Disaster Medicine

P. E. Pepe, K. J. Rinnert, and J. G. Wigginton

Introduction: The Nature of the Problem

Throughout history, disasters, primarily in the form of natural catastrophes, have plagued the human race. Today, however, the risk of multiple injuries and deaths from a given incident has increased dramatically [1–4]. Not only is the earth more heavily-populated with human life settled across many more regions of the planet, but there are also larger pockets of human inhabitants. Most of these population centers are concentrated in high-risk locales such as metropolitan cities where very frequent and multiple person-to-person contacts occur. In addition, the world now faces a broadened spectrum of disasters, ranging from unconventional wars, nuclear releases, transportational mishaps, terrorist bombings, infectious disease epidemics and chemical discharges to floods, famine, earthquakes, tornadoes, cyclones and fires [2, 4].

While epidemics, famine, war, earthquakes and the like have always played a role in human experience, the ever-increasing spiral of human populations, the rapid growth of technology, swift world-wide travel for millions of persons, and exponential expansion of at-risk industries and residences conspire to increase human exposure to disasters. Accordingly, the numbers of casualties resulting from each incident are more likely to be large [2]. The recent undersea earthquake in the Indian Ocean that sent towering, 700 kilometer per hour tsunamis across Southern Asia resulted in a tremendous number of deaths and morbidity because of the sheer volume of exposures. Expanding population bases living and working in vulnerable situations along the at-risk seashores provided a baseline set-up for disaster.

Also, although the recent tsunami disaster occurred in Southern Asia, it affected many other countries worldwide because their citizens and their businesses were involved. In this modern era, mass air travel, expanding technology and economic imperatives have all changed the nature of 'localized' disasters. Over the past 50 years, because of the rapid growth of technology and relatively affluent worldwide economies, travel and sightseeing have evolved from an occasional pastime of the very privileged and the odd adventurer into a prevailing norm of worldwide mass tourism. In many parts of the globe, a 1950s seacoast village of 5,000 inhabitants is very likely now a cosmopolitan resort with millions of annual visitors.

Likewise, industries have also become global, often seeking heavily-populated sites where labor may be more economical and local workforces readily avail-

able to work for lower wages. A large number of the victims of the Indian Ocean tsunamis were foreign nationals operating businesses and many, many tourists, including celebrities, were caught up in this Asian calamity as well. Thus, in many ways, disasters throughout the world have now become multi-national in nature, having global impact, an impact amplified by mass media coverage and internet streaming of the events.

Similarly, despite the relatively fewer number of deaths, the September 11, 2001 attack on the World Trade Center in New York could be considered a multi-national event because of the hundreds of persons from dozens of countries working there. It also pointed out the concepts of modern vulnerability. Not only were highly-concentrated populations in one building an easy target to induce multiple casualties, but because of modern technology (i.e., a large modern transportational device laden with explosive fuel), such a dramatic disaster can now take place, intentionally or otherwise.

Perhaps more worrisome, is the threat of worldwide spread of contagious disease, both naturally-occurring and malicious (bioterrorist) promulgation [5, 6]. Again, with more people on the planet who have the potential to become an infected vector and with more global concentrations of highly-mobile populations (and thus more opportunities for exposure), the risk for pandemics has clearly increased. And while overt threats of nuclear holocaust have seemingly dissipated following the fall of the former Soviet Union, the underlying devices of mass destruction still exist, causing great concern for those who must anticipate how to deal with the aftermath [2, 4].

Beyond the initial impact of injury and illness are the subsequent public health sequelae such as insufficient food supplies, contaminated water, lack of shelter, and the subsequent threat of associated diseases. Finally, the psychological impacts of disasters on populations is only just now beginning to be better appreciated, not just for those directly affected, but for the population as a whole [2]. For example, the economic down-turns in the United States, Europe and elsewhere after the events of fall 2001 are often considered one of the casualties of the terrorist attacks. It emphasizes the under-recognized widespread affects that disasters can have on the international public psyche. Even when loss of life and infrastructure are relatively minimal in the grand scheme of the particular nation involved, disasters can have significant and far-reaching psychological impact (e.g., the 2001 U.S. anthrax postal system attacks). The old adage, "all disasters are local", may be somewhat anachronistic in the 21st Century.

