japan. The crash left 107 passengers dead and injured 549. Used with permission from Scanpix.

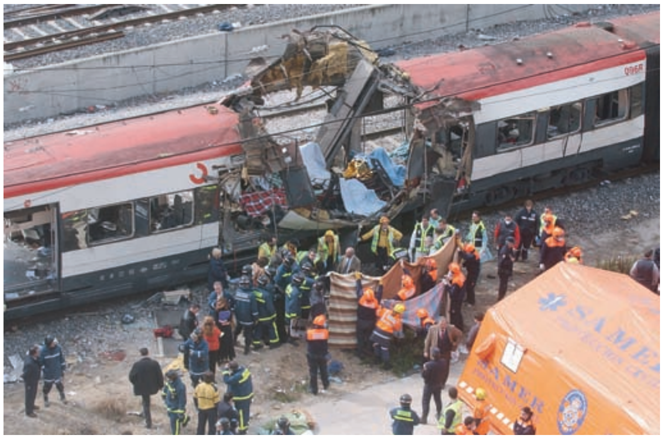


Plate 18.12. The 2004 attack in Madrid was Spain's worst terrorist event in its history to that date. Ten bombs exploded in four different sites, which killed 101 passengers and injured more than 1,500 survivors. Ambulance services established a field hospital close to the railway track, placing themselves and the injured passengers in an area at risk for further bomb explosions. Used with permission from Scanpix.

Plate 18.13. A timber truck with trailer suffered a front tire blow out and became so difficult to steer that it crashed into an oncoming school bus in rural, northern Sweden in 2001. Timber entered the bus and made the rescue effort extremely difficult. Six of the 42 passengers involved died. Used with permission from Scanpix.

Plate 18.14. This tour bus drove off the highway and down an embankment, hit a boulder, rolled 180°, and landed on a roof that subsequently collapsed. Nine passengers died, but only two had lethal injuries. Six were jammed between the roof and interior structures (usually a seat back), and suffocated due to immobilization of the chest. It took 3.5 hours to extricate the surviving passengers.

Plate 18.15. A high-profile intercity bus blew off the road after driving out from a forest into an open field. The final position of the bus across the creek resulted in lack of passenger exposure to the water, likely preventing morbidity and mortality. Victim evacuation was facilitated after rescuers discovered that the windows were so strong that personnel could walk on them. Used with permission from Lars-Göran Halvdansson.

Plate 18.16. If people are trapped under a bus constructed of steel, it can be quickly lifted with extended hydraulic cylinders in the corners of roof hatches or with two air bags.


Plate 18.17. Cutting an opening in the roof, which is feasible in 2 minutes with a circular saw, facilitates evacuation. This intervention permits ambulance personnel to work in the passenger compartment and to evacuate victims by using the most appropriate exit pathways.

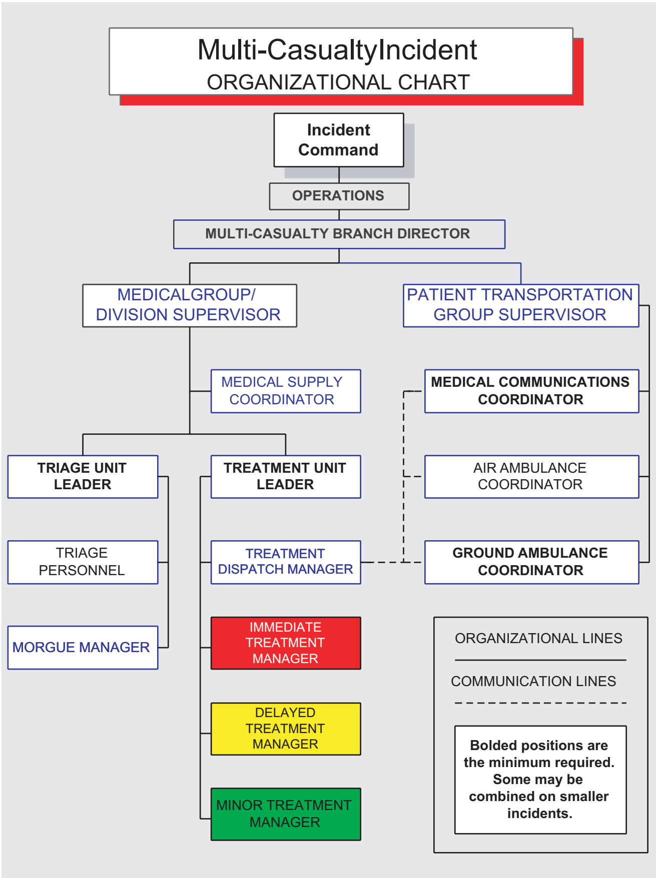


Plate 19.3. Multicasualty incident organization (adapted from FIRESCOPE).

Plate 22.3. WMD Drill.

Plate 22.4. News screen capture.

Plate 22.2. A child's gas hood. *Source:* HFC.

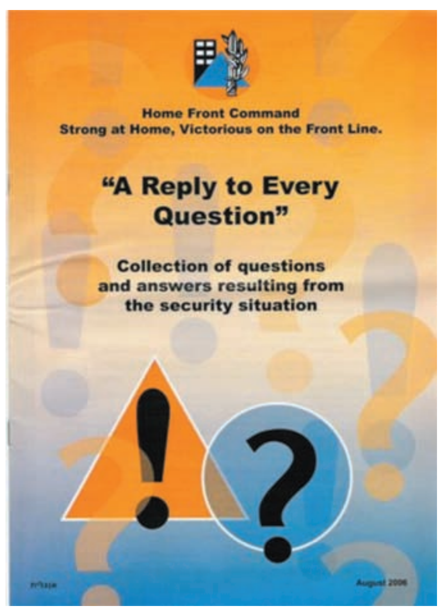


Plate 22.5. Leaflet in English. *Source:* HFC.

Plate 22.6. Leaflet in Russian. *Source:* HFC.

Plate 22.7. Leaflet in Hebrew. *Source:* HFC.

Plate 22.8. Audience relationship to the event.

Plate 23.1. Clinical Video Conferencing System.

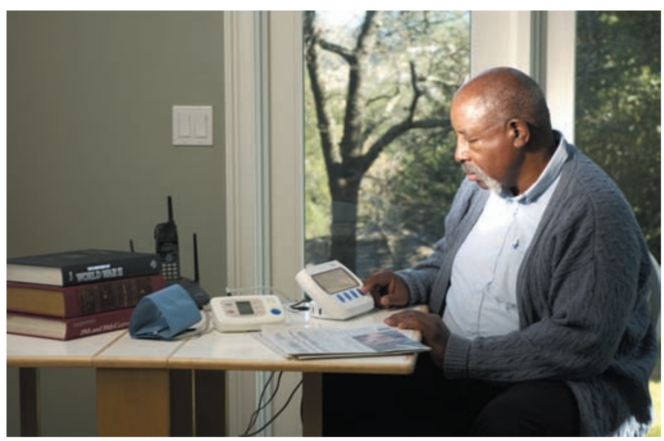


Plate 23.2. Home-Telehealth Device. Used with permission from Kimberly Boltom.

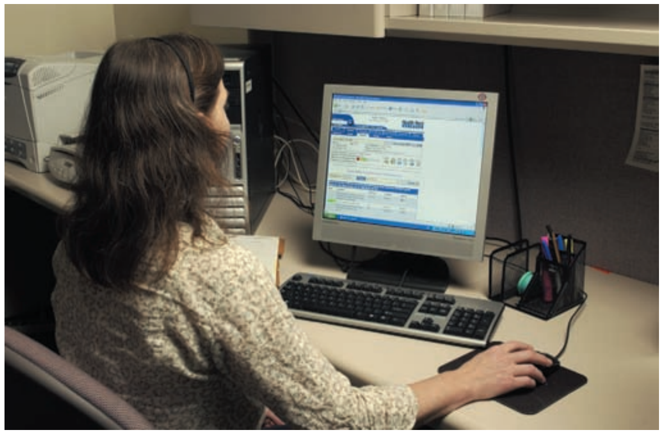


Plate 23.3. Population Management via Home-Telehealth. Used with permission from Kimberly Boltom.

