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ANESTHESIA FOR TRAUMA (TE GRISSOM, SECTION EDITOR)

The Multiple Casualty Scenario: Role of the Anesthesiologist

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Abstract

Purpose of Review Mass casualty disasters (natural and man-made) present an acute, critical situation that taxes healthcare resources and clinician acumen. This review summarizes the characteristics and management skill sets that anesthesiologists possess that make them valuable clinicians during mass casualty events and why we as anesthesiologists must continually educate ourselves on this important topic.

Recent Findings Anesthesiologists should be involved in all aspects of emergency preparedness—mitigation, planning, response, and recovery. The anesthesia department should have a plan for how it will deal with managing patients during natural and man-made (unintentional or intentional) disasters, one that takes into account a risk hazard analysis and institutional goals. Unfortunately, most practicing anesthesiologists have not had training and ongoing education for such events, and few academic centers train anesthesiology residents and staff to prepare for mass casualty scenarios.

Summary The everyday clinical practice of anesthesiologists involves the utilization of some of the skills (vascular access, tracheal intubation) commonly required to successfully manage mass casualty scenarios. Anesthesiologists' knowledge of anti-cholinesterases makes them subject matter experts on nerve agent poisoning, and their experience managing trauma patients will serve them well, depending on the nature of the mass casualty event. Practicing anesthesiologists however need to continually educate themselves on their role during mass casualty events. and current anesthesiology residency programs should develop a curriculum and incorporate simulation training to better prepare future generations of anesthesiologists.

Keywords Anesthesiologist in austere environments · Anesthesiologists and mass casualty scenarios · Anesthesiologists and nerve agents · Anesthesiologists and major disasters · Anesthesiologists and resuscitation · Anesthesiologists and emergency preparedness

Introduction

Leaders in anesthesia have advocated for the involvement of anesthesiologists in disaster preparedness for decades [1–5]. Practicing anesthesiologists however may not regard the topic as relevant to their everyday practice for the same reasons that other physicians do not: (1) a mass casualty event will not happen here, (2) anesthesiologists with military experience should be involved, and (3) governmental resources will be available. These views are not realistic firstly because the incidence of natural (Fig. 1) [6] and man-made disasters (Fig. 2) [7, 8•] continue to increase [9, 10, 11••]. Secondly, the kinds of injuries caused by intentional man-made disasters, once seen only during combat, are now being seen in civilian hospitals [12] and require a change in our educational paradigms [13] and for practicing anesthesiologists, a need for preparedness. Thirdly, it may take hours, as many as 24 or more for the government to mobilize and respond. Finally, as we found during the COVID-19 pandemic, which some have seen as a "medical disaster" [14], that should be managed as any other mass casualty event, anesthesiologists, especially anesthesiologists with critical care training, are the most sought after members of the health care team [15, 16]. As members of the communities in which we practice we have

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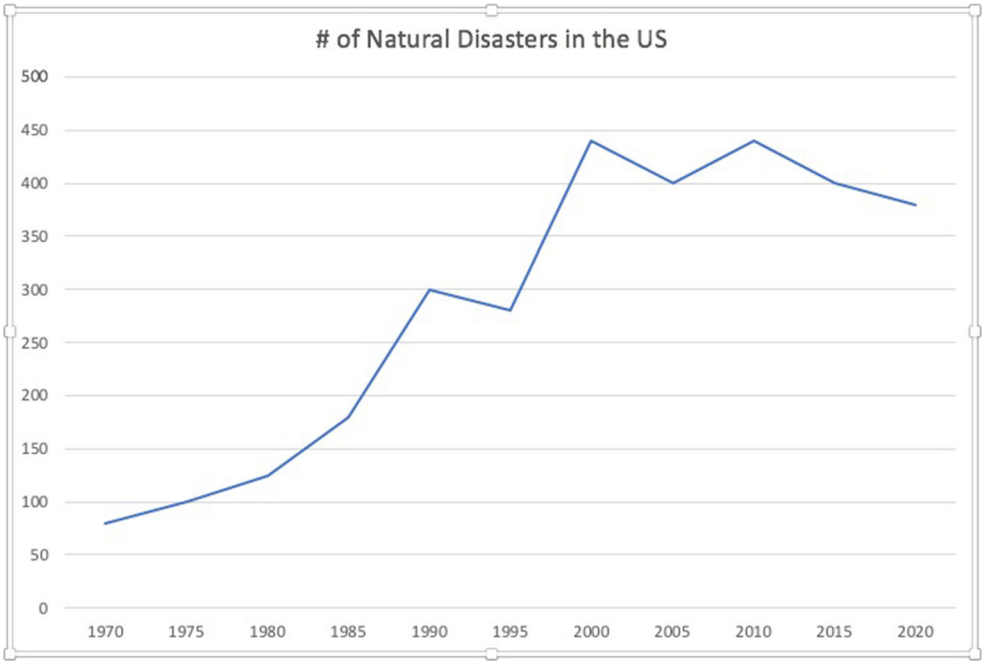