From a sociological point of view, it is logical that countries might stand a better chance of mitigating mortality and morbidity with robust health care systems, solid public infrastructures, substantial community resources and early detection-warning systems. This would occur not only through forewarned prevention of injury and illness, but also through rapid access to sustenance, medical and rescue assets. It could be emphasized that much of the loss of life and morbidity from the 2004 Indian Ocean tsunamis and their subsequent sequelae actually resulted from relative limitations in terms of such characteristics. Nevertheless, the events of the fall of 2001 in the United States and the subsequent Toronto experience with severe acute respiratory syndrome (SARS) also exposed the vulnerability of even relatively healthy and well-resourced nations.

From a medical point of view, even though the death and long-term morbidity toll was not as high as the staggering consequences of the Indian Ocean tsunamis, the public health risk management issues associated with the 2001 U.S. anthrax attacks and other identified *potential* threats were still enormous [2, 5, 6]. Facilitated by obsessive mass media mania, the potential threat of other public health crises (involving large populations) as a result of either terrorism or natural disease (e.g., small pox and avian flu pandemic scenarios) became more of a reality in terms of *public perception*. As a result, tremendous political pressure has developed for medical clinicians and public health officers alike to become better prepared to protect the public from all disasters, let alone doomsday scenarios. This response has played out in political venues such as the development of the Department of Homeland Security in the U.S. and improved worldwide intelligence-gathering cooperation both domestically and internationally. Nevertheless, while some improvements in surveillance and pharmacological resource allocations have evolved, the *medical aspects* of homeland security and public health emergency preparedness remain worrisome and under-developed relative to public expectations of the safety net, be they appropriate expectations or not.

More specifically, at the present time, the great majority of healthcare facilities and emergency medical systems (EMS), even in prosperous Western nations, are overwhelmed in terms of emergency care surge capacity, be they government-based or private entities. Many of the key trauma centers and EMS crews are deluged on a day-to-day basis, brimming with fully-occupied beds, sub-optimal nurse and ancillary personnel staffing, despite increasing demands for service and a higher acuity of illness and injury. One could argue that these existing health care services, including ambulances, emergency centers, operating rooms, and intensive care units (ICUs) are facing a disaster each day as available medical resources outstrip the daily demands for urgent and critical care. This tenuous situation causes the looming threat of additional surges from disasters to become an even deeper concern.

Summarizing these points, there is a spiraling risk for catastrophic events involving multiple casualties and population-based medical morbidity, including proximal injury and illness and subsequent psychological and public health concerns. Such events will likely be multi-national in nature, even when localized to a particular venue. Therefore, this will require international cooperation in terms of prevention, mitigation and relief. However, the medical care infrastructure, even in wealthy countries already seems to operate at capacity, making a major multiple injury event or an influenza pandemic a true challenge. One might, therefore, ask what our ICUs would need to be like in the year 2015 and, in this case, our ICUs would not only be those located in the traditional in-patient facilities, but also ambulances, emergency centers and even field hospitals. In the following discussion, the issues, concerns and respective potential solutions will be analyzed and proposed.

Where are we Now: Specific Vulnerabilities in Current Disaster Management

As multi-faceted as the threats of disasters have become, so are the medical sequelae [2, 4, 6]. Explosions carry the triple threat of thermal, penetrating and blunt trauma [2, 4]. Associated building collapses cause crush injury syndromes and fires induce carbon monoxide poisoning and respiratory tract impairment [2, 4]. Earthquakes cause all of the above. Hurricanes, floods and tidal waves result in drowning, snake bites, and contaminated water supplies [2]. Chemical releases can result in pulmonary injury, burns, nerve system dysfunction, liver damage, and cellular dissolution [2, 4]. Severe radiation exposures cause burns, immunological suppression and diffuse epithelial damage, internally and externally. Biological agents result in a myriad of physiological insults. From pneumonia, coagulopathies, and central nervous system compromise to cardiac suppression and liver failure, the viral and bacterial agents provide often-insidious challenges to clinicians and public health officers alike, regardless if the root source is a natural epidemic or a malicious dissemination.