Plate 24.1.1. Refugee camp conditions in northern Iraq 1992. Camp demographics are critical in determining requirements and vulnerability. As Kurdish men were killed by Saddam's Iraqi forces, or were fighting to keep their own territory safe, the fleeing Iraqi Kurds were primarily children (50%) women (30%) and the elderly (20%). Logistics and health care in the precarious camp tents placed on the side of mountains had to adapt to unique needs. (Burkle, 1992)
All photos in Chapter 24 were taken and are owned by me. I give permission for their use. Frederick M. Burkle, Jr., MD, MPH, DTM.

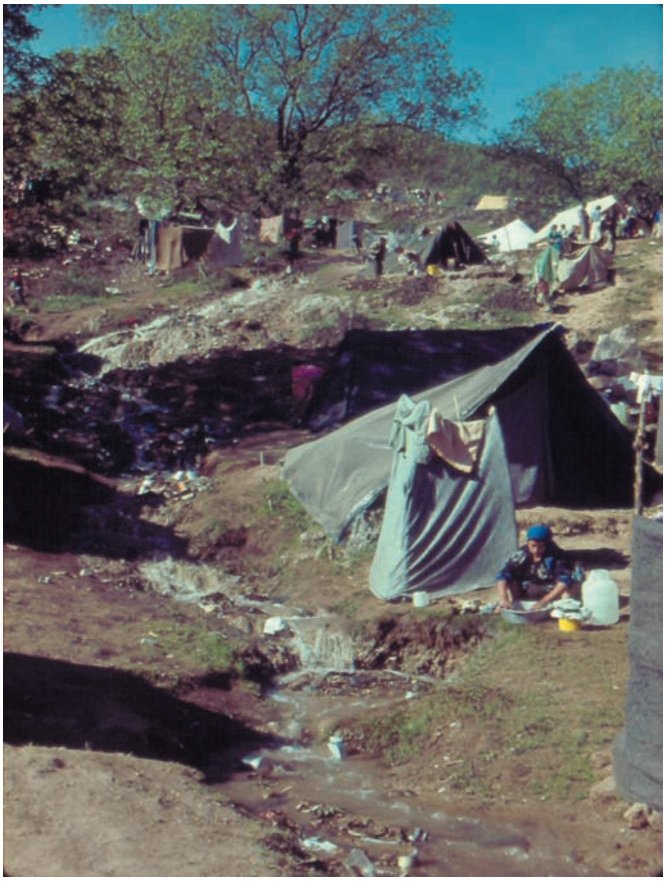


Plate 24.1.2. This figure illustrates camp conditions that contributed to the 80% of childhood deaths resulting from diarrhea and dehydration secondary to common waterborne bacteria and viruses. Water from melting snow that ran through the camp was polluted by makeshift toilet facility runoff and the washing of soiled laundry. (Burkle, 1992)

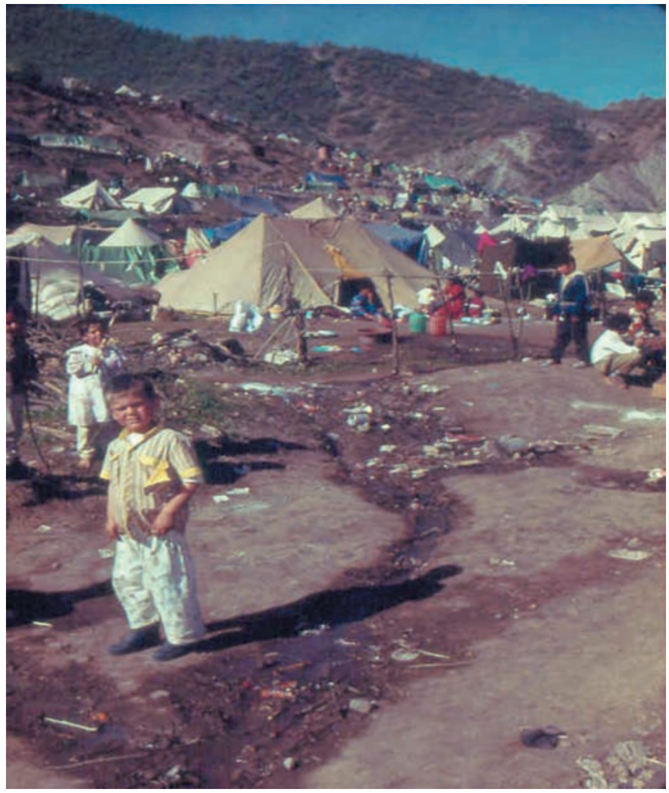


Plate 24.1.3. Mountain streams ended up as stagnant and polluted pools at the base of the camp where children played. Simple and easily corrected public health solutions must be sought to prevent outbreaks. (Burkle, 1992)

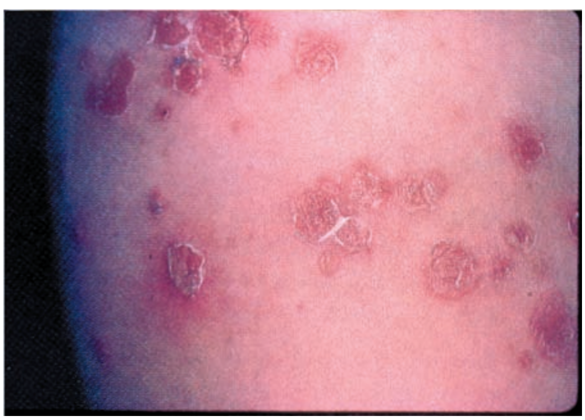


Plate 24.1.4. Although considered a common and treatable problem in the Western world, impetigo patients are triaged as urgent in refugee camps and among internally displaced populations, especially if the victims are malnourished. Impetigo can progress rapidly from a minor skin infection to septicemia when micronutrient deficient and severe malnutrition exist. (Burkle, 1990)

Plate 24.1.5–7: Scurvy, or vitamin C deficiency and other micronutrient deficiencies (especially A and B l) must be suspected in prolonged war where malnutrition exists. These cases, seen in Vietnam in the 1960s presented as minor bruising, severe pain when the limbs were moved and fragile tongue lesions that easily bled. Similar cases were seen in East African camps in the 1990s when the waste diet given to refugees lacked micronutrient supplements. Vitamin C serves as a coenzyme in the metabolic reaction of clotting. Once paraternal vitamin C was administered, the pain from bleeding under the periosteum ceased rapidly. (Burkle, 1968)

Plate 24.2.1-2. Examples of dehydration and malnutrition are common in complex emergencies, especially in Africa and Asia. Severely dehydrated children exhibiting extreme loss of skin turgor. (Burkle, 1968)

Plate 24.2.3. A Kurdish child with severe dehydration from diarrhea. The diagnostic "old man facies" occurs with severe loss of body water and electrolytes. Further examination was not allowed. Confirmatory laboratory tests are rarely available. These cases are usually field managed as isotonic losses with oral rehydration. With clinical improvement the family trusted the physician to complete the physical examination. (Burkle 1992)

Plate 24.2.4. The majority of resupply in complex emergencies is through local logistical networks such as these rehydration salts, from UNICEF, being trekked through jungle trails along the Burmese border to a refugee camp run by the International Rescue Committee. (Burkle, 1993)

Plate 24.3.1. Bubonic and septic plague and other endemic infectious diseases are common when the public health infrastructure is destroyed in war and conflict. This figure illustrates an auxillary bobu. Gram stained confirmed Gram-negative bipolar rods. (Burkle, 1968)

Plate 24.3.2. The humanitarian community must be sensitive to cultural beliefs that are not dismissed as modern medical care is added. In this toxic and comatose child, an inguinal bubo was surrounded with a lime substance believed to prevent spread. A paste material was placed over the umbilicus with "Chinese medical" writings as petitions to the "evil spirits" that caused disease. Onion flakes were placed in the hair for fever. The child had a febrile seizure immediately after this photo was taken. The mother, thinking that I had provoked an evil spirit within her child with the foreign instrument (camera) I held in my hand, fled with her child. The mother only agreed to return the child for treatment if I was removed as the health care provider. This being impossible, I managed the case from a distance through locally trained assistants. (Burkle, 1968)

