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ADVANCES IN ANESTHESIA

Emergency Preparedness and Mass Casualty Considerations for Anesthesiologists

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Keywords

• Anesthesiologists • Mass casualty events • Emergency preparedness

Key points

- The incidence of mass casualty events is increasing.
- The role of anesthesiologists is crucial in the perioperative management of mass casualty victims.
- Preparing for mass casualty events is important and hospitals should provide emergency drills and resources for staff.

INTRODUCTION

Both natural and human-induced disasters result in mass casualty events (MCEs). Recently, there have been numerous natural (eg, hurricanes, earthquakes, flooding) and human-induced disasters (eg, gun violence, bombing, motor vehicle accidents) requiring the activation of hospital emergency response systems. Furthermore, the rising fear of terrorism and potential biochemical, nuclear, and radiological threats should encourage hospital systems and personnel to prepare for such events. Disasters are defined as incidents that require greater help than provided by typical resources of a

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specific geographic area or local services and often rely on outside resources. MCEs occur when the number of victims surpasses the treatment capabilities and resources offered by medical centers [1]. Both require the coordination of various phases of care, recruitment and organization of numerous personnel, and potentially outside resources. The goal is to minimize the burden placed on health care systems and workers due to catastrophic events that overwhelm health care facilities in settings of seemingly exhausted resources, scarce providers, and limited equipment. Degradation of infrastructure and the surge of disaster victims also will have a direct impact on the provision of ongoing services to routine medical and surgical patients. Regardless, these events require the action of hospital providers, including anesthesiologists, to provide care to these patients in various environments, ranging from the field and emergency department (ED), to the operating room (OR) and the intensive care unit (ICU). We describe the various types of MCEs, and discuss disaster preparation and response, the role of the anesthesiologist, and how to prepare for disasters and MCEs.

EPIDEMIOLOGY

The number of disastrous events, including man-made, has increased over the past few decades. This increase may be due to technologic advances, increased transportation vehicle use, and innovations in chemical and weapon design [1]. Database development and improved communications facilitate disaster reporting, which may account for the observed increase in disasters.

The Emergency Events Database (EM-DAT) collected data on the incidence and impact of natural and technological disasters occurring since 1900 [2]. In 2000, EM-DAT began geo-referencing the main types of natural disasters (eg, storms, earthquakes, floods, wildfires, droughts). From 2000 to 2015, more than 5900 disasters occurred worldwide, affecting 3.2 billion people, resulting in the death of 1.2 million people and financial cost of $2.06 trillion US dollars (USD) [2].

In 2016 alone, there were 301 disasters affecting 102 countries, and 411 million people, resulting in 7628 deaths and $97 billion USD in damages. Flooding and storms accounted for 71% of all natural disaster–related deaths, followed by earthquakes (17%) [3]. The United States has been among the top 5 countries affected by natural disasters over the past 10 years [3]. Additionally, countries are afflicted by man-made disasters (ie, terrorism, social unrest, fires, and maritime/aviation, rail disasters); 136 man-made disasters occurred in 2016, resulting in $8 billion USD in damages [4].

TYPES OF MASS CASUALTY EVENTS

MCEs can be due to natural or man-made disasters. Natural disasters include earthquakes, floods, hurricanes, tornados, droughts, and infectious disease pandemics. Man-made disasters include fires, biochemical weapons, nuclear weapons, radiation exposure, mass shootings, bombings, and vehicular accidents. To prepare for a successful event response, potential hazards (ie, hurricanes) must be identified and the signs of exposure to a dangerous substance (eg, chemical, biological, nuclear) must be recognized. Although environmental clues, such as broken containers labeled as "hazardous material," fires, and smoke, may give responders an idea of what they are dealing with, there are also numerous causes of mass casualties that have a delayed presentation (ie, radiation and certain biochemical exposure) or lack overt toxidromes, making diagnosis and coordination of care difficult [5]. We briefly discuss several types of disasters resulting in MCEs.

Nuclear

Nuclear power plant accidents, acts of terrorism using a dispersion device (eg, bomb enveloped by radionuclides like strontium or cesium), or nuclear bomb detonation may result in exposure to ionizing radiation. Radiation injury may result from direct exposure to external sources (eg, devices that emit alpha and beta particles, gamma rays, x-rays), radiation-contaminated debris, or ingesting/inhaling radioactive matter. The type of radioactive material, and the nature, length, and amount of exposure will result in variable effects on humans. For example, alpha particles cannot pass through human tissue, but can infiltrate pulmonary epithelium if inhaled. Lead shields can prevent the penetration of x-ray and gamma particles, whereas aluminum shields provide a barrier against beta particles. Nuclear explosions may result in thermal, crush, or blast injuries, which may occur concurrently. The emitted radiation from the blast may result in short-term and long-term sequelae. Radiation has the greatest impact on tissues with the highest regeneration rate (ie, gastrointestinal, lymphoid, bone marrow, and dermal tissue). Predictable injuries include radiation dermal and oropharyngeal burns, and acute radiation syndrome, which is manifested by bone marrow suppression, gastrointestinal destruction and bleeding, and septic shock. Psychological injury and cancer are long-term effects of radiation exposure. Victims of radiation exposure should be decontaminated at the site, removing all clothing and washing the skin with warm soapy water. Although treatment is supportive, certain medications may be given to reduce absorption or enhance renal excretion of radionuclides. Potassium iodide must be given within 24 hours of radiation exposure to effectively prevent radiation-induced thyroid adverse effects or cancer triggered by iodine-131 (I^{131}) release from a reactor accident [6].

Chemical/biological

Historically, chemical weapons were designed and used in warfare. Although there are 192 nations that have consented to be bound by the Chemical Weapons Convention (a treaty banning the manufacturing, storage, and use of chemical weapons, resulting in the eradication of more than 90% of chemical weapons in existence worldwide), there are still several countries that have not acceded to the treaty [7]. Furthermore, terrorist groups have used chemical weapons in attacks on civilians. Although it seems unlikely that US hospitals will see the effects of chemical weapons, there is no question that these agents may be used in terrorist attacks and clinicians should be familiar with the agents, their presentation, and treatment. Some examples of chemical agents include nerve agents like tabun (GA), sarin (GB), soman (GD), V agents, Novichok agents (which work through inhibiting acetylcholinesterase), blood agents such as cyanogen chloride and hydrogen cyanide (which inhibit oxidative electron transfer in the mitochondria, thus, inhibiting cellular respiration), pulmonary agents such as phosgene and chlorine (which cause asphyxiation by displacing oxygen) [6], and vesicants such as lewisite and sulfur mustard (HD) [1]. Although atropine, oximes (ie, 2-PAM), and benzodiazepines are the classic treatment for nerve agents, Moshiri and colleagues [8] reviewed several promising strategies including the use of magnesium sulfate, alkalinizing the urine with $NaHCO_3$, ketamine, benactyzine, galantamine, and phosphotriesterase.