In turn, there is a need for dealing with surge capacity, not only in terms of medical care equipment, but also the personnel that utilize them. Not only are additional ventilators, dialysis machines and antibiotics anticipated, but also additional nurses, technicians, therapists and specialists. While existing medical personnel would best be used, coordinated plans to incorporate them into a disaster plan (providing them with timely respite and staggered shifts) are the challenges. While additional personnel theoretically could be imported from nearby (unaffected) medical facilities or from other regions or countries, the local personnel best work in their own environments and still would need to provide coordinating leadership roles.

This concept is in keeping with the number one rule of multiple casualty incident management, namely to follow day-to-day routines as closely as possible or modify day-to-day routines as much as possible to meet the unique demands of a disaster [7–9]. The logic here is that unfamiliar activities or settings result in logistical and procedural learning curves for clinicians and that such medical care obstacles can be amplified in a strange venue with overwhelming patient care demands. Learning how the laboratory or pharmacy works or how to operate less familiar equipment or communications systems, can delay and impair the true focus of patient care.

Along this same line of thought, proposed plans to develop specialized turnkey facilities that could be made available for use primarily at the time of a public health emergency (such as a pandemic or smallpox attack) would seem to have its limitations. Even when well-designed with all of the proper accoutrements (negative pressure rooms, modified ventilation systems, appropriate security design, and fully-equipped with the most modern ICU equipment), learning curves for the imported staff could be significant. Also, such a free-standing facility would be less useful for acute injuries (because of delays), with the exception of some burns and focal injuries. Unless the facility operates on a day-to-day basis, its user-friendliness becomes less effective. In some nations, some specialty hospi-

tals do exist, but if their utilization is not brisk, deterioration in medical skills competencies may occur.

In contrast, utilization of highly-experienced trauma centers and ICUs would optimize the medical care skills needed and the efficiency of the delivery of care assuming that they could be off-loaded from some of their day-to-day activities. For example, a busy emergency department could off-load sore throats, urinary tract infections, and broken arms to clinics (a place where surge and delays in care would have less concerning consequences). Likewise, through prospective, government-moderated agreements, ICUs at major receiving centers for disaster victims could transfer certain critical care patients to other community hospitals if necessary. This kind of arrangement has been worked out to a significant degree in venues like Miami, USA, a frequent target for major hurricanes in which certain hospitals themselves are at risk for damage.

In fact, this latter scenario is most likely the option that developed communities will choose for several reasons. Contrary to popular perception, *most* disastrous events do not create an immediate influx of critical patients [7–9]. Victims are either killed outright or they have generally survivable injuries. In most traditional situations, experience has shown that less than 10% of patients (those not killed outright) will require critical care or critical care monitoring [7–10].

For example, in the New York World Trade Center attack in September 2001, despite approximately 3,000 deaths, only about 1,400 patients were seen in area hospitals emergency centers by 0200 hours the next morning, more than 16 hours after the event. Less than a hundred were admitted to ICUs or monitoring beds. Most of these patients had chest pain or respiratory distress, presumably resulting from particulate matter and smoke. Despite being the largest terrorist disaster in US history, the local emergency care system was, in retrospect, able to handle all of these cases. Moreover, a large percentage of these patients were the rescuers sent into the incident such as firefighters and police. Previously, in the March 1993 New York City US Airways crash off the runway at La Guardia Airport, most of the passengers were killed outright and only four or five patients were deemed serious (and not necessarily critical). Again, dozens of the rescuers were injured from jet fuel-induced eye burns, sprains, and evolving hypothermia.

In addition to involving a small percentage of critical care cases, most conventional disasters can be handled by existing resources when those resources are not involved or currently overwhelmed [8]. In fact, the medical skills and experience of traditional, busy burn, trauma, and critical care centers offer more optimal care for patients. In many respects, such centers may see many critical patients in a given evening just on a day-to-day basis. As a result, they are already more familiar with some of the pressures and triage decisions imposed by disasters. Also, most conventional disasters, be they a tornado, explosion, chemical release or transportational mishap, are generally localized and acute medical care is needed only in proximity to the event, unless, of course, the local medical resources are themselves disabled or destroyed (such as the Yrevan earthquake in the late 1980s).