Plate 24.3.3. Flea bite over cervical bubo resulting in highly contagious plague. (Burkle, 1968)

Plate 24.3.4. Vaccine preventable diseases are common. Tetanus arising from a foot lesion caused severe "lockjaw" in this 10-year old male. Hyperventilation with nasal flaring resulted in secondary tetany. This child survived with parenteral penicillin and antitoxin. (Burkle, 1969)

Plate 24.3.5. Tuberculosis is commonly seen and may result in many secondary cases in crowded camps. This child exhibits both Pott's disease and a scrofula lesion of the neck. (Burkle, 1969)

Plate 24.4.1. Makeshift tents for women on the left and infants on the right. Kurdish fathers objected to the resuscitative measures taken on their ill infants claiming that death was dictated by religious beliefs. The humanitarian community must recognize cultural, religious, and ethnic restrictions and develop a dialogue that both addresses and balances health requirements and local values. (Burkle, 1992)

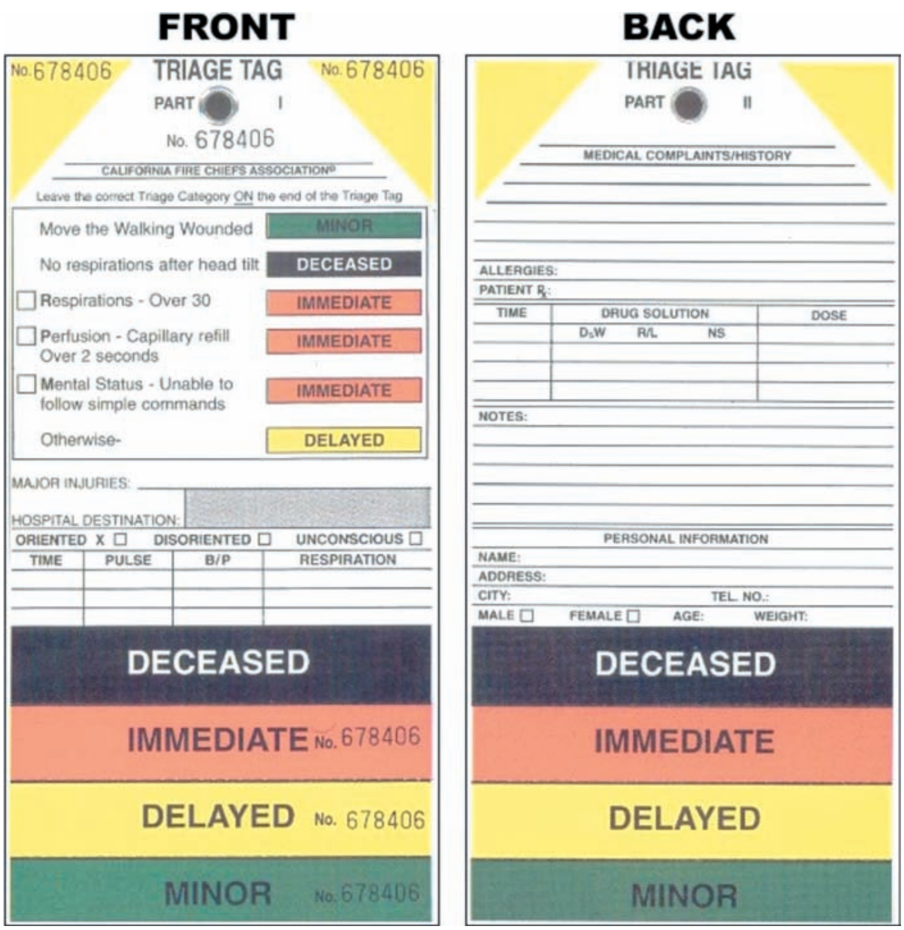
Plate 24.4.2. "Collateral damage" goes beyond injury and death. The fragile and superficially placed piping seen in the foreground was the main water artery to this village in Iraq. Public health infrastructure may be different than the normal standard for civilian contractors, the military, and aid workers. Public health "indirect" deaths are more prevalent than direct deaths from weaponry and violence. (Burkle, 1992)

Plate 24.4.3. This child soldier was a self-designated "general" in the rebellion against the Taylor regime in Liberia. Threatening and unpredictable, he also demonstrated childlike behaviors and needs. Originally from Sierra Leone, he was abducted at the age of eight and knew nothing but war and killing. (Burkle, 2003)

Plates 24.5.1. The picture of mental health problems brought about by war depicts an elderly and overtly psychotic woman abandoned by her family to US military forces believing that the US held magical powers to cure her mental illness. (Burkle, 1992)

Plate 24.5.2. The last remaining survivor of her families' bunker destroyed in an air raid, this child was mute and refused to be held or receive care within the hospital wards. (Burkle, 1968)

Plate 24.5.3. A preadolescent male who built a mine to kill "occupying forces" accidentally triggered the device sustaining these severe injuries. More visible hemorrhage was prevented by massive vasoconstriction physiologically available as a last measure before death in children. With anesthesia this hormonal protection ceased and he rapidly lost what remained of his meager blood volume. In this case, the surgical team was aware of this risk and instituted protective blood, fluids and venous access before anesthesia was begun. Decoding of vital signs looking for fragile stroke volume losses are a required skill when Western monitoring technologies are unavailable. (Burkle, 1968)



FRONT

No. 678406 TRIAGE TAG No. 678406

PART I

No. 678406

CALIFORNIA FIRE CHIEFS ASSOCIATION®

Leave the correct Triage Category ON the end of the Triage Tag

Move the Walking Wounded	MINOR
No respirations after head tilt	DECEASED
☐ Respirations - Over 30	IMMEDIATE
☐ Perfusion - Capillary refill Over 2 seconds	IMMEDIATE
☐ Mental Status - Unable to follow simple commands	IMMEDIATE
Otherwise-	DELAYED

MAJOR INJURIES:

HOSPITAL DESTINATION:

ORIENTED X ☐ DISORIENTED ☐ UNCONSCIOUS ☐

TIME	PULSE	B/P	RESPIRATION

DECEASED

IMMEDIATE No. 678406

DELAYED No. 678406

MINOR No. 678406

BACK

TRIAGE TAG

PART II

MEDICAL COMPLAINTS/HISTORY

ALLERGIES:

PATIENT ℞:

TIME	DRUG SOLUTION	DOSE
	D₅W R/L NS	

NOTES:

PERSONAL INFORMATION

NAME:

ADDRESS:

CITY: TEL. NO.:

MALE ☐ FEMALE ☐ AGE: WEIGHT:

DECEASED

IMMEDIATE

DELAYED

MINOR

Plate 25.1. Original triage tag, with unique numeric identifier but no barcode. Copyright California Fire Chiefs Association. Reprinted with permission.