Fig. 1 Annual incidence of natural disasters in the USA over the past five decades

a civic duty to help our neighbors should calamity strike, and the best way to do that is to plan and be prepared.

Definitions

The World Health Organization defines a disaster as "A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources" [17]. A mass casualty *incident* refers to a situation in which a number of "casualties" arrive at a hospital, and though the number of patients may challenge the capabilities of the facility and staff, the hospital has the resources to manage the influx, whereas a mass casualty *event* arises when the number of patients overwhelms the facility's resources, often times necessitating a request to state or federal agencies for assistance. A large urban hospital with a Level 1 Trauma Center is in a much better position to handle 10 trauma patients (*incident*) than a small rural hospital (*event*). However, a large urban hospital may be overwhelmed if the facility loses electricity due to a hydrometeorological event or sustains structural damage from a geological event.

Background

Whether man-made or natural (e.g., Ebola and SARS epidemics and the SARS-CoV-2 pandemic are "natural" but to some extent "man-made" events, in the sense that they are caused by ingestion of meats that are not acquired nor prepared in ways that minimize the transmission of infectious agents), mass casualty situations often result in critically ill patients that require resuscitation. The resuscitation can vary therefore, based on the etiology of the injuries or disease. Specific to geophysical disasters a classification system has been proposed by various organizations to maximize efforts to provide care to those that have higher likelihood of surviving their injuries. A report by the Disaster Reanimatology Study Group that gathered information on earthquake survivors from Armenia (1988), Costa Rica (1991), and Turkey (1992) as well as the autopsy reports after the Great Hanshin-Awaji earthquake in Japan (1995) [10] demonstrated several notable characteristics of the mortality profile of patients.

Most deaths were similar to what is seen in combat, non-survivable injuries to the head, chest, or abdomen. One third of all deaths occurred within hours to days and could be categorized into two groups. One group consisted of minimally injured patients who were unable to receive appropriate care in a timely fashion (e.g., because extrication from collapsed buildings was prolonged), and even though the injuries were relatively minor, the delay in receiving care led to organ injury that then resulted in death within 24–48 h. The second group of patients consisted of severely injured patients that were found in a timely manner but had delay in transport to receive appropriate care. From these findings a 4-class system was created to group patients to help identify those with the highest likelihood of rescue, of which class 3 (patients with intermediate injuries who can be stabilized with simple measures such as fracture stabilization or maintaining airway until further help arises) had the greatest chance of surviving [10]. The