These concerns become further confounded by legal issues such as licensure and credentialing of medical professionals at hospitals. A physician coming to

provide aid at another locale or hospital may not be authorized to do so if they are not licensed to practice medicine in that jurisdiction (i.e., country, state, province). Moreover, even if licensed, hospital accreditation, in most venues, requires prospective scrutiny of physicians with relevant background checks and certain administrative requirements. All of these procedures take time and are therefore essentially impossible to provide at the time of a catastrophic event. While some communities have set up mechanisms to cross-credential physicians, only a few have done so and this does not account for the issues of familiarity and skills utilization. Moreover, the key practitioners that might be needed to provide assistance at alternative locations in a disaster are skilled nurses, respiratory therapists, dialysis technicians, pharmacists and the like. While all of these practitioners could also be 'cross-credentialed', it still does not account for motivators to have any of those persons participate. Motivators are not just the dedication of an avid volunteer or the lure of a financial incentive, but they also include care for those practitioners' families in the midst of a disaster during which time the families may be vulnerable as well (no food or water, loss of electricity, trapped by flooding, possible exposure to contagious disease, etc). Furthermore, there are concerns about liability coverage and protection from malpractice lawsuits when providing services outside of one's routine location [5].

All of these concerns strengthen the argument that existing facilities, particularly major trauma centers and critical care hospitals, should all be fortified and better prepared for surge capacity. Not only are there issues of skills, experience, familiarity, learning curves, licensure, credentialing, motivation and liability protection with which to be concerned, but, again, this paradigm follows the basic disaster tenet to follow one's day-to-day routines as closely as possible [7–9]. It relies on the premise that one should prepare for such events by modifying day-to-day activities to accommodate requirements for a multi-casualty event. One of the major reasons why disaster scenarios, be they drills or actual events, often go awry is that they are encumbered by plans or procedures that fall outside normal routines. Therefore, working in environments that facilitate familiar clinical and procedural behaviors in a disaster is the most advisable strategy.

On the other hand, a major nuclear or biological event can pose a more regional-national threat, if not a global risk [4–6]. For example, even if only a fifth of a population becomes infected with a highly contagious disease over a several week period and only 5% of such patients require critical care, this can mean 10,000 critical care patients in a city of 1,000,000 residents. Assuming a week's stay for each patient whether they live or die, it still translates into the need for thousands of ICU beds at any given time. Also, under such circumstances, patients more than likely would not be transferred out to other communities because those other venues also may be experiencing similar, or even worse, surges in patient demands in such scenarios. Similarly, certain catastrophes may involve those 'routine facilities' and transport services themselves. They may be destroyed or inaccessible due to flood, earthquake, terrorist bombing or contamination. This scenario also entreats a plan for working outside one's normal routine or enormous surge at other facilities, either local or at a distance.

Ultimately, another problem with either building separate specialized facilities or modifying current resources for dealing with a major disaster is that it requires major economic resources to re-build or replace existing infrastructures. Obviously, the construction and operation of a free-standing facility in a standby mode for a low probability mega-event with mass casualties (i.e., a once or twice in a generation event somewhere in the world such as Bhopal, Chernobyl, or the Indian Ocean Tsunamis), especially considering the likely vulnerability of that facility in such catastrophes. In like manner, re-building or renovating current medical facilities to make them more secure and more appropriate for dealing with weapons of mass effect, bioterrorism and natural epidemics, would cost some nations billions of dollars. The re-working of water supplies, the renovation of ventilation systems, the creation of universal capabilities for negative pressure rooms, expansion of critical care units and operative capabilities, the installation of decontamination mechanisms, both internal and external, and the acquisition of many additional ventilators, pharmaceuticals, and antidotes (placed in storage) would entail costs that are almost incomprehensible for many governments and the administrators of most medical facilities.

Already strapped with budgetary challenges, such infrastructure changes would be unreasonable without full public support (government assistance) and the commitment that all other facilities would share in similar burdens. In fact, beyond the costs of constructing circumferential barricades (e.g., mitigating the effectiveness of car-bombs) and better controlling and minimizing hospital entrances, are the sociological conflicts. Such security measures defeat the purpose and current philosophy of hospitals, clinics and medical facilities which should strive to provide even easier, patient-friendly access to medical care, particularly for the elderly, sick and chronically-ill who need comfortable entrance.