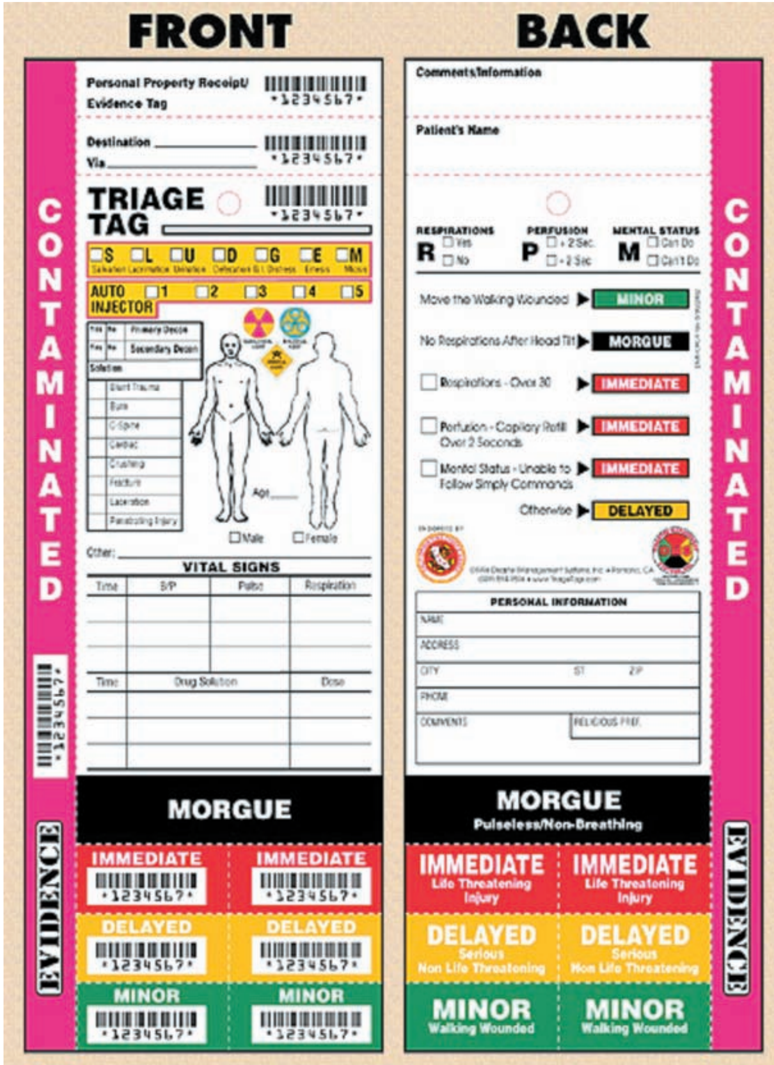


Plate 25.2. Medical all risk triage tag – Note the “1-d” barcode on the front.

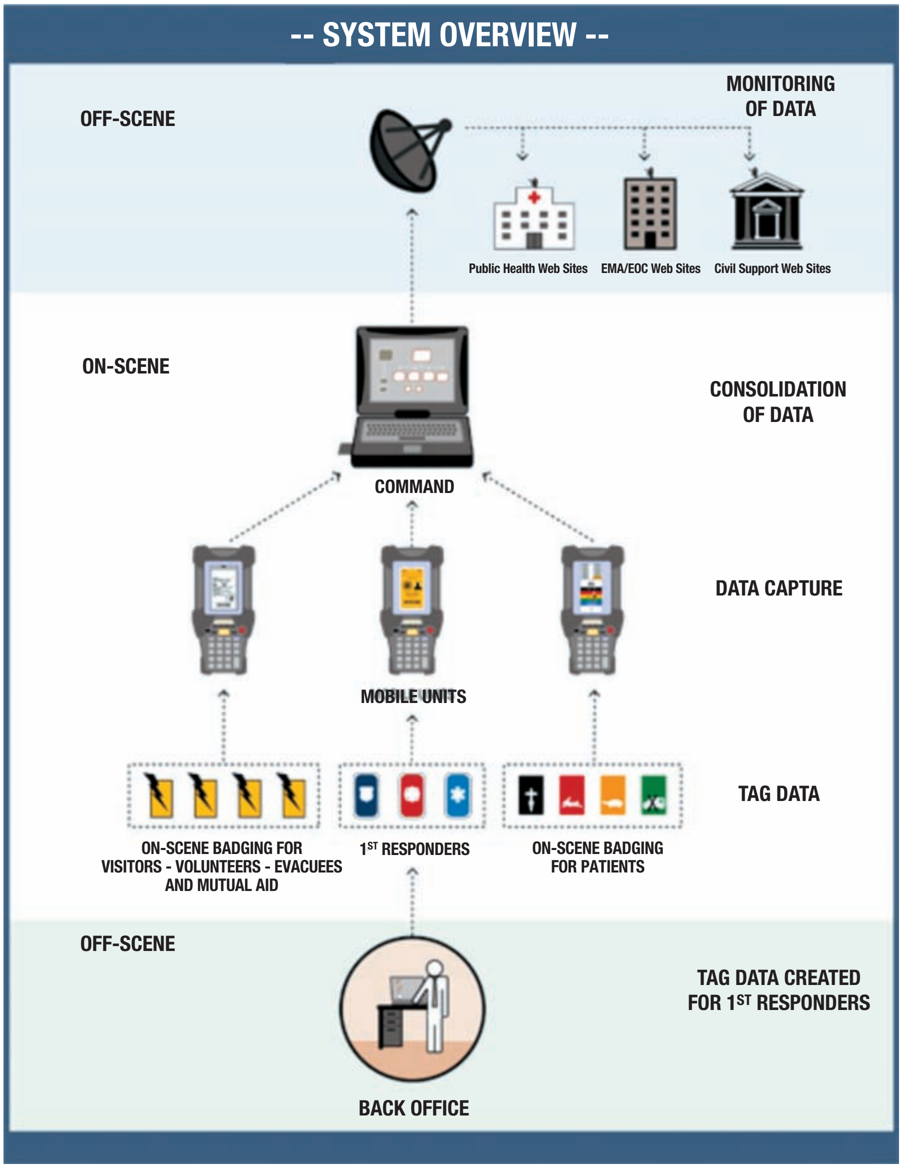


Plate 25.4. Data capture is performed via handheld units capable of scanning triage tags; these units then upload data to a local laptop, where data are consolidated, viewed, and sent to off-scene users (including hospitals and command centers, etc.). Reprinted with permission.

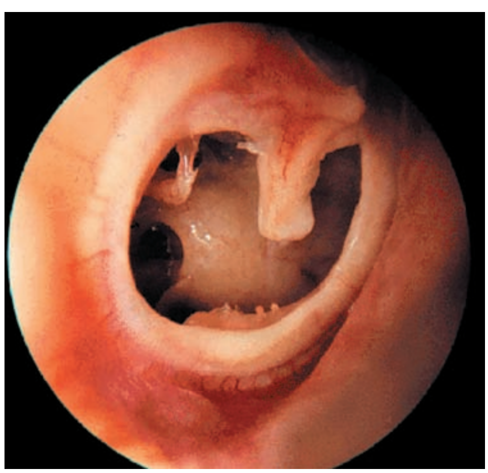
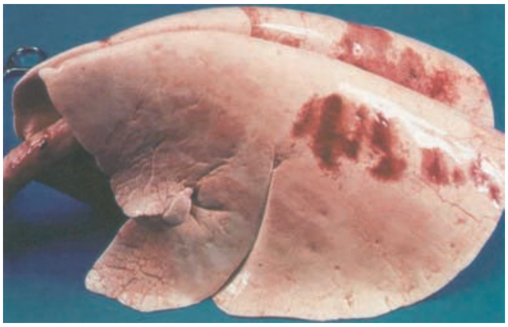


Plate 26.3. TM ruptured by blast impulse. Note nearly complete loss of tissue, which will likely require grafting. Most ruptures will heal spontaneously. Photograph courtesy of Dr. Bartolomé Scola, Head of ENT Service, University General Hospital Gregorio Marañón, Madrid, Spain.

A



B

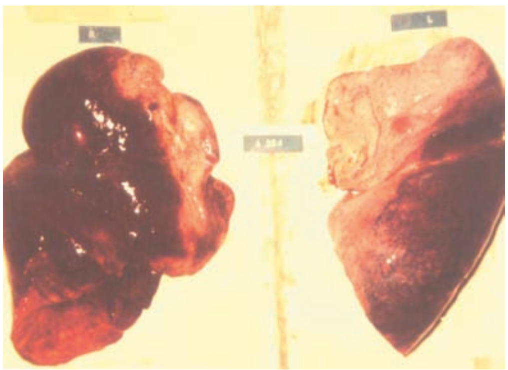


Plate 26.4. Spectrum of BLIs showing: (**A**) survivable localized areas of contusion following a relatively small blast impulse in a sheep model; and (**B**) fatal diffuse internal contusions and external lacerations from a battle casualty. These photographs are in the public domain as published by the Office of the Surgeon General of the United States Army, Falls Church, Virginia, USA. Reproduced from the *Textbook of Military Medicine*. 1991:276 and 228, respectively.