Existing infectious agents, such as viruses and bacteria, have also been weaponized for use in warfare and bioterrorism. Biological weapons can be classified into 1 of 3 categories (Table 1) based on their potential to cause extensive harm. Category A agents pose the greatest threat to the population. Most agents have specific and recognizable presentations and/or toxidromes, and some have antidotes or treatments to combat their toxic effects [6]. Anesthesiologists should be able to recognize signs of biochemical toxicity and be familiar with its treatment.

Infectious diseases and pandemics

Pandemics are infectious diseases that have affected large populations either across a continent, or worldwide, and can have either gradual or abrupt onset.

Table 1
Categories of biological warfare agents

Characteristics	Category A	Category B	Category C
Definition	Highly contagious agents, cheap, easy to manufacture, little to no natural immunity, and easily spread. Associated with high morbidity and mortality rates.	Easy-to-spread agents; low mortality rates.	Incipient pathogens that may be engineered for mass dissemination in the future due to accessibility, easy spread, and possibility of high mortality rates.
Examples	• Viral hemorrhagic fevers (ie, Ebola, Lassa) • *Bacillus anthracis* (anthrax) • *Yersinia pestis* (plague) • Variola major (smallpox) • *Clostridium botulinum* (botulism)	• *Salmonella* species • *Escherichia coli* 0147:H7 • *Vibrio cholerae* (cholera) • *Coxiella burnetii* (Q fever) • *Rickettsia prowazekii* (typhus fever)	• Hantavirus • Nipah virus

Adapted from Kuza CM, McIsaac J. Human-induced and natural disasters. [Chapter 43]. In: Pardo M, Miller RD, editors. Basics of anesthesia. 7th edition. Philadelphia: Elsevier, Inc; 2018. p. 762; with permission.

They place a substantial burden on health care resources and costs and cause significant morbidity and mortality [9].

Anesthesiologists should be familiar with contagious diseases such as influenza, severe acute respiratory syndrome (SARS), West Nile virus, Zika, Ebola, and other or new emerging viruses. Health care providers must have an intense level of suspicion of these infections, wear proper protective equipment (PPE), use appropriate contact and isolation precautions, receive and advocate for available vaccines, and notify the appropriate public health organizations to assist in diagnosis, treatment, and prevention of the spread of infection [1]. Aerosol-generating procedures, such as intubation, bronchoscopy, and tracheal suction, require a higher level of PPE than routine patient care. The Centers for Disease Control and Prevention (CDC) and other experts develop vaccines and treatments, and provide educational materials and resources on disease transmission, preventative strategies, and how to prepare for infectious disease disasters [9].

Cyber-attacks and high-altitude electromagnetic pulse events

With the increasing dependence on computers and technology in our society, we are extremely vulnerable to cyber-attacks. Cyber-attacks can be released from anywhere in the world and cause extensive damage within a short timeframe. They may disrupt power grid control systems, which can affect governmental and local agencies and jeopardize vital national infrastructures. This may compromise economic and national security, disrupt the ability to obtain information, impair communication technology, and may indirectly result in death [10]. Furthermore, if a cyber-attack were to occur during a disaster or MCE, it could interfere with acquiring critical information and hinder communications between disaster responders, such as local and governmental agencies, hospitals, health care providers, and police officers. This could significantly impede the rescue and response efforts and result in serious adverse consequences and damages. Hospital computer networks also may be compromised, which may interfere with services provided and risk the appropriation of personal patient health information by cyberterrorists [11]. Strong security protocols, regular computer network security checks, using password-protected log-ins, auditing system usage, enforcing encryption guidelines, backing up and protecting hardware, and securely storing backups may help protect against cyber-attacks [11].

A high-altitude electromagnetic pulse (HEMP) results from the detonation of a nuclear weapon above the earth, creating an electromagnetic energy field that perturbs the earth's magnetic field due to the interaction of emitted gamma-radiation and the atmosphere. Although harmless to people, it causes widespread power surges and disruption of equipment connected to power grids, telecommunication infrastructures, and communication systems. The current and voltage surges can destroy electric circuitry and damage electronic devices and computers; this includes hospital equipment (eg, life-support systems, computed tomography scans, diagnostic equipment) and computer systems, which are some of the most vulnerable systems. Equipment may be compromised even if it is not directly connected to a conductor [12]. The effects are less severe over greater distances, and electronic equipment that is powered off at the time of the incident is less likely to be affected. The effects can be severe enough to cause a blackout lasting months to years and destroy electrical grid infrastructures that may take years to replace [12]. Using EMP-resistant circuits, solar-powered equipment, batteries, unplugging and turning off unused electronic equipment, shielding vulnerable devices (eg, hospital monitors, pulse oximeters), and having an available back-up power system may help mitigate the effects of HEMP incidents. A cache of equipment can be maintained wrapped in nonconductive bubble-wrap that is then sealed in layers of aluminum foil. This will block both the electric and magnetic components of an HEMP impulse.

Mass shootings and bombings

There has been an international increase of terrorist activities [13]. Mass shootings and explosions are common terrorist acts that result in MCEs. Such events mainly occur in areas of combat, but they also occur in noncombatant regions (eg, Oklahoma City bombing in 1995, 2005 London metro bombings, 2017 Las Vegas shooting), affecting civilians [13,14]. Medical professionals have a responsibility to prepare for and respond to these events that result in numerous victims suffering from extremely severe and complex injuries [13,15]. Gunshots and explosions result in different injury profiles and hospital resource allocation [15]. Although explosion victims often present to hospitals at the same time in groups, gunshot victims are more likely to arrive as individuals. The treatment, resources, and hospital organizational response differ between the 2 injury patterns. A sudden and simultaneous presentation of multiple victims to a hospital puts a strain on resources that may result in the hindrance of patient treatment [15]. Some bombs may be constructed with nails, metal, and other sharp objects. This results in victims suffering from most or all of the following injuries: perforated eardrums and hearing loss; and penetration, blunt, burn, and crush injuries [13,15]. Thus, surgeons must prioritize which injuries to address first and how to manage complex cases, such as the presence of 2 concurrent injuries with conflicting treatment strategies (eg, blast lung with extensive burn injuries complicating fluid management for hemorrhagic shock) [13,15]. Explosive injuries are more likely to affect different regions of the body, whereas gunshot wounds may be more localized. Additionally, gunshot wounds are associated with higher early mortality rates compared with bomb victims. Explosion victims typically have longer hospital courses and require ICU care more than gunshot wound victims [15]. In both these injury types, large numbers of victims often require immediate surgical intervention, massive transfusion protocols, mechanical ventilation support, ICU-level care, and prolonged hospitalization. This strains hospital resources, such as blood bank supplies, equipment (eg, ventilators), beds, ORs, and staff [16]. It is important to have hospital management guidelines in place for such events to triage patients, allocate resources, and provide adequate staffing.

