Chapter 17
Disaster Planning for the Intensive Care Unit: A Critical Framework

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Abstract Safe and efficient delivery of critical care during disasters is a complex endeavor that requires meticulous planning. Development of an initial plan should take an "all-hazards" approach, building a basic plan that covers all disaster types. Planners can then use a hazard-vulnerability analysis (HVA) to focus more specific planning on those disaster types for which a given health system, hospital, or intensive care unit is at greatest risk. Plans should incorporate three equally important areas: the availability and use of physical space, hospital resources (supplies and equipment) both on site and readily available, and staffing concerns. Potential need for evacuation should also be addressed. Horizontal (within hospital) and vertical (complete) evacuation planning should also be undertaken. Finally, disaster plans should include guidance for the allocation of scarce healthcare resources if all surge capacity is exhausted and evacuation is not possible. Scarce resource allocation planning is essential to maximizing the likelihood that limited resources will be distributed in a fair and transparent way during a crisis. Disasters create a myriad of challenges for healthcare delivery. Careful planning can mitigate the potential harms to patients in such situations and provide a structure for delivering safe, efficient care in spite of those challenges.

Keywords Intensive care unit • Disaster planning • All-hazards planning • Hazard vulnerability • Evacuation

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Introduction

Healthcare disaster preparedness is a rapidly expanding field. Much thought and funding has been dedicated to healthcare disaster planning, both at the individual hospital level and through various government entities and university-based centers [1, 2]. The evidence base needed to guide healthcare disaster planning, however, remains limited. Most available critical care disaster planning guidance is based on expert consensus on best practices [3]. In 2007 a task force was convened by the American College of Chest Physicians, which produced the most comprehensive summary of best practices in the field at that time. These recommendations were first summarized in 2008 by the Task Force for Mass Critical Care of the American College of Chest Physicians Critical Care Collaborative Initiative and are currently undergoing revision [4–8] (Devereaux A, 13 July 2013, Personal Communication).

Healthcare disaster planning is complex and can be daunting. Here we argue that the foundation of all disaster planning should involve an all-hazards approach and should be based on a carefully executed hazard vulnerability analysis (HVA). We then address planning for surge capacity, focusing on three major planning areas identified by the Working group on Emergency Mass Critical Care: Increase in critical care space, equipment availability, and personnel [6]. Finally we address the logistics of the evacuation of the critically ill, and we explore life-saving resource allocation when all surge options have been exhausted and evacuation is not possible. Although we limit our focus here to the intensive care unit (ICU), we believe successful planning requires coordination across hospital units and departments and between regional and, at times, national organizations.

All-Hazards Planning and the Hazard Vulnerability Analysis

When initiating disaster planning, hospitals should adopt an all-hazards approach. This approach focuses initial, core planning efforts on response needs common to all disasters, simplifying both planning and implementation [9]. For example, all disaster responses should be carried out using an incident command system, with a clear hierarchical structure. Likewise, all responses require a communications plan, both within the hospital and with regional and national agencies. Given the variety and scale of many potential disasters, planning for all disaster types is an enormous undertaking; focusing on the capabilities common to all responses creates a foundation which can be augmented with additional detail to enable swift, efficient response to a broad range of disaster types, from a catastrophic weather event to an earthquake or a nuclear detonation.

Specific planning efforts beyond the all-hazards model should be focused on those disasters for which a given institution is most at risk. Those disasters are best identified through a systematic HVA [10]. An HVA may be undertaken at regional, hospital-wide, and unit levels to identify hazards that are most likely to occur in that area, hospital, or unit, so that plans can be tailored appropriately.

Disasters are inherently unpredictable. In recent years, the USA has experienced a large series of "never" events. These include an earthquake on the East Coast during the summer of 2011 [11], and the "super storm" hurricane Sandy impacting New York City and much of the mid-Atlantic in late 2012. Damage from the super storm necessitated evacuation of three hospitals with costs into the billions of dollars [12]. Although pre-event planning within a defined framework is essential for preparing an ICU to face disaster, planners must be aware that disaster response requires flexibility and learning in real time.

Planning for Surge Capability

Surges in critical care occur along a continuum of scale, and, as such, surge capability plans should be scalable. Conventional capability must be scalable to have contingency capability and even expand with the largest of disasters to "crisis" capability. Conventional capability refers to disasters in which medical care can be provided without disruption of services at the receiving hospital. Contingency capability refers to the ability to provide usual care, but only after modifications are made to standard utilization of space, supplies and staff, described below. Crisis capability represents the extreme situation in which the ability to provide usual care may be limited, even with implementation of all resources available for surge capacity [13].

Space

In a disaster, ICUs may face an influx of patients either immediately or over a period of weeks. Defining a hospitals specific surge capability (resources available above those used routinely) begins with identifying what physical locations (capacity) are available to care for the critically ill. There are nearly 94,000 ICU beds (nonfederal) in the USA. On average, 68 % of these beds are filled, although many hospitals have much higher average ICU occupancy [14, 15]. In an era of rising healthcare costs, it is rare for hospitals to maintain reserve critical care beds to manage surges in patient flow, simply because the cost of doing so is high. Thus, in the event of a surge of patients, many will likely need to be cared for outside of traditional ICUs. Post-anesthesia care units (PACU), emergency department critical care areas, and procedural areas equipped with oxygen and suction equipment should be evaluated and inventoried for surge capability. A preliminary estimate of surge capacity may be calculated taking into account these areas and the number of traditional critical care beds a given hospital typically has available. Planners must be aware that usual hospital operations and associated revenue are likely to be significantly hampered if areas such as PACUs and ORs are removed from normal use and elective surgeries are cancelled in order to provide surge capability. Depending on the duration of the disaster, cost considerations may become extremely important and may need to be addressed on a state or federal level. Of note, during a response, use of non-traditional patient care areas for delivery of critical care should only be undertaken after all patients that may be safely cared for outside of ICUs have been transferred to lower levels of care and others that may be safely evacuated elsewhere have been moved.