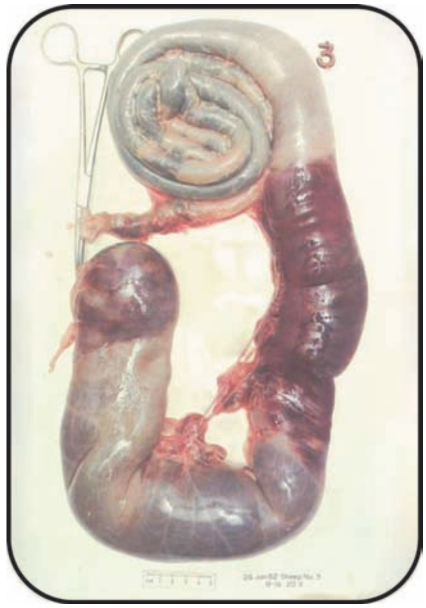


Plate 26.5. BII from a sheep model. Note segmental parenchymal hemorrhage and intraluminal blood visible through other areas of relatively intact bowel wall. This figure is in the public domain as published by the Office of the Surgeon General of the United States Army, Falls Church, Virginia, USA. Reproduced from the *Textbook of Military Medicine*. 1991:288.

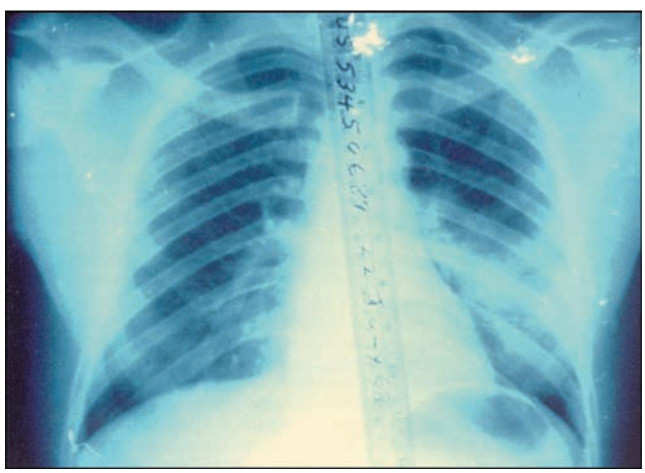


Plate 26.7. Plain chest radiographs of blast-injured casualties showing: mild unilateral left-sided contusion.

Plate 29.1. Cutaneous anthrax. Note the painless black eschar and moderate surrounding erythema. Photograph: Courtesy of the Centers for Disease Control and Prevention, Atlanta, Georgia. www.bt.cdc.gov/agent/anthrax/anthrax-images/cutaneous.asp.

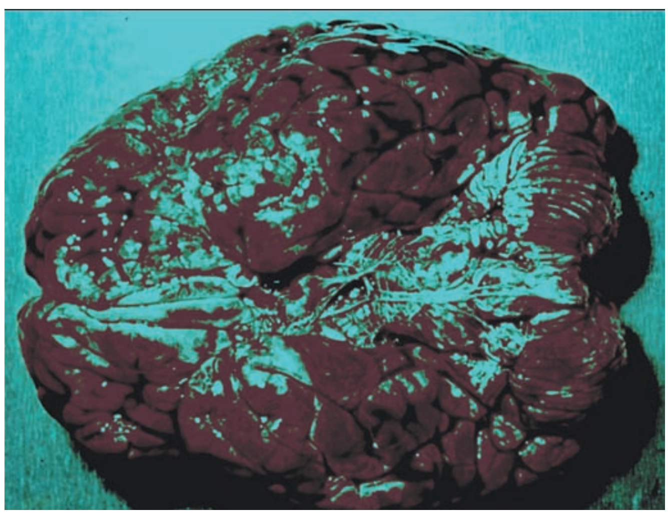


Plate 29.3. Brain from a man from Thailand with meningitis and subarachnoid hemorrhage who died 5 days after eating undercooked carabao (water buffalo). Reproduced from: Binford CH, Connor DH, eds. *Pathology of Tropical and Extraordinary Diseases.* Vol 1. Washington, DC: Armed Forces Institute of Pathology; 1976: 121. AFIP Negative 75-12374-3.

Plate 29.4. Series of photographs illustrating the evolution of skin lesions in an unvaccinated infant with the classic form of *Variola major*. (**A1**, **A2**) The third day of rash shows synchronous eruption of skin lesions; some are becoming vesiculated. (**B1**, **B2**) On the fifth day of rash, almost all papules are vesicular or pustular. (**C1**, **C2**) On the seventh day of rash, many lesions demonstrate central umbilication, and all lesions are in the same general stage of development. Reproduced with permission from reference 27.

Plate 29.5. Flat-type smallpox in an unvaccinated woman on the sixth day of rash. Extensive flat lesions (**A** and **B**) and systemic toxicity with a fatal outcome were typical. Reproduced with permission from reference 27.

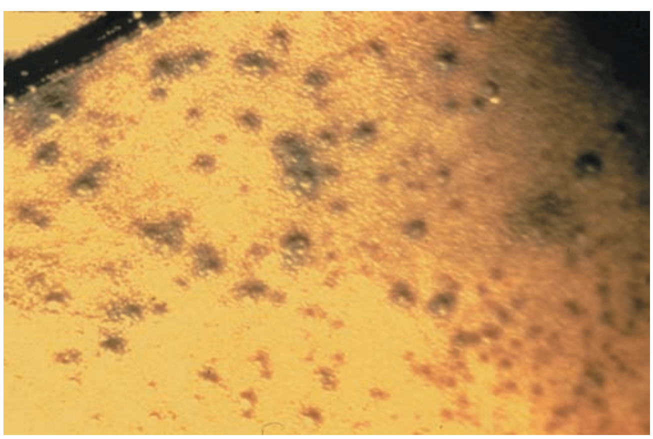


Plate 29.6. Early hemorrhagic-type smallpox with cutaneous signs of hemorrhagic diathesis. Death usually intervened before the complete evolution of pox lesions. Reproduced with permission from Herrlich A, Munz E, Rodenwaldt E. *Die pocken; Erreger, Epidemiologie und klinisches Bild.* 2nd ed. Stuttgart, Germany: Thieme; 1967.

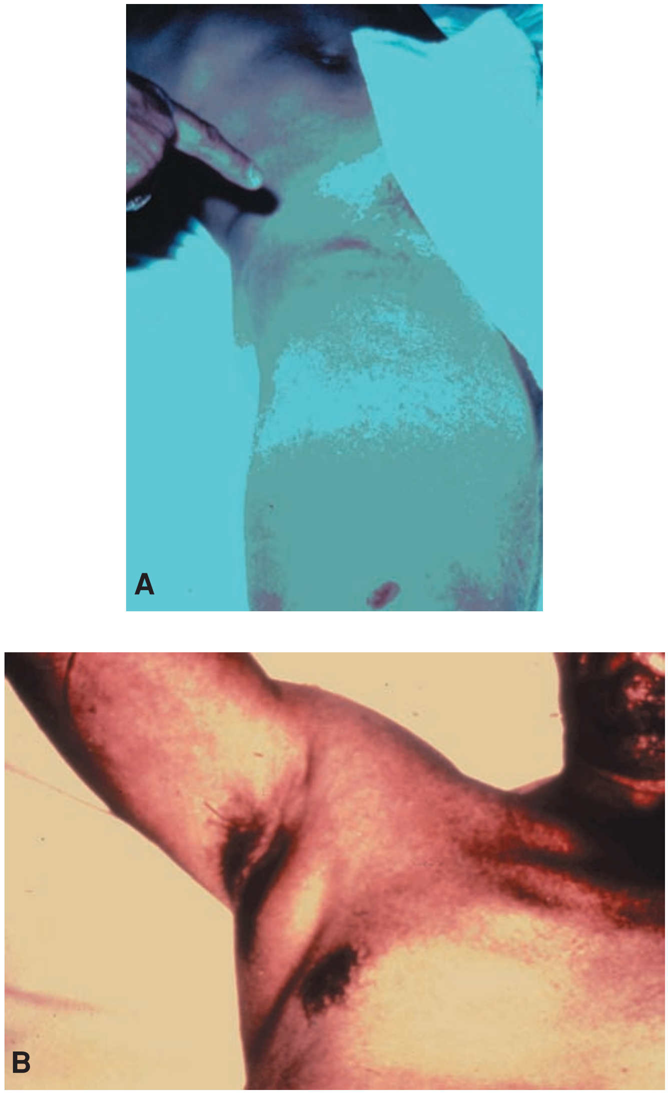


Plate 29.7. A femoral bubo (**A**) is the most common site of an erythematous, tender, swollen, lymph node in patients with plague. The next most common lymph node regions involved are the inguinal, axillary (**B**), and cervical areas. Bubo location is a function of the region of the body in which an infected flea inoculates the plague bacilli. Photographs: Courtesy of Kenneth L Gage, PhD, Centers for Disease Control and Prevention Laboratory, Fort Collins, Colorado.