DISASTER PREPARATION AND RESPONSE

Phases of a disaster

The goals of disaster management are to reduce or prevent the potential losses from hazards, provide prompt and appropriate assistance to victims, and achieve rapid, effective recovery. Disaster responsiveness requires the coordination and collaboration of responders, civilians, and government agencies to plan for and reduce the impact of disasters. Disaster management also incorporates developing public policies and plans that prevent or minimize the harmful effects of disasters on people, structures, and communities. There are 4 phases of a disaster that have been defined to help plan, organize, and execute response activities (Table 2). The phases can sometimes overlap and do not necessarily proceed in order [1,17].

Disaster preparedness and mitigation

Personal and family preparedness. In preparation for disasters, a personal and family emergency plan should be created. There must be a plan in place to assist pets, children, and disabled or elderly persons. Plans should be tailored to specific events (eg, fire, earthquake), establish meeting places or alternate methods of communication in the event a cell phone tower is damaged, and prepare evacuation routes. Emergency drills should be occasionally performed to prepare for unanticipated emergencies. There are numerous online Web sites of organizations, such as the Federal Emergency Management Agency (FEMA), which have family plans, materials geared toward kids, communication resources, and updated information on what to do in certain disasters [6]. The

Table 2
Four phases of a disaster

Phase	Action	Example
Mitigation	Predisaster; preventing or attenuating the effects of the disaster	Having hurricane or flood insurance
Preparedness	Planning appropriate disaster response; notifying appropriate response personnel; establishing the resources required	Emergency kits, planning evacuation routes, having a disaster response system in place
Response	Carrying out disaster response plans. Attempt to mitigate hazardous situations created by disasters	Search and rescue, provide medical care, obtain necessary resources (eg, food, water)
Recovery	Returning the community to normal, reconstruction, and collecting data to learn from experience	Rebuilding communities, temporary housing, postdisaster medical care

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American Society of Anesthesiologists Committee on Trauma and Emergency Preparedness (ASA COTEP) has also provided a document on necessary supplies, first aid and disaster kits, clothing, utilities, and items needed to pack in the event of an emergency or evacuation (Table 3) [18].

Hospital preparedness. MCEs result in an overwhelming burden on hospital resources and staff due to the abundance of victims. Additionally, hospital infrastructure may be in peril in natural disasters, such as a flood or hurricane, and health care workers and responders are at risk of contamination and exposure to toxic substances when dealing with biochemical or nuclear events. Hospitals

Table 3
Family emergency preparedness checklist by American Society of Anesthesiologists Committee on Trauma and Emergency Preparedness

Shelter	Evacuate
Supplies (at least 3 d) • Medications • Food and water (1 gallon per person/per day) • Pet care • Batteries First aid and disaster kit Communications (battery-powered radio) Security plan Sanitation/hygiene plan Cash Utilities • Ability to safely shut off • Establish alternative power and lighting	Supplies (72 h or more) • Medications • Food and water (1 gallon per person/per day) • Pet care • Batteries Communications (battery-powered radio) Clothing (weather/climate appropriate) Transportation and fuel • Preplanned routes and alternatives Utilities • Shut off water and electricity if instructed "Go bags" • Documents/supplies • Maps/compass • Flashlight • First aid and disaster kit • Cash Meeting place • Right outside home • Outside neighborhood Critical documents (in waterproof container) • Identity (passport, driver's license) • Marriage license, divorce decree • Birth certificates • Medical license • Insurance documents • Financial records and deeds • Irreplaceable photos

Make sure every member of the family knows the plan, that you post in it an accessible place, and that you practice yearly. For more details: www.ready.gov.

From American Society of Anesthesiologists Committee on Trauma and Emergency Preparedness (ASA COTEP): Family Preparedness Checklist. Available at: https://www.asahq.org/resources/resources-from-asa-committees/committee-on-trauma-and-emergency-preparedness/emergency-preparedness. Accessed March 3, 2018; with permission of the American Society of Anesthesiologists, 1061 American Lane, Schaumburg, IL 60173.

must first perform a hazard vulnerability analysis that determines if there is an internal disaster (eg, fire, flooding, power outage) or external disaster (eg, terrorist bombing). They may even be faced with challenging situations when both internal and external disasters occur simultaneously [19]. Hospitals then determine the impact the event(s) would have on its institution, and the extent of their response capabilities and available resources. They must factor in space (eg, hospital bed availability; waiting room space; triage areas; OR, ICU, and ED beds; use of other care areas, such as clinics), supplies (eg, medications, ventilators, blood products), and staffing (eg, physicians, nurses, pharmacists). It is important to note that in addition to the victims of an MCE, the hospital already has routine patients who require medical attention. Hospitals must also triage these routine patients, provide treatment, and/or transfer them to a different facility [20]. It is crucial to avoid overadmitting patients, as resources become quickly consumed, and the quality of care may suffer [21]. Hospitals should have emergency plans in place, and should activate the Hospital Emergency Incident Command System (HICS) (see HICS section later in this article) [1]. Communications plans for staff call-up should be tested with the expectation that external wireless systems may be limited or unavailable; internal systems that rely on external wireless networks may be affected as well. Hospital emergency plans facilitate communication between responders, hospital staffing, and governmental agencies, coordinate obtaining additional resources, and have a chain of command that assigns various personnel specific roles and responsibilities [1,20]. Clinicians must be prepared to be called into the hospital, stay in the hospital for more than 24 hours, and assume roles outside their usual practice. The hospital command center manages the disaster response until the event is resolved, and helps reestablish typical hospital operations.

Government preparedness. Disasters or MCEs may exhaust local resources and require the assistance of federal and governmental agencies. Once a state of emergency is declared, FEMA may respond to the disaster. The US Department of Homeland Security's (DHS's) National Preparedness Goal states its main objective is "A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that post the greatest risk." The goal is based on core capabilities provided by the coordination of several governmental agencies and targets 5 areas: prevention, protection, mitigation, response, and recovery (Fig. 1) [22]. Based on the particular disaster, FEMA will coordinate the relief efforts through various governmental agencies and specific disaster management teams (ie, Disaster Medical Assistance Teams [DMAT]). Some of the key agencies involved in disaster response include US Departments of Health and Human Services (DHHS), Justice, Defense, Agriculture, and Commerce [6]. The DHHS created and uses the National Disaster Medical System (NDMS) for crisis management [1]. Disasters related to public health threats may require CDC intervention to provide specialty trained medical staff, medications, and equipment [1].