Such financial concerns are one matter, but without appropriate education and training of healthcare personnel in these matters, all of this expense would be less meaningful. Up until the last few years, there were only pockets of international expertise, mostly military in nature, in terms of dealing with weapons of mass effect. In terms of training healthcare personnel as a whole, there was little interest and 'NBC' (nuclear, biological, chemical) training courses were often referred to as NBC meaning 'nobody cares' courses. Worse yet, the training offered by military might be different from governmental training efforts, even within the same country. In turn, these efforts were also independent of civilian medical care training initiatives as limited as they have been.

For example, in the US, this disconnect was epitomized by just the titular aspects of training. The military used 'CBRNE' (for Chemical, Biological, Radiological, Nuclear and Explosive) and the federal agencies used 'COBRA' (for Chemicals, Ordinance, Biologicals, RAdiation). Also, the focus was not always an 'all-hazards' approach to disaster management and it did not focus on other risks to the civilian populations such as hurricanes and pandemics. Moreover, just as a few examples, it did not always address the needs of all levels of healthcare workers in multiple disciplines (e.g., nursing, pharmacy, physicians, primary care providers, paramedics, veterinarians) nor did it focus on ancillary hospital staff (custodians, engineers, security) who need to know about decontamination procedures. As a result, there was a clear need to provide an all-

hazards, multi-disciplinary, interoperable, standardized training initiative that provided uniformity and consistency in nomenclature, procedures and protocols for major disasters [2].

Such standardized, multi-disciplinary courses have been developed for the management of other major threats to life, namely cardiac arrest and trauma (e.g., the American Heart Association [AMA] Advanced Cardiac Life Support [ACLS] and the American College of Surgeons Advanced Trauma Life Support [ATLS]). They have even been demonstrated to be effective in increasing life-saving. However, unlike cardiac arrest and trauma cases that can present in certain facilities on a daily basis, disaster events are uncommon and infrequent events, even worldwide, making additional training and practice even more critical.

What Challenges Does the Future Hold?

It has been made clear that due to facilitated global travel, exponential growths of underserved populations and burgeoning technological advances, the risk for disasters is also accelerating. Added to those factors is the ever-evolving threat of terrorism, a problem that may even be further exacerbated by several nations' efforts to thwart such threats. Even in the post-Cold War era, the threat of nuclear bomb detonation and radioactive exposure still remains a concern, whether by rogue operatives or governments at war. This past year alone, the state of Florida in the United States experienced four major hurricanes over an expanding at-risk population base and many experts claim that major earthquakes along major fault lines are long overdue throughout the globe. The December 2004 Indian Ocean 9.0 Richter Scale event may have been a heralding event.

More likely, many infectious disease experts would predict that we are due for a clear 'shift' in the genetic make-up of influenza virus. Versus the typical drift that leads us to modify our influenza vaccines each year, most of the population will have little immunological memory and limited protection from any aspect of this new antigenic entity. It is feared that with the typical current processes for producing vaccines, an entirely new influenza virus could sweep through even healthy worldwide populations in a matter of months, long before a vaccine could be developed, processed, and distributed, not to mention the time it takes for inoculated persons, particularly children, to develop adequate protective antibodies.

A similar genetic jump from animal populations (e.g., 'avian flu') could proliferate with the same scenarios. In both cases, with more people to infect, more ways of rapidly transmitting the virus around the globe, and more persons with immunological suppression alive today, the risk for pandemic will become even more of a threat, not only for the population as a whole, but also for the ambulance crews, emergency department staff and ICU practitioners. If they become ill as well, there will be even fewer healthcare providers available to care for the throngs of ill persons, making the disaster scenario even worse.

Recently, there have been other evolving threats such as methicillin resistant S*taphylococcus aureus* (MRSA) found in untraditional sites. It is unknown what other new transmissible processes will occur. For example, the concept of SARS

was unknown three years ago. Also, with tremendous advances in genetic engineering, it is feared that both malicious and unintentional contagion threats will become new realties. In the realm of chemical disasters, everyday there seems to be an ever-widening fleet of chemicals being transported by rail, highway and ships, increasing the likelihood of mishaps.

While threats for disaster are increasing, medical care resources are being spread thinner and thinner, from sociological factors (nursing shortages and increased re-focus on families in affluent societies) to financial constraints (decreasing reimbursements for medical practitioners and facilities or sparser resources from governments for healthcare). Ironically, with increased demands for protection from terrorism and other public health threats, financial resources have been diverted from healthcare to national defense and homeland security efforts. Unfortunately, most security efforts are overhead costs and not at all revenue-generating. Even within hospitals, dealing with disaster management is generally administrative in nature (training, equipment, procedures, personnel) and consumes and diverts medical care professionals' time and efforts from their day-to-day patient care activities.