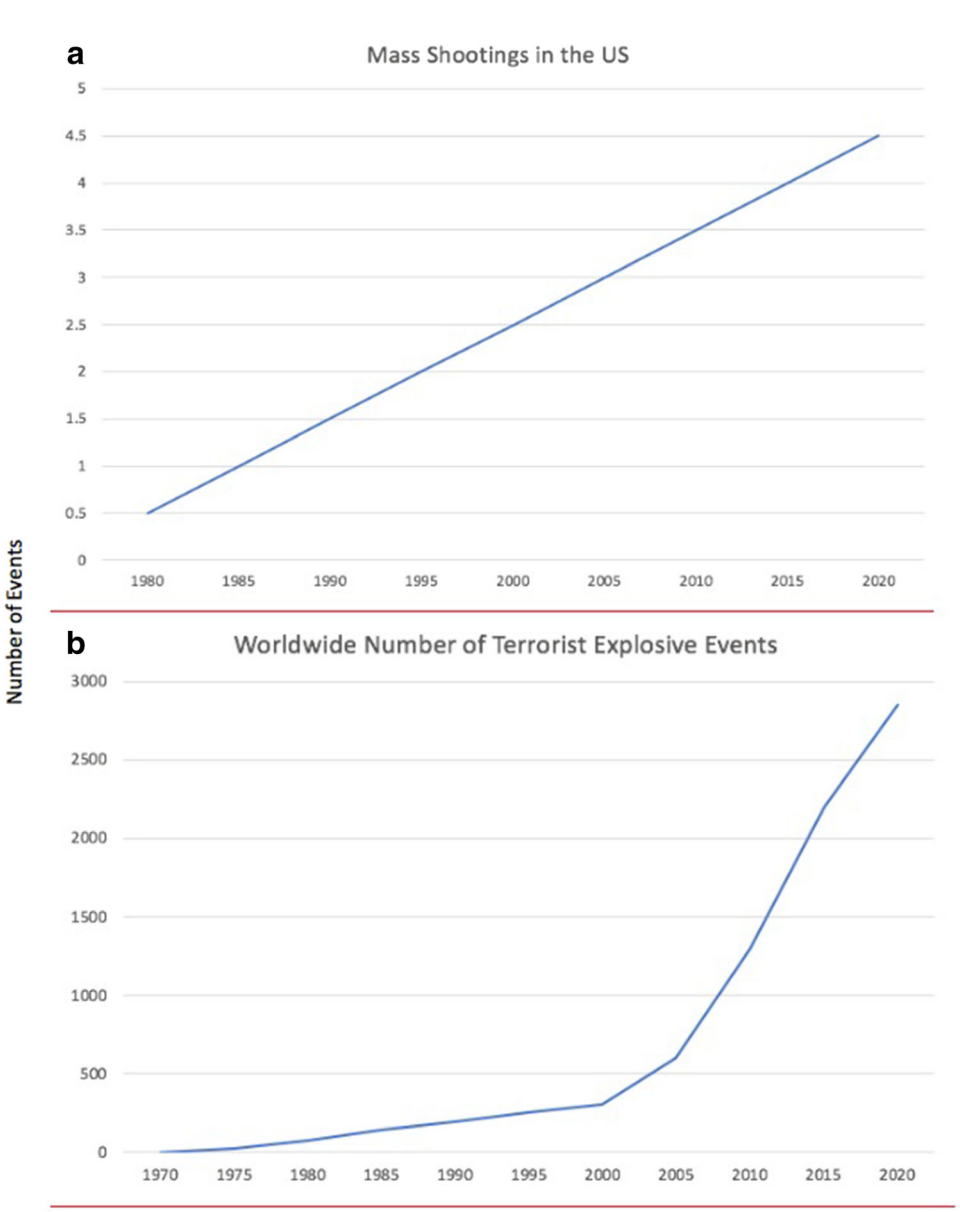

Fig. 2 Incidence of man-made disasters. **a** Annual number of mass shootings in the USA within the past four decades. **b** Annual number of worldwide terrorist explosive events within the past five decades

conclusions of the study were that a better system of triage at the injury site would lead to an overall improvement in survival for the greatest number of casualties. This conclusion has been made multiple times over the last several decades when dealing with mass casualties from geologic events, or from intentional man-made (terrorist) events. As important as these observations are, the reality is that many patients arrive at a hospital emergency department (ED) without any triage either at the site of injury, or at a triage site outside the ED. Independent of whether or not a patient has been triaged or not, whether a patient has been partially resuscitated or not, if an anesthesiologist is assigned to manage a patient, he or she must provide the highest level of care possible under the circumstances in which she or he is practicing.

Disaster Management

Effective disaster management is divided into 4 phases: mitigation, planning, response, and recovery.

Mitigation Anesthesiologists are unlikely to be involved in this phase, which decreases the risk of loss of life and injury by establishing for example, building codes that will mitigate the effects of hurricanes or earthquakes. However, in terms of mitigation an anesthesiologist should avoid purchasing a home in a flood plain or a house that does not meet building code; otherwise, they may not be available if and when disaster strikes. Likewise, they need to be aware that an evacuation during a hurricane or road closures following a terrorist attack

may limit access to transportation or to roads normally used for traveling to the hospital and therefore should have planned in advance how they would travel to the hospital.