Prevention	Protection	Mitigation	Response	Recovery
Planning				
Public Information and Warning				
Operational Coordination				
Intelligence and Information Sharing		Community Resilience; Long-term Vulnerability Reduction; Risk and Disaster Resilience Assessment; Threats and Hazards Identification	Infrastructure Systems	
Interdiction and Disruption			Critical Transportation; Environmental Response/Health and Safety; Fatality Management Services; Fire Management and Suppression; Logistics and Supply Chain Management; Mass Care Services; Mass Search and Rescue Operations; On-scene Security, Protection, and Law Enforcement; Operational Communications; Public Health, Healthcare, and Emergency Medical Services; Situational Assessment	Economic Recovery; Health and Social Services; Housing; Natural and Cultural Resources
Screening, Search, and Detection				
Forensics and Attribution	Access Control and Identity Verification; Cybersecurity; Physical Protective Measures; Risk Management for Protection Programs and Activities; Supply Chain Integrity and Security			

Fig. 1. Core capabilities of 5 mission areas: prevention, protection, mitigation, response, and recovery. (*From* US Department of Homeland Security: national preparedness goal. 2nd edition. 2015. Federal Emergency Management Agency (FEMA). Available at: https://www.fema.gov/media-library/assets/documents/25959. Accessed March 14, 2018; with permission from FEMA, U.S. Department of Homeland Security.)

Situational awareness

SA is defined as the recognition and understanding of critical events associated with a disaster [23]. SA is crucial for recognizing, responding to, and tempering threats. It helps in the formulation of response plans, execution of rapid decisions in dynamic situations, proper allocation and utilization of resources, and improves outcomes [23]. SA relies heavily on the correct information and good communication of the information among multiple event respondents [24]. Incorrect or insufficient information may lead to endangering rescuers and poor outcomes [24]. There is also shared SA, which entails communicating and relaying information about the event to authorities and other responders and promoting teamwork and cooperation [24]. An established flow of communication among disaster responders and the transmission of important information in a timely fashion is crucial. Awareness of cultural norms is also part of SA. Electronic surveillance and wireless communication systems help facilitate information flow and distribution [24,25]. Barriers to satisfactory SA include (1) lack of universal operational models; (2) poor communication; (3) incorrect, insufficient, or outdated information; and (4) undefined information-sharing plans and routes [24]. Norri-Sederholm and colleagues [24] surveyed emergency paramedics to determine what information was crucial to successfully respond and manage emergency medical situations. There were 5 important information categories identified: mission status, area status, incident data, safety at work, and tactics. Incident data was the most important category, as this provides basic information about the event, number of victims, nature of the event, ages of the victims, and other details about the event (eg, are there victims trapped somewhere, are there any obstacles preventing responders from getting to the victims). Mission status includes the number and type of personnel assigned to respond to the event, the number of respondents required for that particular event, estimated time, and confirmation of a completed mission. Area status refers to the number of responding units available, the type of units that are available, the location of the units, and urgency of the missions. Safety information is obtained from police or authorities at the scene to let responders know if there are any safety risks to personnel (eg, active shooter, biochemical exposure, unexploded ordinance). Finally, tactical details include coordinating response and obtaining instructions from the police, devising a response plan, and communicating said plan to other authorities involved (ie, police) [24].

SA is also a critical skill and principle of crisis resource management in anesthesiology [26]. SA is in part dependent on individual's cognitive abilities (memory, time management, visual recognition) but also can be taught. These skills can be developed through training exercises aimed at focusing attention, multitasking, and pattern recognition. The ultimate goal is that practitioners can learn how to gather, identify, and interpret information, and exercise expectant management. SA is a very important and relevant aspect of our training, but more training and education on it is necessary [26].

Response systems

Hospital emergency incident command system. The HICS is based on the Incident Command System (ICS), a standardized management system that coordinates the emergency response efforts of numerous personnel and agencies by establishing a chain of command with designated responsibilities and well-defined communication channels. The elements of ICS include command, operations, planning, logistics, and finance/administration. HICS, like ICS, is an adaptable system that can be used at any hospital. HICS uses a standard format for responses that is both effective and recognized by other responding agencies, thus enabling coordination of response efforts among various organizations during a disaster. Fig. 2 shows the structure of the hospital incident management team. The principles of HICS include facilitating smooth transitions of care between hospitals and outside responding providers, appointing a recognized

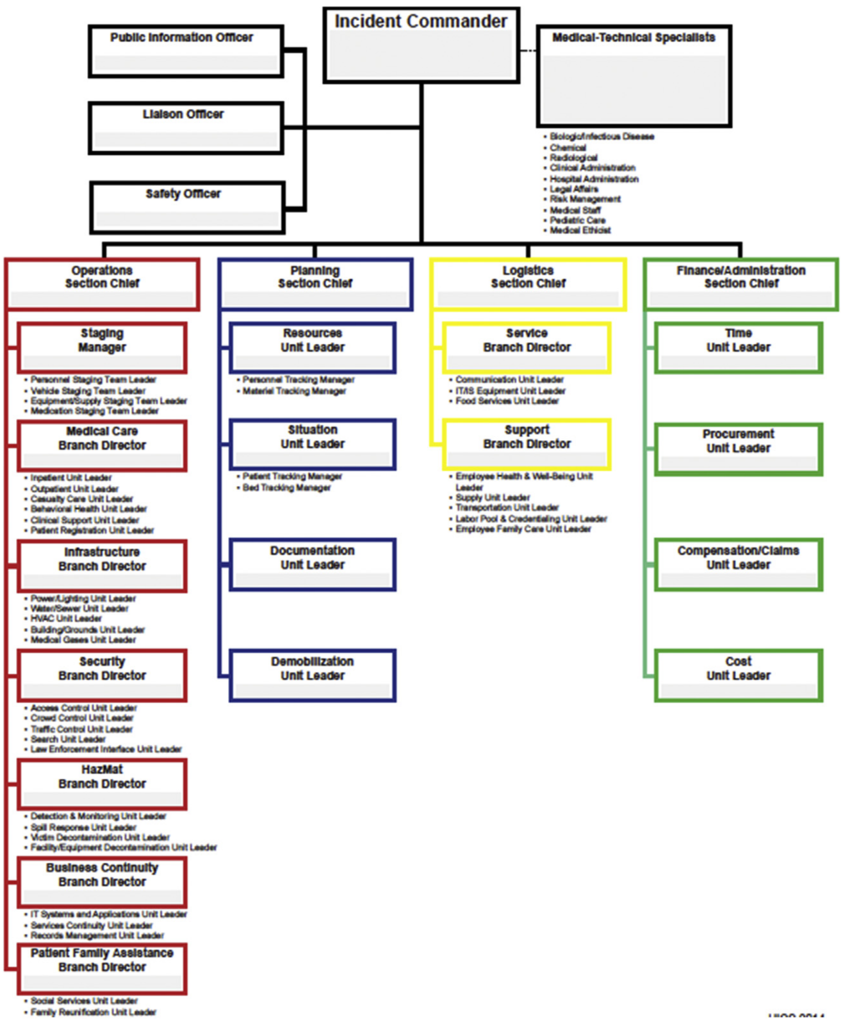

Fig. 2. Hospital incident management team. (*From* Backer H. California Emergency Medical Services Authority (EMSA). HICS guidebook. 5th edition. 2014. p. 59. Available at: https://emsa.ca.gov/wp-content/uploads/sites/47/2017/09/HICS_Guidebook_2014_11.pdf. Accessed March 4, 2018; with permission from the California Emergency Medical Services Authority (EMSA).)

chain of command, assigning specific responsibilities to personnel and designated teams, using response checklists, clear documentation, planning and coordinating support requirements, emphasizing efficient communication, and obtaining necessary equipment or supplies from outside sources [27–30].