To summarize these concerns about the future, it is predictable that, over the next ten years, there will be a substantial risk for more disasters, both natural and otherwise, and that these disasters will occur with dwindling healthcare funding and resources and more populations at risk. From the enhanced alerts for terrorism and pandemics to increased potentials for natural disasters in a more vulnerable world, there is a growing need to address solutions to these issues.

What Are the Possible Solutions?

It has become clear that many disasters are, in several respects, multi-national in nature. Also, with modern technology, every disaster can be brought into almost every home worldwide through television or the internet, sociologically affecting humans worldwide, even those not affected by involvement of loved ones or business colleagues. At the same time, most conventional disasters truly are local in terms of the medical response. Be it a chemical release, terrorist bombing, tornado touchdown or jumbo jet crash, it makes sense that existing local services still need to be fortified.

Structural Solutions

In a cyclone, tornado or hurricane belt, reinforced hospitals will have their ICUs secured within the center of the edifice, well above the level of potential storm surges and flood levels and far below the roof-top levels where spin-off tornadoes can rip off the top floors and blow out exterior windows. All hospitals, particularly those in recognized earthquake zones, should have 'earthquake-proof' designs with applicable structural integrity. When a hospital is a potential terrorist target such as any main receiving facility, trauma center, burn center, or chil-

dren's hospital, security measures will dictate the need for barricades to bombs and specialized ventilation systems that detect and can control the spread of aerosolized poisons or biologicals. These hospitals will have a disproportionate number of negative pressure rooms and well-established decontamination zones around the potential entrance and receiving personnel (e.g., trained triage nurses and security personnel will be staged further out into the periphery and prepared with universal precautions and easy access to decontamination suits, including high level personal protective equipment (PPE).

Access to the hospital from more distant entry points may be facilitated by moving walkways or light rail systems (such as those used in many airports) to ease access from parking, drop-off points and mass transportation sites. However, entrances will be limited in terms of the number of access points with detection devices at all sites. Just as our airports are protected, so should our medical care facilities be.

Within the next ten years, spurred on by additional major terrorist events and further recognition of the vulnerability of the medical safety net, governmental resources will begin to make these changes and architects for new facilities will incorporate them into future design. But, economically-intensive, this aspect of preparation will lag being other efforts.

While the first approach to enhancing the structural aspects of disaster management would be to make improvements in existing facilities, this paradigm would be most value to handle the more likely conventional disasters. However, one might then return to entertaining the concept of a specialized facility to manage pandemics and disseminated bioterrorism incidents such as a mutated smallpox organism. In this case, to overcome the concepts of lack of familiarity with equipment and resources, credentialing, liability and medical skills utilization, a mitigating solution would be to dedicate a reserve team of medical personnel in the way a government entity deploys a fire service or army as a dedicated standing force. Currently, a hybrid for this type of concept is accomplished through the mobile medical teams and tent hospitals designed by the National Disaster Medical System (NDMS), an element of the Federal Emergency Management Agency (FEMA) in the United States Department of Homeland Security. Although it does not employ a round-the-clock standing team, it does utilize a 'stand-by' team of medical and allied health volunteers who are trained and routinely exercised to operate mobile hospitals. Currently, these teams would likely be inadequate for a mass casualty scenario with tens of thousands of victims, but still they are somewhat helpful in areas where the standing facilities have been destroyed, impaired or rendered inaccessible.