Planning Similarly, long before a disaster strikes individuals should have prepared a family emergency plan [18] and a personal response plan. In a severe storm electricity is often lost, therefore, have cash and a car refueled because automatic teller machines and gas pumps require electricity to function. Of even more importance, the hospital's anesthesia department should be prepared. Departmental leaders should have characteristics that help them to effectively respond to the disaster, i.e., knowledge of incident command and of trauma anesthesia, and good communication and problem-solving skills [19]. Unfortunately, as the recent COVID-19 pandemic demonstrated some medical departments did not realize that a command center would be of benefit until the pandemic occurred [20].

Because true mass casualty events are uncommon, it is difficult to adequately prepare, but there are several options though that can be utilized to prepare for a disaster. Regulatory agencies require that hospitals have semi-annual disaster management drills. Departments should request that such drills require the involvement of not only departmental leadership but the department staff as well. If hospital leadership is unwilling to include anesthesiologists in disaster drills, departments can use experience gained in mass casualty *incidents* to help prepare and train for mass casualty *events* [21]. Simulation training can be used in evaluating personal protection equipment (PPE) worn when managing patients with infectious biologic agents or contaminated by chemical or radiologic agents [22]. If simulation is not an option, individuals can train donning and doffing PPE in a controlled environment before ever actually caring for patients, as the Chinese did during the COVID-19 pandemic [23].

As we realized during the COVID-19 pandemic, organizational preparation from local, regional, and national disaster planning is paramount for successful response. However, comprehensive physician input has not always been sought or implemented [24]. Concern regarding adequacy of physician preparedness for mass casualty situations was poignantly noted as early as the 1950s [25]. Later in the 1970s a survey of physicians in Massachusetts revealed that most physicians have not been invited to participate in community disaster preparedness programs even though 48% said they would attend if invited [26].

Since then, the need for training in these events has been identified yet active implementation of such training programs has been slow to be adopted for residency programs. A survey was sent to program directors or chairpersons for 135 accredited US anesthesiology residency programs with response from 90 programs in 2005 showing that only 33 (37%) of the responders had any form of training to care for patients inflicted with weapons of mass destruction [27]. Of this group, 10 of the 33 (30%) had not repeated training within 2 years of the initial training. Furthermore, only 14 of the 33 programs (42%) made the training mandatory [27].

Response The standard "minimal but acceptable care" maximizes the ratio of patients being treated to the resources available [28]. Commonly utilized healthcare resources (e.g., oxygen and blood products) are quickly depleted if not effectively managed [29, 30], a point underscored during the COVID-19 pandemic when many efforts were made to conserve oxygen [31].

During mass casualty disasters many patients do not wait for emergency medical services (EMS) transport and will quickly find and utilize the nearest hospital facility, not necessarily the one most appropriate for their care. Hospitals closest to the site of the disaster may find that staffing is a significant limiting factor to the number of patients for whom they can provide care. Multi-institutional surveys of hospitals throughout the USA have uniformly shown that the majority of hospital employees were willing to report during these disasters. Those who are unable often have conflicting emergency responsibilities such as caring for ill family members, or working with local fire, police, or military forces which concurrently require their attention [32], or they find that roads are closed as occurred following the October 2017 Las Vegas shooting.

Oftentimes, disasters test the capabilities of involved hospitals that typically do not care for certain patient populations regularly. A case example of this was during the July 14, 2016, Bastille Day Attack in Nice, France, when Lenval University Children's Hospital (LUCH) was charged with the care of several adult trauma patients [33]. In total, 47 patients were evaluated at LUCH of which 11 required surgery (including 3 adults). Of the 47 patients that were evaluated, 5 died (one adult, four pediatrics) with a mortality of 10.6%. A review of the planning by the authors after the event identified several key actions for success including hospital-wide resource management including making open beds available, maintaining staff on duty, a means to notify staff at home of the event, preparing the trauma bay with resuscitative tools, and making a second area accessible for non-mass casualty incident emergencies [33].