Hospital emergency management plans. Hospitals should have emergency management plans to provide prompt medical care, justly allocate resources, and minimize deaths from disasters or MCEs. The plans should educate and prepare the staff on disaster management, with the goal of appropriately allocating and using hospital resources to provide the best care possible. The hospital disaster plan should incorporate HICS principles, such as a simple and comprehensive plan, well-recognized chain of command, flexible and adaptable organized plans for various disasters, and explicitly defined roles and responsibilities. The plans are developed by a hospital disaster/emergency management committee composed of a multidisciplinary team of clinical and nonclinical staff from various departments in the hospital. Members may include clinical division chiefs, hospital administrators, hospital operations personnel (eg, security, engineering, environmental services), and staff from clinical support services (eg, radiology, laboratory, blood bank). The hospital emergency plan also defines when disaster deactivation should occur. Following a disaster, committee members debrief and evaluate the overall performance, identify issues/errors, and amend the plan if warranted [31,32].

National response framework. The national response framework describes the response disciplines and processes for all types of disasters and emergencies, regardless of their severity or scale. It is designed for use by communities, families, individuals, federal governments, and private and nonprofit sectors, among others. It applies the concepts defined by the National Incident Management System (NIMS) and describes the best practices for managing disasters. It outlines organizational structures and the responsibilities of members of the entire community in response to incidents and how to prepare and coordinate the delivery of the response [33].

National incident management system. The NIMS outlines the best practice guidelines, doctrines, and structural processes for managing all types of minor to major disasters and emergencies. It is not an official incident management plan. It describes resource and communication and information management and outlines operational systems that guide personnel to coordinate response efforts during disasters or emergencies. It directs nongovernmental organizations, various levels of government, and the private sector to work together to prevent, mitigate, respond to, and recover from MCEs [34].

National disaster medical system. The NDMS partners with the DHHS, Department of Defense, DHS, and Department of Veterans Affairs to provide support and response to major emergencies and federally declared disasters, including natural disasters, technological disasters, terrorist acts, and major transportation accidents. The NDMS provides additional and temporary medical support to a specified disaster area through providing additional medical and support personnel, training, funding, and providing equipment. It transports patients from disaster areas to safe zones, and delivers medical care at participating hospitals in unaffected areas. NDMS has formed specific disaster response teams, such as the Trauma and Critical Care Team, DMAT, Disaster Mortuary Operational Response Team, National Veterinary Response Team, and most recently, Medical Specialty Enhancement Teams [1,35,36].

PREPAREDNESS OF ANESTHESIOLOGISTS

Role

Anesthesiologists play a crucial role in disaster response. Victims of disasters often require surgical intervention, so anesthesiologists' services will be greatly needed in the OR. Anesthesia care providers may be called on to act as "first responders," as they are adept at airway management, intravenous catheter insertion, resuscitation, and have a broad knowledge base that includes physiology, pharmacology, and management of trauma and critically ill patients. Their training teaches them to be adaptable to critical and changing situations and they are comfortable providing care for patients in different hospital settings such as the ED, OR, and ICU. Depending on the type of disaster and hospital's emergency preparedness plan, anesthesiologists may be asked to help triage patients and provide services outside the OR (eg, at the disaster site, ED, post anesthesia care unit (PACU), and ICU). European countries have already expanded the role of anesthesiologists to be an integral part of the emergency medical services, providing prehospital and on-site care for traumas and disasters [37].

Triage

Anesthesiologists may be assigned to triage patients during MCEs. Several MCE triage algorithms exist, but the 2 most commonly used systems are SALT (sort, assess, lifesaving interventions, treatment/transport) (Fig. 3) and START (simple triage and rapid treatment) (See http://www.start-triage.com/) [38–40]. There are insufficient studies and data comparing the various triaging systems to recommend the use of one over the others. One study demonstrated that SALT was a more accurate triage method compared with START, but this was performed in MCE simulations and the results have not been reproduced [41]. The SALT system is endorsed by the American College of Emergency Physicians, American College of Surgeons Committee on Trauma, and the American Trauma Society [38], but any triage system may be used. The purpose of the triage systems is to categorize victims based on the severity of their injuries and likelihood of survival, and to prioritize management and resource allocation [42]. Victims will be assigned to 1 of 5 categories: (1) Immediate, (2) Delayed, (3) Minimal, (4) Expectant, and (5) Dead [42]. Victims who are categorized as dead typically have unsurvivable injuries and present with no pulse; resuscitative efforts should not be initiated in this group. The expectant group is composed of patients with severe injuries who are unlikely to survive, and attempts at treating them would expend resources that are better allocated to others who are more likely to survive. The expectant patients should receive medications for comfort to allay their pain and suffering (eg, an elderly patient who has an 80% total body surface area burn presenting to the ED along with 10 other victims simultaneously). Victims categorized as minimal have minor injuries that do not require hospitalization. Delayed patients are hemodynamically stable and have injuries that may be addressed at a later time without adversely affecting outcomes. Finally, those who are categorized as immediate have survivable