In the future, such mobile hospitals may have reasonable value in some circumstances, but community-wide plans to enhance existing facilities for surge capacity will supersede all other plans. Inter-hospital agreements to facilitate transfers of patients to balance out surges throughout the system will be in play in the best prepared communities. Such agreements will also include specialized storage facilities for antidotes and antibiotics, perhaps in a separate, undisclosed and protected storage facility, but close enough for easy access. The regional hospitals will purchase these items in bulk to leverage economies of scale (cheaper prices), but they will also coordinate receipt so that expiration dates on the

drugs will be staggered and not all expiring at once. Such coordination would also include the use of healthcare and ancillary personnel in case of over-load at a given hospital or incapacity of another. Not only will prospective cross-credentialing be accomplished ahead of time using familiar mechanisms, but the process may even be facilitated by course completion in Advanced Disaster Life Support (ADLS) and Hospital Disaster Life Support (HDLS) types of courses [1, 2]. In all likelihood, arrangements will first focus intra-murally. For example, they may prioritize the use of nurses from the same hospital system (i.e., many hospital systems operate more than one hospital) because of the similarities in policies, procedures, liability coverage and payroll considerations. Such coordination of efforts would be a massive under-taking, but well-prepared communities will cooperate in such approaches.

Again, many disasters are multi-national and often occurr in under-resourced countries with relatively poor infrastructures. The creation of more than 100 disaster teams by the United Nations worldwide could be considered. Equipped with fast transport air-craft and mobile emergency units, these teams will be available on any site within less than 6 hours and will work closely with local organizations. Very likely, each disaster team will be staffed and operated by a multi-national force, and most likely a standing military team. As in any other military organization, teaching and training in disaster medicine will be part of military education in all countries and the teams will continuously drill and work together in coordination on a routine basis.

Training

Over the past two years, the AMA has begun to help develop a family of standardized, interoperable, multi-disciplinary, all-hazards courses to deal with the medical aspects of disaster medicine and counter-terrorism [1–3]. Working in close conjunction with several academic (university-based) trauma center leaders as well as multiple federal and military agencies and, more recently, other professional societies such as the American College of Emergency Physicians (ACEP) and the Society for Critical Care Medicine (SCCM), the AMA courses are beginning to lay the groundwork for standardized training and improved personnel preparations for disasters [1–3]. Like ACLS and ATLS courses, the ADLS course provides hands-on, multi-disciplinary scenarios in which participants learn to provide antidotes and other resuscitative skills in simulated austere, hazardous conditions requiring the donning and use of high-level PPE in insecure environments [1].

In addition to ADLS, a pre-requisite Basic Disaster Life Support (BDLS) course [2] provides intensive exposure to the didactic elements of disaster preparation from recognizing the main sequelae of explosions (tympanic membrane perforation, hollow viscus disruption, and contusions) to the elements of the Haddon matrix and other psychological aspects of disaster management as well as the main antidotes and therapies required in each scenario, be it chemical, biological, radiological, or traumatic in nature [2, 4].

Within the next ten years, it is predicted that, at the very least, within the United States, BDLS will be required for every medical student, paramedic student, nursing and other applicable allied health personnel [2]. ADLS will be provided to applicable trainees and nursing staff in critical care areas including advanced life support ambulances, emergency departments, and critical care areas. In addition, it is predicted that specialized in-hospital spin-off courses (e.g., HDLS) will address elements of decontamination tactics by custodians, engineers and others as well as the important and unique needs of caring for dozens of patients with highly-communicable diseases and strict need for nosocomial control.

Currently, many of these issues are already addressed in several excellent existing courses such as the SCCM's 'Fundamentals of Disaster Management' and other European counterparts [11]. However, it is predicted that these efforts will coalesce into a standardized set of courses that will be stewarded, in the future, by a team of consensus-building organizations and agencies worldwide. Such endeavors will become similar to the efforts conducted by the International Liaison Committee on Resuscitation (ILCOR) for cardiac resuscitation medicine. Although such training in itself will not fully prepare healthcare professionals for dealing with infrequent events such as disasters, it certainly will improve the chances of mitigation and improved outcomes, not to mention better safety for the healthcare providers themselves.

In addition, paramedics and emergency medical technicians will be trained to deliver prophylaxis in a public emergency preparedness situation such as a smallpox or yersinia outbreak or even a influenza pandemic. Prospective rules about who can be denied or provided vaccination or antibiotics and how one receives protection from liability will be arranged in the most prepared systems.

Equipment

In anticipation of a major event, facilities will develop a cadre of antidotes, antivirals and antibiotics for biological threats. More importantly, they will ratchet up ICU equipment, ventilators and respiratory care equipment as well as PPE and decontamination equipment. Ambulances and emergency departments and hospitals at large will be fortified by new computerized technology that enhances detection and discrimination of abnormal gases, chemicals, aerosolized biologicals and other threats in ventilation systems and ambient air, just as a carbon monoxide detector or Geiger counter would provide sentinel detection of carbon monoxide or radioactivity in one's home.