Ensuring smooth transition to initiate care for mass casualty events requires not only clinical expertise but organizational familiarity. A survey of emergency response personnel for key attributes for effective disaster responders and leaders was published in 2016. The findings of this study showed that aside from medical knowledge and cognitive ability, interpersonal proficiencies including communication skills and decision making as well as calm demeaner ranked in the top 10 of desirable attributes of leaders during mass casualty incidences [34]. Interestingly, this survey was resent later with findings

published in 2019 that showed that while the same attributes were deemed important, greater emphasis was placed on interpersonal skills such as communication and decision making, which were ranked more important than cognition and knowledge for leaders [35•].

Modern-day anesthesiology practice in the USA incorporates a multifaceted care team model where attending anesthesiologists work within a team-based health care environment. Aside from working with other staff anesthesiologists, fellows, residents, and nurse anesthetists, anesthesiologists coordinate patient care with perioperative nurses, technicians, perfusionists, and physicians from other services. Their clinical skillset makes them uniquely qualified to assist during mass casualty disasters.

Outside of the USA anesthesiologists have roles that expand outside of the hospital environment. During the Egyptian Revolution in 2011, anesthesiologists were used in trauma resuscitation rooms to resuscitate patients as well as triage them to the intensive care unit or medical-surgical ward prior to surgery [30]. The 2013 Rana Plaza tragedy in Bangladesh highlighted the extensive role anesthesiologists had in managing casualties [28]. During the various mass casualty situations in Israel, anesthesiologists likewise play a significant role outside the OR [36].

In Europe, notably France, anesthesiologists have a large role in prehospital care; they participate in the Service d'Aide Medicale Urgente (SAMU). The French casualty management plan is two tiered with red and white plans. The red plan is focused on managing the cause of the mass casualty while extricating and rescuing patients. Once triaged, the white plan is instituted during which evacuation from the site and resuscitation begin [37, 38]. Aside from resuscitation, anesthesiologists provide regional anesthesia services to patients with orthopedic injuries en route to the hospital. Should a patient decompensate, transport is stopped and the anesthesiologist manages the resuscitative efforts.

The difference between the US and international philosophies for prehospital care may be due to the etiology of the traumatic event. In the USA, there are greater numbers of patients with penetrating trauma in which fluid resuscitation and medical management has a limited role as surgical intervention is the definitive treatment. In Europe, however, the majority of patients have blunt trauma in which there is more of a role perhaps for fluid resuscitation prior to transport. As a result, US disaster medicine focuses on urgent transportation to trauma centers for evaluation and definitive treatment [38].

Phases of Care

Three general phases of care exist in management of mass casualty patients including prehospital care, triage, and in-hospital care [10, 37]. Prehospital care includes the efforts of extrication, basic and advanced life support, and stabilization care prior to arrival to the hospital. Triage includes the risk stratification and placement of patients into appropriate care teams, while in-hospital care encompasses the execution of the care plan whether it be operative or medically based. In the USA, as mentioned previously, anesthesiologists focus on the perioperative care of patients in hospitals. The types of disasters for which their skill sets might play an important are many.

Natural Disasters

Compared to the rest of the world, we in the USA are relatively fortunate, but not completely so, in that the effects of the weather (hurricanes, tornadoes, drought—increasing the number of forest fires) have not been as severe as seen elsewhere in the world where over one half people are affected annually [39]. However, if you experienced first-hand hurricane Sandy, or the Northfield earthquake of 1994, or developed acute respiratory failure from COVID-19, then you know well that Mother Nature can throw quite a punch, one that the entire planet strives to avoid.

Meteorologic (Storms), Hydrologic (Floods), and Climatologic (Extreme Temperatures) In September 2017 Hurricane Irma, at the time the most powerful Atlantic storm ever, hit the Caribbean and the South-east USA, causing $77.2 billion in damages and resulting in 134 deaths, 92 in the USA. Flooding disabled many hospitals. Those hospitals still functioning had to provide care for "routine" cases such as caesarian sections and appendectomies, those transferred from other hospitals, and those injured by the primary and secondary effects of the storm. For staff at those hospitals, the basics mentioned above were critical, i.e., family and personal plans, ability to function without electricity, means of communications, and maintenance of physical and mental health [40].