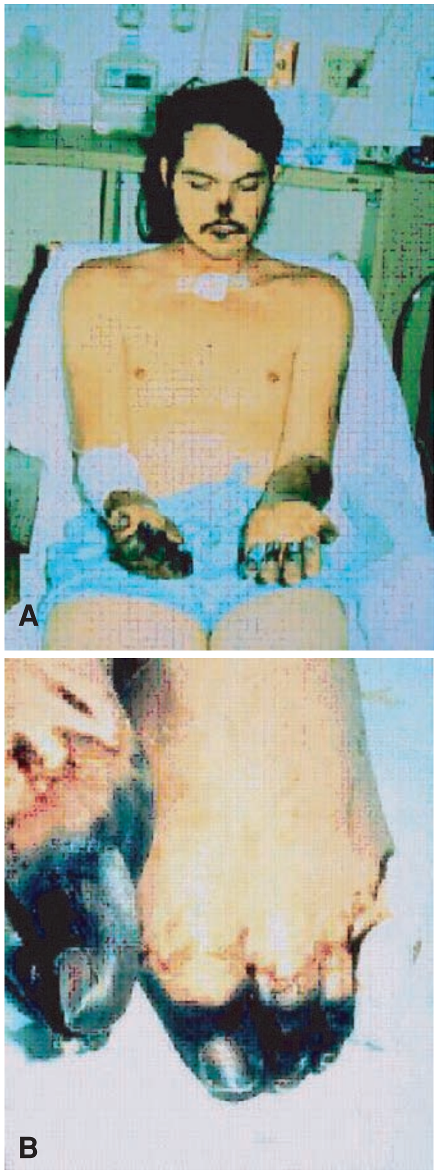


Plate 29.8. (**A**) This patient developed bubonic plague that progressed to the septicemic and pneumonic forms after the causative organism, *Y. pestis*, disseminated from his buboes into his bloodstream. (**B**) Note the necrosis of tissue involving the tip of the nose, the fingers and the toes. This is due to thrombosis of distal arterioles and is a known complication of septicemic plague. Photographs: Courtesy of Kenneth L Gage, PhD, Centers for Disease Control and Prevention Laboratory, Fort Collins, Colorado.

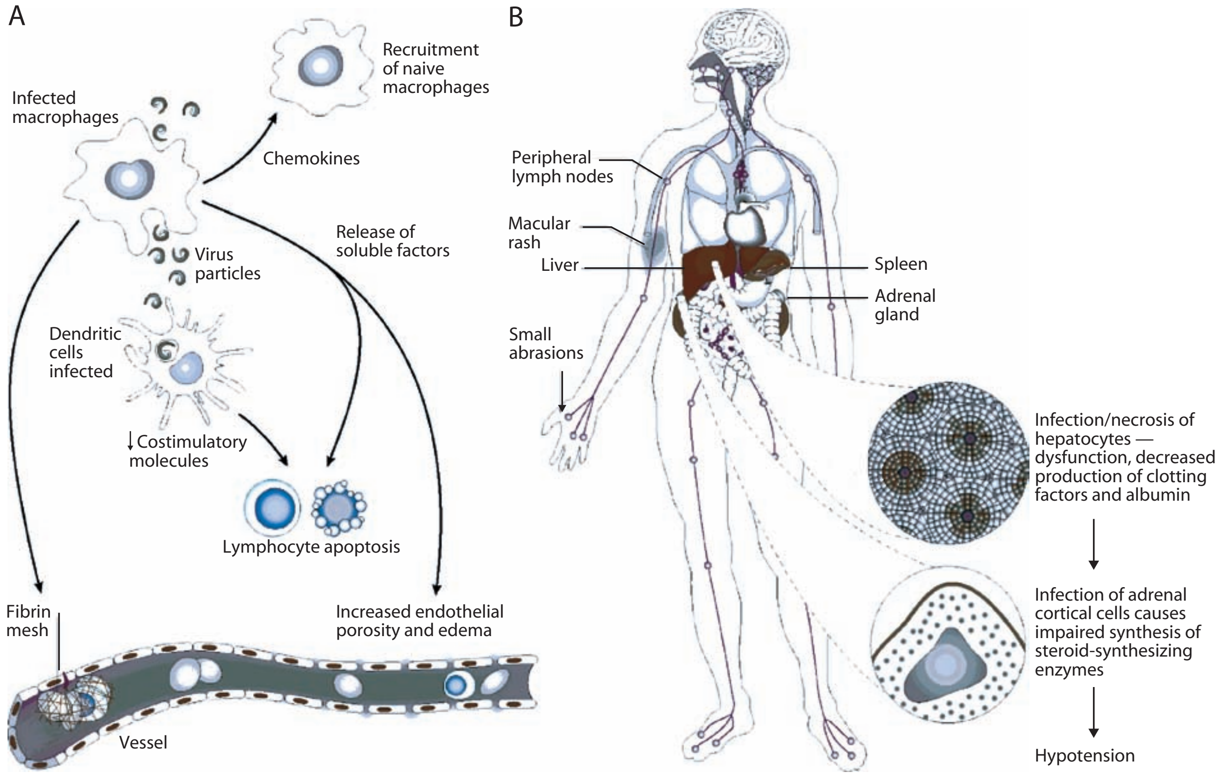


Plate 29.9. Model of VHF pathogenesis. (**A**) Virus spreads from the initial infection site to regional lymph nodes, liver, and spleen. At these sites, the virus infects tissue macrophages (including Kupffer cells) and dendritic cells. Soluble factors released from virus-infected monocytes and macrophages act locally and systemically. Release of chemokines from these virus-infected cells recruits additional macrophages to sites of infection, making more target cells available for viral exploitation and further amplifying the dysregulated host response. Although none of these viruses infect lymphocytes, the rapid loss of these cells by apoptosis is a prominent feature of disease. The direct interaction of lymphocytes with viral proteins cannot be discounted as having a role in their destruction, but the marked loss of lymphocytes is likely to result from a combination of factors, including viral infection of dendritic cells and release of soluble factors from virus-infected monocytes and macrophages. For example, viral infection of dendritic cells impairs their function by interfering with the upregulation of costimulatory molecules, which are important in providing rescue signals to T lymphocytes. Additionally, release of soluble factors from infected monocytes and macrophages results in deletion of lymphocytes, both directly by release of mediators such as nitric oxide, and indirectly by contributing to upregulation of proapoptotic proteins such as Fas and tumor necrosis factor–related apoptosis-inducing ligand. The coagulation abnormalities vary in nature and magnitude among the VHFs. For example, Ebola virus induces the overexpression of tissue factor that results in activation of the clotting pathway and the formation of fibrin in the vasculature. As another example, coagulation disorders are less marked in Lassa fever, and impairment of endothelial function contributes to edema, which seems to be a more prominent finding in Lassa fever than in other VHFs. (**B**) The hemodynamic and coagulation disorders common among all of the VHFs are exacerbated by infection of hepatocytes and adrenal cortical cells. Infection of hepatocytes impairs synthesis of important clotting factors. At the same time, reduced synthesis of albumin by hepatocytes results in a reduced plasma osmotic pressure and contributes to edema. Impaired secretion of steroid-synthesizing enzymes by VHF-infected adrenal cortical cells leads to hypotension and sodium loss with hypovolemia. Macular rashes are often seen in VHFs. Reproduced with permission from: Geisbert TW, Jahrling PB. Exotic emerging viral diseases: progress and challenges. *Nat Med.* 2004;10(12 suppl):S110–121.

Plate 29.10. Ecchymosis associated with late-stage CCHF infection 1 week following development of clinical signs and symptoms. Ecchymosis indicates significant impairment of the patient's coagulation system and loss of vascular integrity. Photograph: Courtesy of Dr. Sadegh Chinikar, Pasteur Institute of Iran, Tehran, Iran.