New ventilators will be impervious to chemical and biological agents and provide protected ventilation in such environments. In addition, artificial hemoglobin-based oxygen carriers that can be stored in ambulances or in far-forward military conditions will be placed in massive storage places as well and ready to use for mass casualties [12]. Some products now in early test stages can be stored without refrigeration for several years and are likely to be standard equipment in all critical care settings, be it pre-hospital, emergency center or ICU settings [12].

Inter-Governmental and International Cooperation

In the end, the new challenges will require a new level of international cooperation particularly because many natural disasters can be superimposed upon on-going complex emergencies, including on-going famines, civil wars or rebel insurgencies [13]. Such circumstances can further complicate rescue and restoration of normalcy [13]. At the same time, in the recent tsunami crisis, the World Health Organization (WHO) predicted the potential for many additional deaths from subsequent water-borne or mosquito-borne disease epidemics. However, it appears that such problems were apparently prevented by a prompt and well-funded response by both local and international communities.

Conclusion

Worldwide, there is a spiraling risk for catastrophic events involving multiple casualties and medical morbidity, not only in terms of acute injury and illness, but also subsequent psychological and public health concerns. Today, such events will likely be multi-national in nature, even when localized to a particular venue. Such events will require international cooperation in terms of prevention, mitigation and relief. Nevertheless, the best approach to preparing for disasters is to expand, modify and enhance current local infrastructures and capabilities for managing the multiple types of disaster scenarios and also to create a number of inter-facility cooperative agreements in advance. Aside from safer internal locations for ICUs and surgical theaters, certain structural changes will need to be installed such as modified ventilation systems, protected water supplies, decontamination mechanisms and security renovations. Another key action will be the proliferation of an international, interoperable, multi-disciplinary, all-hazards training initiative such as that being currently developed by the AMA and the NDLS family of courses. Specialized surveillance equipment that can detect and isolate poisons and infectious biological agents will be placed throughout medical facilities and cadres of antidotes, antibiotics and hemoglobin-based oxygen carriers will be stored in secure locations and made readily available for the applicable disaster scenario.

References

1. American Medical Association (2003) Advanced Disaster Life Support® Version 2.0. American Medical Association Press, Chicago
2. American Medical Association (2002) Basic Disaster Life Support® Version 2.0. American Medical Association Press, Chicago
3. American Medical Association (2004) Core Disaster Life Support® Version 2.0. American Medical Association Press, Chicago
4. Keyes DC, Burstein JL, Schwartz RB, Swienton RE (2004) Medical Response to Terrorism: Preparedness and Clinical Practice. Lippincott, Williams and Wilkins, Philadelphia, USA

5. Pepe PE, Rinnert KJ (2002) Bioterrorism and medical risk management. The International Lawyer 36: 9–20
6. Bartlett JG (2002) Bioterrorism and Public Health. Thomson Medical Economics, Montvale
7. Pepe PE, Stewart RD, Copass MK (1989) Ten golden rules for urban multiple casualty incident management. Prehosp Disaster Med 4:131-134
8. Pepe PE, Anderson E (2001) Multiple casualty incident plans: ten golden rules for prehospital management. Dallas Med Journal November:462–468
9. Pepe PE (1990) Responding to emergencies – review of the Phillips Petroleum explosion. Council of State Governments, March issue. Council of State Governments, Louisville, p 9
10. Pepe PE, Kvetan V (1991) Field management and critical care in mass disaster. Crit Care Clin 7:401-420
11. Farmer JC, Jiminez EJ, Rubinson L, Talmor DS, Markenson DS (2003) Fundamentals of Disaster Management, 2nd Edition. Society for Critical Care Medicine, Des Plaines
12. Manning JE, Katz LM. Brownstein MR, et al (2000) Bovine hemoglobin-based oxygen carrier (HBOC-201) for resuscitation of uncontrolled, exsanguinating liver injury in swine. Shock 13:152–159
13. Spiegel PH (2005) Differences in world responses to natural disasters and complex emergencies. JAMA 293:1915–1918

How Might Critical Care Medicine be Organized and Regulated?