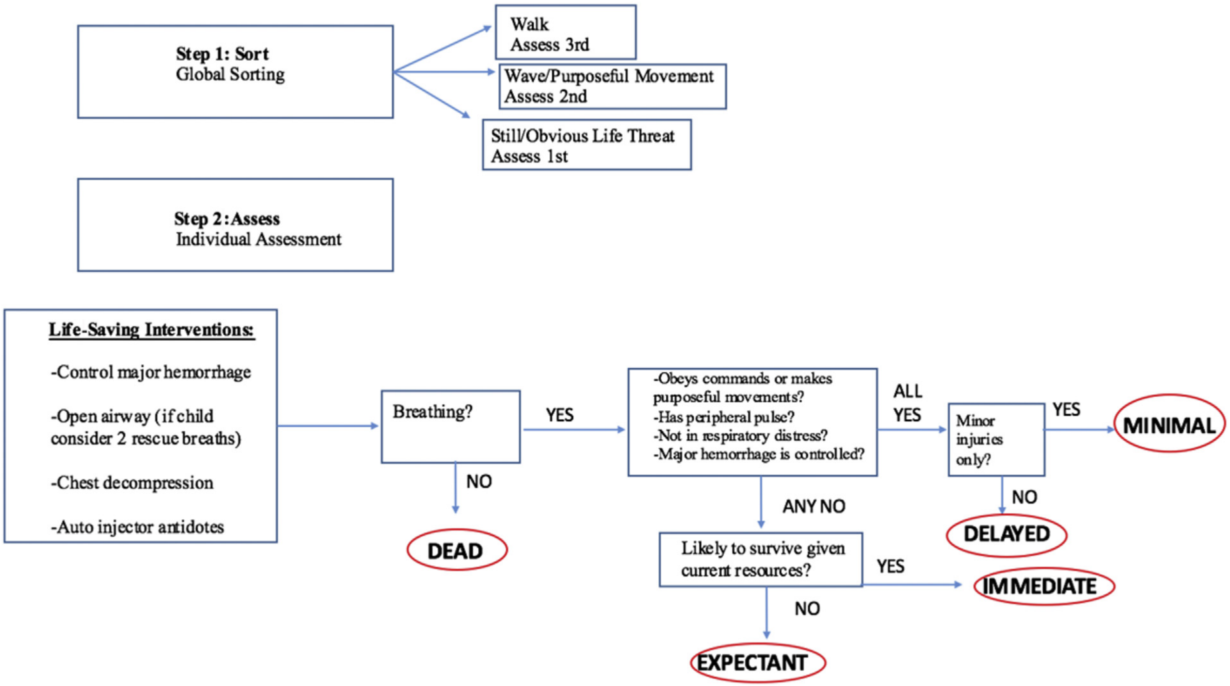

Fig. 3. SALT triage algorithm. (*Adapted from* Lerner EB, Schwartz RB, Coule PL, et al. Mass casualty triage: an evaluation of the data and development of a proposed national guideline. Disaster Med Public Health Prep 2008;2(Suppl 1):S30; with permission.)

life-threatening injuries requiring immediate intervention, and are prioritized for early OR intervention [42]. Anesthesiologists not only help make decisions on whether or not the patient needs emergent OR or ICU care, but they also provide patient management and address life-threatening conditions (eg, performing intubations for respiratory insufficiency, administering fluids and blood to those who are hemodynamically unstable, treating pain). During disaster events, hospitals are still expected to provide care to patients unaffected by the disaster, who may be suffering from life-threatening conditions (eg, myocardial infarction, stroke). These patients also require urgent medical attention, and providers should be mindful of the limited resources, beds, and staff when designating their treatment plans. Some of these patients may require transport to less burdened facilities so that the most critically ill patients receive top-priority care [20].

Airway management

Anesthesiologists are often responsible for airway management in MCEs. In these circumstances, anesthesia providers face numerous challenges due to situational urgency, potential airway injuries, hemodynamic instability, difficult intubation, aspiration risk, limited equipment and supplies and potential exposure to infectious or harmful biochemical/radiation agents. Certain disasters or MCEs may result in a large number of victims requiring intubation. In these situations, it is important to be mindful of infectious epidemics and biochemical agent poisoning. Furthermore, certain disasters (ie, fire, explosions, mass shootings, natural disasters) may result in a large number of victims suffering from blunt, penetrating, or burn injuries that require intubation. The safest method and gold standard of securing the airway in MCEs is endotracheal intubation [43]. Rapid-sequence intubations are commonly performed, and manual in-line neck stabilization should be performed if a cervical spine injury is suspected. If the patient is affected by a nerve agent, succinylcholine should be avoided or administered in lower doses [44]. In the setting of biochemical toxicity or an infectious epidemic, staff and other patients may be exposed to the pathogen or toxin, especially in the setting of fulminant respiratory failure necessitating immediate intubation before safeguards can be put into place. Anesthesiologists may need to intubate patients wearing PPE, which may impair airway visualization, encumber manual dexterity, and result in prolonged intubation times. A supraglottic airway can be a faster way to establish an airway while in PPE or during difficult intubations, but it should be replaced by an endotracheal tube when deemed safe [45]. There is no difference in intubation times when comparing direct laryngoscopy to video laryngoscopy while wearing PPE; both intubating techniques are reasonable choices [46,47]. The intubating instrument should be chosen based on provider preference, equipment availability, and the clinical picture. Supraglottic airways can be useful as a bridge to intubation or when large numbers of casualties preclude definitive airway management.

Decontamination

Chemical and radioactive material exposure necessitates patient decontamination by emergency personnel. Health care providers should don proper protective attire (ie, hazardous material suits) and perform decontamination in a designated area with its own water source to prevent environmental pollution. If life-threatening injuries are present, they must first be addressed before decontamination; this includes administering medications and antidotes. Patients' clothing should be immediately removed and stored in a double polyvinyl chloride bag. They are then cleansed with warm soapy water (hot water is contraindicated as it increases absorption of toxins) and flushed with water for approximately 1 minute [48]. It is advisable to provide airway protection against aerosolized or off-gassing agents to those waiting in queue for decontamination. Low-cost evacuation hoods that fulfill this purpose can be found on the Internet and purchased in bulk.

Personal protective equipment

Anesthesiologists should be prepared to deal with various MCE situations that may put them at risk of infection or toxicity. These include pandemics and infectious diseases (eg, Ebola, influenza, tuberculosis), and biochemical or nuclear events that can contaminate and affect health care responders when not wearing appropriate PPE. In the 1995 Tokyo subway sarin terrorism attack, victims were not decontaminated on-site and transmitted the agent to unsuspecting hospital providers [49]. The inability to immediately identify the symptoms or toxidromes of a particular biochemical or radioactive agent has the potential to affect health care providers; thus, a high index of suspicion should be used and responders should wear the PPE with the greatest level of protection (Level A). The different levels of PPE are shown in Table 4 [1,50]. Anesthesiology responders should be familiar with the appropriate PPE for specific

Table 4
Description of levels of personal protective equipment

Level	Personal protective equipment
A	Positive-pressure self-contained breathing apparatus (SCBA) Fully encapsulating chemical-resistant suit Double layer of chemical-resistant gloves Chemical-resistant boots Airtight seal between suit and gloves and boots
B	Positive-pressure SCBA Chemical-resistant long sleeved suit Double layer of chemical-resistant gloves Chemical-resistant boots
C	Full-face air-purification device (respirator) Chemical-resistant suit Chemical-resistant outer gloves Chemical-resistant boots
D	No specific respiratory or skin protection, but may include gloves, gowns, safety glasses, or face shield

Adapted from Kuza CM, McIsaac J. Human-induced and natural disasters. [Chapter 43]. In: Pardo M, Miller RD, editors. Basics of anesthesia. 7th edition. Philadelphia: Elsevier, Inc; 2018. p. 748–68; with permission.

agents/diseases. A survey of 90 anesthesiology programs found that only 33 of these programs provide training on responding to biochemical events, and of those 33 programs, 10 have not continued this training annually [49]. Ideally, hospitals should provide periodic training and education on PPE and respirators to potential disaster responders to ensure safe use and maintain competency.

Emergency department care

Most American hospitals do not have a strong anesthesiology presence in the ED. In MCEs, anesthesiologists may be assigned to the ED to help with airway management, obtain vascular access, provide cardiopulmonary resuscitation, administer medications, and treat chemical or biological toxicity [6]. Anesthesia providers may also be responsible for triage and ensuring the availability of appropriate equipment and supplies [51]. Because anesthesiologists have experience assisting ED providers with airway management or patient care, they may be more effective in this environment during an MCE than staff who are not as familiar with the ED [52].