Geologic Earthquakes fortunately are not as common as weather-related disasters, but morbidity and mortality can be significantly higher. Because many hospitals are destroyed or non-functional, transportation of casualties out of the earthquake zone to healthcare facilities elsewhere is a major challenge, especially if no triage has been performed. Under these circumstances, triage is critical; many can receive first aid or delayed treatment allowing for attention to be directed towards the most critically injured. The "urgent" patients are those with crush injuries or amputations requiring immediate care. The earthquake that struck Haiti in 2010 killed 316,000 and injured another 300,000 [41]. Because the island was so devastated, anesthesiologists in the USA responded to this humanitarian

crisis, providing critically important services in a delayed fashion [42].

Biologic Viruses such as Ebola [43] and SARS-CoV-19 [16] are highly contagious and, as we have seen with the COVID-19 pandemic, can create much more havoc as would the use of anthrax by terrorists. Because of their airway management skills anesthesiologists will be at the forefront of providing care for many of these patients [44•, 45–50], and for those anesthesiologists with critical care training they will likely be involved in the management of patients who are candidates for ECMO [51].

Man-Made Disasters (Intentional)

Terrorism

Chemical An area where anesthesiologists offer unique insight due to familiarity with cholinergic and anticholinergic pharmacology is the mass casualty disaster involving chemical agents. Within the chemical classification, subclassifications exist to include mustard gas and nerve agents of which two forms exist, G series volatile (tabun, sarin, soman, GF) and non-volatile agents (VX) [52–54]. Volatile agents have a boiling point higher than water, resulting in sufficient vaporization at room temperature with quick absorption and onset of agent. Non-volatile agents have a lower vapor pressure with slow onset but also slow offset due to their lipophilicity and binding nature making removal from skin and clothing difficult [52]. Regardless of chemical agent, the first line of treatment is adequate decontamination.

Mustard gas is a lipophilic agent that targets cells with high rates of mitosis (i.e., respiratory tract, gastrointestinal tract) resulting in tissue injury. Care for these patients is largely supportive as many will require airway management because of the extent of respiratory tract injury. Antibiotic treatment may be necessary at some point due to the injury sustained by the respiratory mucosa placing patients at risk of developing respiratory infections.

Nerve agents are organophosphate compounds that reversibly or irreversibly inhibit the acetylcholine esterase enzyme resulting in parasympathetic (acetylcholine) surge. Patients develop clinical symptoms including altered mental status, muscle weakness, hypersecretion, dyspnea, and miosis [55]. The familiarity that anesthesiologists have with neostigmine in daily practice, similar to radiologists who are subject matter experts for radiological injury [56], will make them subject matter experts for treating organophosphate poisoning. Furthermore, if respiratory failure is present, definitive airway management will be needed, an area in which anesthesiologists have the most expertise.

Biological In recent years the threat posed by biological agents has increased [57]. These agents include organisms that can be spread by atmospheric dispersal, food contamination, or conventional warfare agents containing biologics [54]. Commonly associated pathogens include anthrax, botulism, plague, smallpox, tularemia, and viral hemorrhagic fever. Treatment for patients afflicted with these conditions are often supportive care including intubation and mechanical ventilation on a scale that would eclipse the COVID pandemic in the locale where it was used. While this scenario might seem farfetched, not that long ago members of the Aum Shinrikyo cult traveled to Zaire with the expressed purpose of bringing back samples of the Ebola virus with the goal of using it as a biologic weapon [58].

Major (Group A) biologic agents used as weapons of mass destruction are as follows:

- Bacillis anthracis (anthrax)
- Variola major (smallpox)
- Yersina pestis (plague)
- Clostridium botulinum (botulism)
- Francisella tularenis (tularemia)
- Viral hemorrhagic fever (Ebola, Lassa, Marburg, Argentine)

Anthrax and smallpox are the two infectious agents most likely to be used as weapons of mass destruction as small inoculums of either agent are incredibility potent—they are highly infective, very contagious, and in unprotected individuals, are associated with 50% fatality rates. If small pox is used as a weapon of mass destruction, the US and state governments have prepared to vaccinate the entire population within 48 h to prevent the spread of the disease.