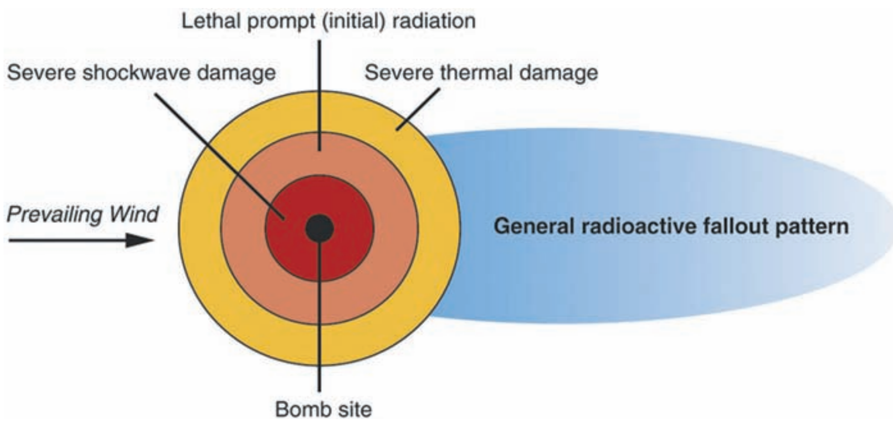


Plate 30.1. Flat-plain damage patterns from a ground-level nuclear detonation (viewed from above).

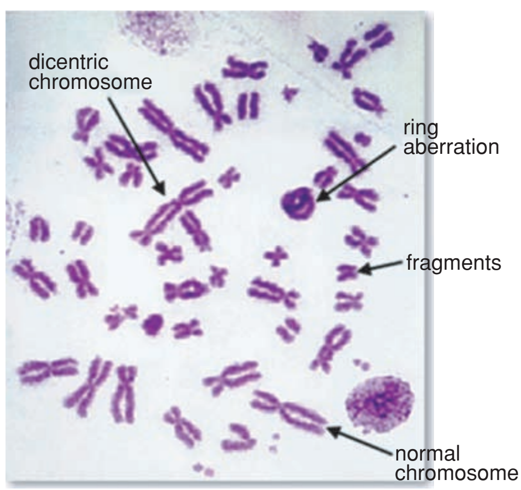


Plate 30.4. Cytogenetic abnormalities noted after irradiation in peripheral blood lymphocytes of a patient exposed to high-dose radiation. Dicentric chromosomes and ring abnormalities are relatively radiation specific and are characteristic of changes observed. Used with permission from REAC/TS.

Plate 30.6. Progression of skin lesions in a patient receiving a focal high-dose exposure to the right hand. (**A**) Shortly after exposure, (**B**) approximately 12 hours postexposure, (**C**) day 25 postexposure, (**D**) day 34 postexposure, and (**E**) day 46 postexposure. Images provided by the Radiation Emergency Assistance Center/Training Site. Used with permission from REAC/TS.

Plate 31.1. Boxes of equipment on trolleys packed pre-event for rapid deployment with medical field teams located next to the exit.

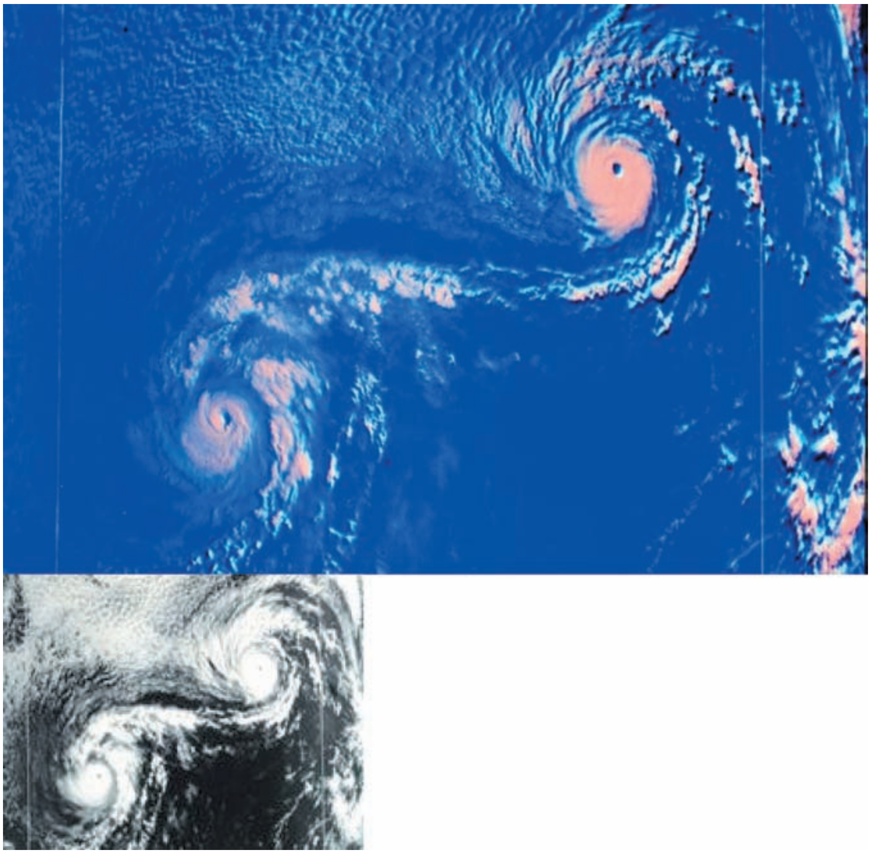


Plate 33.1. Fujiwhara effect: Typhoons Ione and Kirsten, August 24, 1974. *Image ID:* wea00481, NOAA's National Weather Service (NWS) Collection *Source:* NOAA Photo Library.

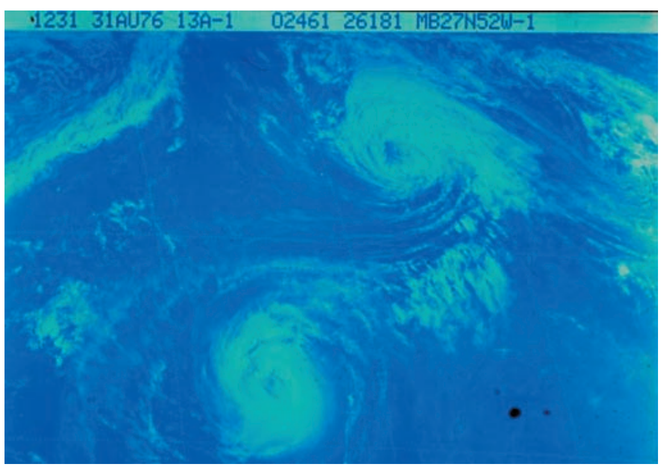


Plate 33.2. Fujiwhara effect: Hurricanes Emmy and Frances, August 31, 1976. *Image ID:* wea00489, NOAA's National Weather Service (NWS) Collection. *Source:* NOAA Photo Library.

Plate 33.3. Area of mudslide resulting from deforestation. Personal photo, Hawaii, 2007.


Plate 34.1. Funnel cloud in Ardmore, Oklahoma, 1985.


Plate 34.2. Tornado in Mayfield, Oklahoma, 1977.