Operating room care

Anesthesiologists provide a crucial role in the OR during traumas, emergencies, and MCEs. They should work closely with nursing staff, surgeons, and anesthesiology technicians to determine the number of ORs that can be used, ensure there are sufficient supplies (ie, intubating and difficult airway equipment, fluids, functioning ventilators, monitors, and medications), and recruit enough staff to run these ORs. Anesthesiologists should help set up ORs for emergent surgical cases and ensure that all necessary supplies are restocked in a timely fashion. In addition, they are crucial in coordinating communication and care among the ED, pharmacy, laboratory, and blood bank [53]. During an MCE, elective or less urgent surgeries are deferred. Surgeons should perform damage control surgery, which addresses the life-threatening injury, but the definitive management is delayed to optimize surgical care to the most victims in a short timeframe [54].

Anesthesiologists perform airway management, resuscitation, analgesia/anesthesia, administer antidotes/medications, and carry out massive transfusion protocols. In cases of hemorrhagic shock, balanced resuscitation should be used and blood products should be administered preferentially over crystalloids and colloids in a red blood cell to fresh frozen plasma to platelet ratio of 1:1:1 [55]. The administration of antifibrinolytics (eg, tranexamic acid) within 3 hours of injury is recommended for patients with uncontrolled hemorrhagic shock [56]. The ASA committee on trauma and emergency preparedness released a checklist for mass casualty OR management (Box 1) to help organize tasks, promote teamwork, and ensure equipment and blood product availability [57]. The OR burden, situational stress, and complex nature of the cases may affect anesthesiologists. A system should be in place to recruit additional anesthesia personnel to assist with difficult

Box 1: American Society of Anesthesiologists Committee on Trauma and Emergency Preparedness operating room procedures for mass casualty: management step by step

Objective: To be able to manage the flow of patient care in the operating rooms (ORs) during a mass casualty situation.

Steps (Indicate date and time for each item):

☐ Refer to facility's Operations Manual

Open up appropriate annex.

☐ Activate call-in tree

Assign an individual to activate. Use clerical personnel or automatic paging system, if available.

☐ Assess status of ORs

Determine staffing of ORs 0 to 2, 2 to 12, and 12 to 24 hours. Hold elective cases.

☐ Alert current ORs

Finish current surgical procedures as soon as possible and prepare to receive trauma.

☐ Assign staff

Set up for trauma/emergency cases.

☐ Anesthesia Coordinator should become OR Medical Director

Work with OR Nursing Manager to facilitate communication and coordination of staff and facilities.

☐ Report OR status to Hospital Command Center (HCC)

Enter telephone, e-mail address of HCC.

☐ Ensure adequate supplies

Coordinate with anesthesia techs/supply personnel to ensure adequate supplies of fluids, medications, disposables, other.

☐ Contact post anesthesia care unit (PACU)

Accelerate transfer of patients to floors/intensive care units (ICUs) in preparation for high volume of cases.

☐ Anesthesiologist should act as liaison in the emergency department (ED)

Send an experienced practitioner to the ED to act as a liaison (your eyes and ears) and keep communications open to Anesthesia Coordinator.

☐ Consider assembly of Stat Teams

Combination of anesthesia, surgical, nursing, respiratory personnel to triage, as needed.

☐ Hazardous materials/weapons of mass destruction (HAZMAT/WMD) event

Review special personal protective procedures, such as decontamination and isolation techniques. Consider if part of the OR or hallways should be considered ''hot'' or should have ventilation altered. Good resources include Chemical Hazards Emergency Medical Management/Radiation Emergency Medical Management (CHEMM (https://chemm.nlm.nih.gov/)/REMM (https://www.remm.nlm.gov/)) Web sites

☐ Coordinate with blood bank

Verify blood availability

☐ Coordinate with other patient care areas

ICUs, Obstetrics, Pediatrics, and so on to ensure continuity of care for new and existing patients

From American Society of Anesthesiologists Committee on Trauma and Emergency Preparedness (ASA COTEP): OR Mass Casualty Checklist. Available at: https://www.asahq.org/resources/resources-from-asa-committees/committee-on-trauma-and-emergency-preparedness/emergency-preparedness. Accessed March 3, 2018; with permission of the American Society of Anesthesiologists, 1061 American Lane, Schaumburg, IL 60173.

cases, offer breaks, and provide relief to anesthesiologists working 24 to 48 hours [51].

Postoperative care

Anesthesiologists often coordinate patient care with PACU and ICU nurses; a shortage of staff or beds may require them to provide postoperative care to mechanically ventilated or critically ill patients requiring additional resuscitation [58]. Anesthesiologists who specialize in critical care may be called in to help manage ICU patients with complications such as acute renal failure, shock, disseminated intravascular coagulopathy, fluid overload, or rhabdomyolysis [59].

Resilience

Resilience is the ability to successfully adapt to, cope with, and recover from a traumatic or stressful event, such as a disaster [60–62]. Resilience may apply to individuals or communities [62]. Individual resilience is a person's ability to emotionally and psychologically handle a traumatic event and return back to normal [60]. Individual resilience may result from innate personal traits and previously learned behavior or through social support (ie, psychological first aid [PFA]) [62]. Community resilience consists of individuals and local and governmental organizations working together and using information and knowledge gained from previous incidents, to acclimate to and recover from disasters or traumatic events [59,63,64]. Frequent team and organizational training under austere, stressful conditions (including failure of critical systems) is a time-tested way to develop a high degree of resilience.

Psychological first aid

PFA is a term that refers to the early psychological support after a traumatic event. Several professional societies developed information and training materials for civilians to provide PFA to others in times of crisis. In 1990, the Danish Red Cross initiated a PFA training program that educated and established an organization of staff personnel who were capable of supporting individuals and family members during a disaster or traumatic event. PFA is analogous to physical first aid, and is not provided by mental health professionals. It is often provided by friends, family members, or other disaster victims. The training model is composed of 3 elements: disaster intervention, providing support, and knowing when to involve mental health professionals. The International Federation of Red Cross and Red Crescent Societies built on this model and developed a training manual in addition to training sessions for volunteers. The training model is based on 6 components: background of psychological support, communication skills, a basic understanding of stress and coping mechanisms, fostering community involvement, providing support for special needs populations, and providing support for PFA volunteers. The American Red Cross created its own PFA model that employed mental health professionals during disasters. However, this model had several drawbacks including a limited number of professionals, inconsistent availability schedules, the inability to access the professionals (ie, incapability of transporting the professionals to where their services are required), and inadequate individual support when a large number of people are affected. The Institute of Medicine committee developed a PFA model based on evidence-based techniques that educates and equips individuals with skills that can be used to provide PFA for themselves and others. The skills taught may be applied in both small-scale stressful situations and during disasters. It helps individuals focus on their own mental health and well-being. Although ordinary individuals may provide PFA, it is important for them to recognize when a mental health professional's assistance is warranted [65].