Of potentially greater concern is the aerosolized delivery of anthrax spores to large populations. The most recent data indicate that vaccination and treatment with antibiotics are the best way to provide prophylaxis against anthrax. Unfortunately, vaccination of the entire population is difficult, and we would need to rely on the use of antibiotics to control a disease that is highly infectious with a high mortality rate.

Public health care teams in the USA are recommended to be vaccinated against small pox, and US military policy is that all personnel in combat zones must be immunized against anthrax—6 immunizations over 18 months and annually thereafter. Ciprofloxacin is an excellent for prophylaxis, but the best prophylaxis is a combination of immunization and ciprofloxacin.

Radiologic/Nuclear When it comes to radiation injury events, incidents at nuclear power plants over the last 30 years have created the most damage, destruction, and long term health problems. Public health officials, however, are concerned that terrorists might use a "dirty" bomb, one with radioactive

material wrapped around an improvised explosive device. The sequelae from the release of radiation in a major population center such as NYC [59] would be hugely disruptive in terms of (1) the panic, (2) the amount of radioactive waste produced, (3) lost productivity and health screening of the population, and (4) resettling many displaced from their homes.

The major challenge to the healthcare system would be screening the entire "exposed" population of individuals who will demand to be examined. Most individuals will have no exposure, and the majority who are exposed will often be externally radiated only and, depending on the amount of radiation, may require no treatment. As mentioned previously, individuals who have no symptoms within 6 h are unlikely to require hospitalization. Symptomatic individuals should be hospitalized with serial white blood cell (WBC) counts measured. If the WBC remains stable for 48 h, the patient may be discharged. The US and state governments plan to distribute potassium iodide tablets to protect the thyroid of all individuals potentially exposed within 24 h—assuming those who are supposed to distribute the tablets will do so. Individuals who have symptoms within minutes or hours of exposure will require hospitalization and treatment of the most common sequelae of radiation sickness including bone marrow failure (infection and coagulopathy), and gastrointestinal bleeding secondary to mucosal damage and the thrombocytopenia from the bone marrow failure. Antibiotics, volume resuscitation with blood products, and treatment with granulocyte colony stimulating factor may be lifesaving.

Explosive Worldwide use of improvised explosive devices is the terrorist's favorite weapon. Patients have burns, fractures, lacerations, multiple shrapnel injuries, soft tissue trauma, and traumatic amputations. As the weapons have become more sophisticated and powerful, the extent of injuries has increased significantly.

Patients with any evidence of burns to the face or airway will require appropriate airway management. Patients should be intubated, awake if possible, as a significant number of these patients will have mild to moderate glottic edema at the time of intubation. Those patients with burns must be managed aggressively with respect to fluid resuscitation. With isolated total body surface injury, fluid resuscitation is aggressive. With polytrauma and no third-degree burns, "damage control resuscitation/surgery" is the norm [60]. For patients with extensive third-degree burns body temperature is maintained (operating rooms maintained at > 100 degrees Fahrenheit) and surgery is performed as soon as possible to stop the bleeding decreasing the need for blood products and the chances of developing a dilutional coagulopathy. Patients who do develop a coagulopathy may benefit from a ratio of pRBCs to fresh frozen plasma to platelets of 1:1:1 as a part of their volume resuscitation related to hemorrhagic shock [61]. The CRASH-2 study demonstrated that tranexamic acid decreases the need for additional blood products [62].

Conclusions

Modern-day disaster planning has grown to include input from physicians in emergency medicine and trauma surgery. However, anesthesiologists have not been consistently included or utilized in these scenarios and do not know the hospital contingency plans during mass casualty events [37]. Many of the daily clinical responsibilities of anesthesiologists make them well suited to manage patients during mass casualty incidents. As intraoperative intensivists who deal with difficulty airway management, resuscitation, perioperative medicine, operative resource management, and pharmacologic implementation (notable for relevant use of cholinergic and anticholinergic medications), anesthesiologists can offer a great deal during mass casualty incidents regardless of their cause. This model is already in existence in many European countries highlighting the ease and utility of similar practices in the USA. The first step towards this paradigm change requires not only increased involvement of anesthesiologists in disaster planning but also early exposure of residents through relevant training simulations.

Compliance with Ethical Standards

Conflict of Interest Christopher M. Lam and Michael J. Murray declare they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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