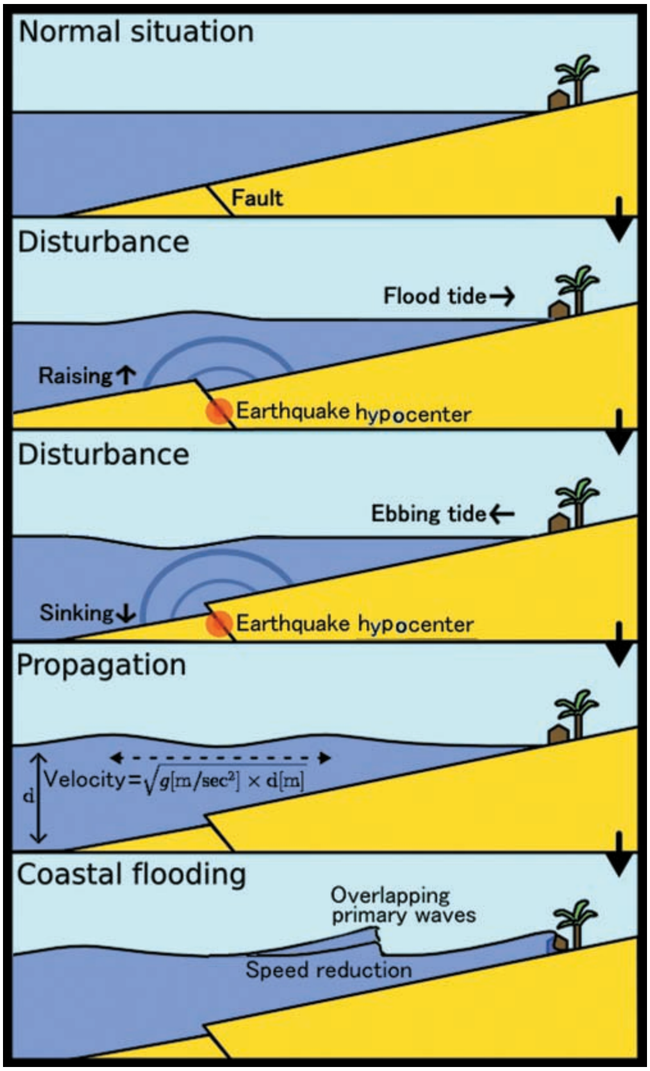


Plate 36.1. Diagram showing the generation of tsunami waves by a submarine earthquake. With disruption of the ocean floor, energy is transferred to the water mass causing displacement of a large mass of water. The energy of the ocean floor disruption is then dispersed in the form of a water mass or wave. When the tsunami strikes a shoreline, the energy stored in the form of water mass is dissipated on the shoreline.

Plate 36.2. During tsunami events heavy debris is churned onto and off shore as shown by this large coral rock thrown on shore in the Solomon Islands during the 2007 tsunami. (Source: United States National Oceanic and Atmospheric Administration, by John Beba, Woodlark Mining Limited.)

Plate 36.3. Sri Lanka 2004 tsunami wave striking shore, submersing bases of trees and low-lying buildings. Note the forceful churning of water as the wave is striking. (Source: United States National Oceanic and Atmospheric Administration, by Chris Chapman, Cambridge, UK.)

Plate 36.4. A Sri Lanka 2004 tsunami wave receding and pulling debris and objects into the ocean with forces that nearly equal the energy of the incoming wave. (Source: United States National Oceanic and Atmospheric Administration, by Chris Chapman, Cambridge, UK.)

Plate 36.5. This picture taken in Karaikal, India after the 2004 Indian Ocean tsunami shows the debris field left by the tsunami waves. High-force movement of heavy debris and sharp objects within a tsunami wave cause major injuries to exposed humans and animals. (Source: United States National Oceanic and Atmospheric Administration, by Joseph Trainor, University of Delaware, Disaster Relief Center.)

Plate 36.6. The initial receding of water from shore before the run-up of a tsunami wave during the 2004 Indian Ocean tsunami. During this "warning" phase of a tsunami run-up, rocks and sand that are normally submerged along the outer shore become exposed. This receding of the ocean serves as a warning for those along the shore to move to higher ground to avoid a possible incoming tsunami wave. (Source: United States National Oceanic and Atmospheric Administration, by Chris Chapman, Cambridge, UK.)

Plate 37.1. Power lines can be downed by the direct weight of ice or by trees and limbs felled by ice, as in this example from Springfield, Missouri, following a January 2007 ice storm. This photograph is in the public domain. It was retrieved from Wikipedia at: http://en.wikipedia.org/wiki/Image:Icestorm˙003.jpg.

Plate 36.7. A protective sea wall constructed to repel and limit potential tsunami damage along the shoreline of Nice, France. This tsunami sea wall was constructed after Nice was struck by a tsunami triggered by a construction-generated shoreline landslide. (Source: author.)

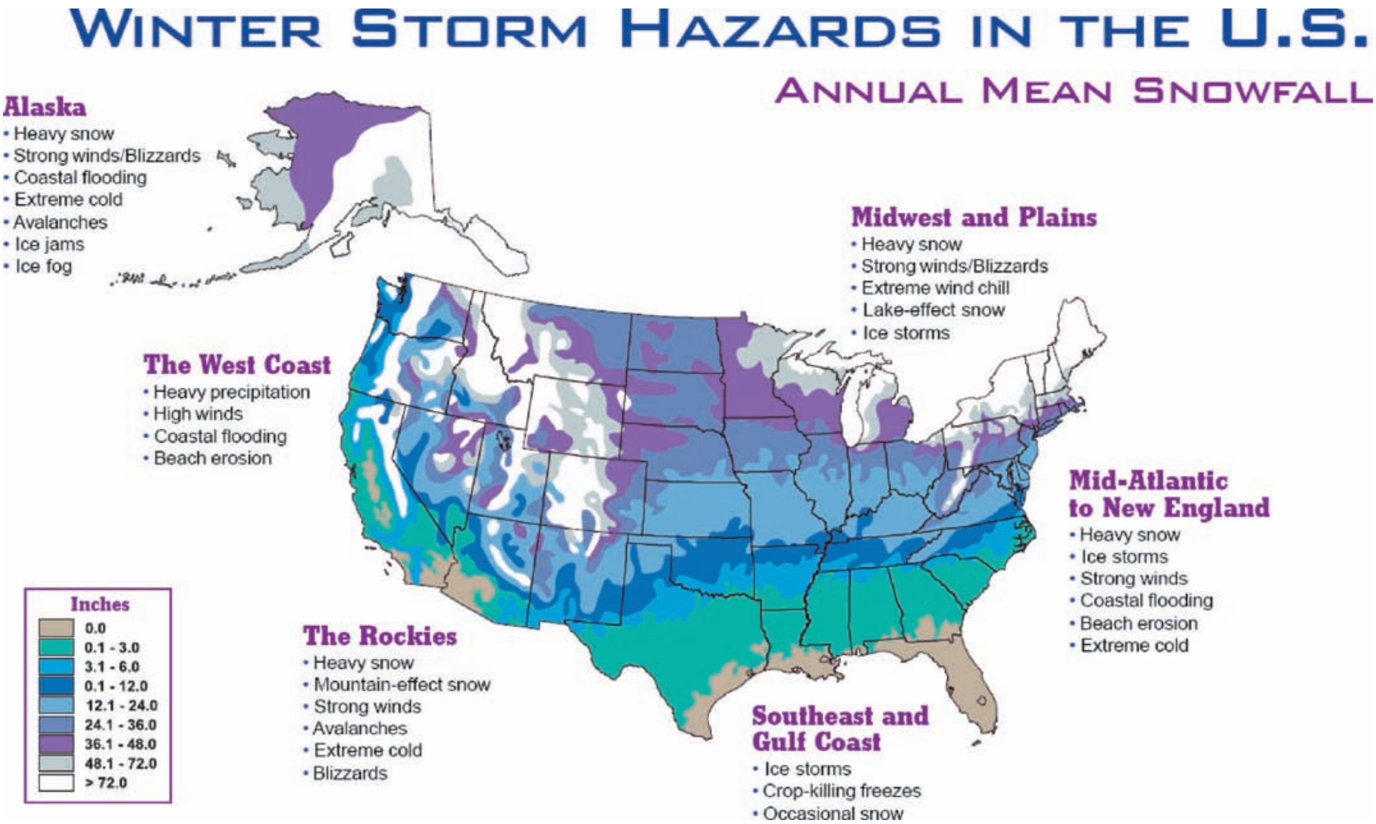


Plate 37.2. Winter storm hazards in the United States. This figure is in the public domain. It was reproduced from the National Weather Service's pamphlet entitled *Winter Storms: The Deceptive Killers.*

Plate 37.3. Typical snowblower injury. The patient placed his hand into the running auger to remove a chunk of ice with resulting open fractures of index and long fingers. The avascular, denervated index finger was amputated at the metocarpalphalyngeal joint. Photograph courtesy of William H Dice, MD.