Work and sleep discipline

Sleep is important for concentration, cognitive functioning, problem solving, memory storage, behavioral responses, and decision making. In stressful situations, such as responding to a disaster or MCE, responders often work long hours under trying circumstances leading to sleep deficits. Preexisting poor sleep habits, work schedules, inadequate sleep environments, and failure to recognize the importance of sleep by the institution or individual may contribute to insufficient sleep. Inadequate sleep may result in poor performance and predispose personnel to making mistakes, some of which may be life-threatening. The hospital response system should ensure that there are appropriate shift changes of personnel to allow other responders to maintain sleep. Additionally, health care personnel should be educated on the importance of sleep and maintaining sleep hygiene. In the Army, solders are specifically trained in sleep education, planning, management, and to develop unit sleep plans [66]. These practices should be adopted by institutions responding to disasters to encourage sleep hygiene practices and ensure adequate sleep to ultimately reduce the negative effects of sleep deprivation, including potentially making errors that may result in poor outcomes/deaths.

Improvisation and older methods of anesthesia

MCEs overwhelm health care systems and resources, and anesthesiologists may need to provide care in austere environments; thus, anesthesiologists should be prepared to improvise anesthetic techniques when commonly used modern equipment (eg, ventilators, anesthesia machines, ultrasound machines, medications) is unavailable. Anesthesiologists must be prepared to deliver anesthesia through alternative methods. For example, patient ventilation may need to be performed by hand. Regional and neuraxial techniques may be performed in certain surgeries and in the absence of anesthesia equipment. Alternatively, in developing countries, older anesthesia machines, breathing apparatuses, and volatiles seldom used in the states (ie, halothane), may be the only equipment available. Finally, the wide range of medications we have at our disposal in everyday use may be unavailable. Ketamine is a preferred anesthetic in developing world ORs during disasters. It preserves airway reflexes and spontaneous respiration, has analgesic properties, supports the cardiovascular system, and does not need complex supportive equipment. However, access may be extremely limited to a few older drugs (eg, diethyl ether, chloroform). Providers should be familiar with the routes of administration, dosage, and adverse effects [67].

The infrastructure of hospitals and ORs may be underdeveloped with unreliable oxygen supply, electricity, and nonfunctioning or unavailable necessary anesthesia equipment (eg, endotracheal tubes, laryngoscopes). These limitations can be challenging. Under these circumstances, anesthetic procedures that can be carried out safely and effectively in resource-limited settings include neuraxial/regional anesthesia, general anesthesia without intubation (spontaneous ventilation), total intravenous anesthesia while spontaneously breathing, general anesthesia with intubation, or combined anesthesia [68]. Providers must be flexible in their anesthetic practice and not be dependent on technology or drug variety [69]. Ultrasounds may not be available, and placing central lines and regional blocks are performed using anatomic landmarks. Providers may also need to bring their own portable monitors (eg, pulse oximeter, blood pressure cuff) to austere or underserved areas [70].

The 2010 earthquake in Haiti led to the destruction of most medical facilities, making the delivery of immediate surgical management challenging. Physicians were required to work out of tents without power, sterile conditions, means to administer oxygen, and anesthetics, in addition to having limited surgical supplies. Most of the procedures needed to be performed using regional/neuraxial techniques [71]. Regional techniques also help manage pain.

HOW TO PREPARE FOR A MASS CASUALTY EVENT?

The common occurrence of unpredicted natural disasters and rising numbers of terrorist attacks make any hospital, independent of its size, potentially vulnerable to being the primary center to manage disasters and MCEs, as in the case of the 2017 Las Vegas attack. Although most large disasters and MCEs are allocated to designated trauma centers in metropolitan areas, it is also likely that small rural community hospitals may need to respond to MCEs and provide care for victims. Failure to adequately prepare for these devastating situations may lead to delayed patient care and poor outcomes, as well as total hospital system collapse. Most hospital disaster preparedness training is focused on the ED.

However, due to the increased need for surgical interventions as a result of these events, anesthesiologists must familiarize themselves with what to do in these challenging situations and provide care for an unexpected number of victims.

Disaster drills

Anesthesiology departments should make a concerted effort to be involved in hospital emergency preparedness meetings, plan development, and serve as committee members. Furthermore, they should participate in regularly scheduled drills within their department and hospital. Epstein and colleagues [72] demonstrated issues with communication when attempting to activate MCE responders in the anesthesia department. When anesthesiologists were called, half the personnel did not respond or had their phone turned off. Anesthesia departments should at the very least, have a disaster activation plan, a call-in system, and periodically test the system.

In addition, anesthesiologists should participate in hospital emergency response and disaster plan drills. The Joint Commission requires 2 emergency response drills, with 1 serving as a community-wide exercise, and another simulating an event in which local resources are exhausted. Certain states require biannual disaster drills. Internal disaster and fire drills should occur quarterly for each shift of hospital personnel. Drill performance should be evaluated with feedback to participants, and response plans should be regularly assessed for updates/revisions.

Resources and online training

A survey examining anesthesiologists' experiences with emergency preparedness revealed that only a third of residency programs provided disaster education, and half no longer provided this training [53]. Hayanga and colleagues [73] reported similar results in a 2017 survey of anesthesiologists on disaster medicine; few respondents reported that their hospital provided sufficient emergency event preparation and training, and more than 70% expressed a desire for their hospital/department to provide such training. Anesthesiologists should know where to find resources pertaining to disaster management, and locate hospital emergency plans, MCE policies, and protocols.

Most responders are novices, and even if a provider has dealt with an MCE, they seldom have exposure to such an event again, let alone the same type of disaster. Those who participate in emergency drills often cannot use these skills for long periods, which results in knowledge and skill deterioration. Providers who desire additional emergency disaster response training have several programs available to them. The National Disaster Life Support Foundation provides Core, Basic, and Advanced Disaster Life Support Courses (https://www.ndlsf.org/index.php/courses/ecdls). Providers can become certified in Advanced Trauma Life Support, and take courses through the American College of Surgeons Committee on Trauma's Disaster Management and Emergency Preparedness, the World Association for Disaster and Emergency Management, the World Health Organization's Emergency and Trauma Care Training, and the International Society for Disaster Medicine [1]. Finally, the Agency for

Healthcare Research and Quality prepared a manual that aids hospitals in preparing for disasters through preparedness exercises and simulations [74,75].

SUMMARY

The increased incidence of MCEs has reinforced the need to prepare and plan for a hospital response. The role of anesthesiologists is crucial in various environments beyond the OR, especially in disaster situations. Anesthesiologists should be familiar with their potential role during an MCE and their hospital emergency response system. They should participate in emergency response drills and complete courses on disaster management to maintain their knowledge and skills. Anesthesia departments should also make concerted efforts to perform disaster drills within the department to identify systems issues and promote education, teamwork, and communication. Anesthesiologists should be familiar with the various types of disasters and how to apply their knowledge and clinical skills to each situation.

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