Additionally, hospital-wide bed management and patient tracking will increase in complexity, resulting in more opportunity for error. For this reason, early involvement of hospital information technology teams is recommended to optimize tracking of admissions, transfers, and discharges. For example, in some electronic medical records (EMRs), virtual patient beds will need to be created in areas not traditionally used to house in-patients.

Given the complexity of care for the critically ill and need for hospital resources such as oxygen, medical air, suction and monitoring equipment, these patients should remain in hospital areas, while other, non-critically ill patients may more safely be transferred out of the hospital setting. As a general rule, care should be provided in the area that care would be provided if no emergency existed, (i.e., initially the ICU). When that space fills, then the next most equipped space should be mobilized. This would likely be the PACU and emergency department followed by procedural areas. Monitored acute care wards and non-monitored wards may then be mobilized. All of these areas have the benefit of existing within the hospital structure. Only if the hospital is at capacity or has been structurally compromised should care of the critically ill outside of the hospital be considered.

Equipment

As healthcare delivery has become more sophisticated, the amount of equipment required to provide care for critically ill patients has increased dramatically. Although the number of ventilators is often thought of first when planning for increased capability, medical gas, pharmaceuticals and equipment for appropriate infection control practices are equally important. Before consideration of stockpiling equipment in preparation for an emergency, an evaluation of the hospital physical plant is appropriate. Do the beds identified as available for surge each have the electrical and medical gas infrastructure to support a ventilator? These questions are critical, as the capability of a hospital's physical plant may be the true "rate-limiting step" for increasing numbers of available critical care beds.

Sufficient amounts of medical grade oxygen must be available, ideally through the existing hospital infrastructure. Replacement or supplemental oxygen supplies may be obtained including compressed gas cylinders and oxygen concentrators, but liquid systems are the best option given the ability to store in bulk and provide oxygen to the greatest number of patients. Compressed oxygen tanks are acceptable for short-term use but are not feasible for long-term supply, given cost and storage constraints. Oxygen concentrators are generally not acceptable except for use in non-ventilated patients requiring supplemental oxygen, because most are unable to deliver the high flows needed to power positive pressure ventilation [16].

Numerous epidemics result in respiratory failure, and the need for respiratory support should be expected to increase in any mass casualty event. Without planning for increases in the need for ventilator support, many patients will likely die. Planners should work with facility managers at their institutions to quantify the number of ventilators a hospital's physical plant can support, as well as the number of ventilators available. Machines capable of providing positive pressure ventilation for mass casualty care include not just full-featured mechanical ventilators, but also anesthesia machines, portable (both pneumatically powered and internal gas source) as well as EMS transport ventilators. Although manual ventilation is acceptable for transport, it is not feasible from a staffing, infection control, or oxygen conservation standpoint and should not be considered a significant option for long-term ventilation. Options to rapidly increase the overall number of available ventilators for a national response has been assessed and was found to be lacking [16, 17].

It is estimated that there are approximately 62,118 full feature mechanical ventilators nationwide (median of 19 per 100,000 people) [18]. Relocation of these ventilators in the event of a disaster presents a considerable logistical challenge [6]. Strategies to increase ventilator supply in a given institution or region include renting, accessing the Strategic National Stockpile (SNS), or repurposing anesthesia units. Rental supplies may be helpful but cannot be expected to adequately meet demand. A regional drill of a respiratory failure epidemic affecting a 27-hospital network revealed 16 ventilators available to meet surge demand capable of handling 2,500–3,500 beds [19]. The SNS is maintained by the US Centers for Disease Control and Prevention. This stockpile initially consisted of approximately 4,400 ventilators. An additional 4,500 ventilators were added to the SNS in 2009–2010. Each state designates an SNS official to maintain their allocation policy, which is organized by region [20]. Institutions can request stockpile ventilators during a disaster through their state's designated official [21–24].

Pharmaceutical supply is also an important area of concern and focus, and pharmacists should be included in preparedness planning efforts. Most hospitals rely on lean inventory and frequent restocking, given the cost of storing medications and their limited shelf life. Pharmaceutical shortages occur nationwide even in the absence of a disaster, secondary to the supply chain and possible over-reliance on individual manufacturers for some of our most frequently utilized medications [25]. Given the realities of the current healthcare funding environment, processes for rapid procurement of essential medications should be established and evaluated. Utilizing knowledgeable pharmacists will also be paramount, given the need to employ alternative medications when supplies of first-line medications run low. In a pandemic, specific supplies of certain medications (antibiotics, antivirals) may become dangerously low. As with ventilators, the federal government through the SNS maintains a stockpile of medications that can be distributed in an emergency

[26]. Planners should be aware that accessing stockpiled medications is likely to take at least several days and should prepare accordingly.

Additional preparedness activities should include careful estimation of ancillary equipment needs, including ventilator supplies (extra circuits, pulse oximetry probes, humidification devices), monitoring supplies (EKG leads, temperature probes), and infection control equipment (masks, gowns, gloves). Determining the amount of supplies necessary for a fully functional ICU bed and then determining multiples to equal the number of critical care surge beds will provide an estimate for the amount of supplies needed. Depending on the type of disaster, these supplies may be available from stockpiles in other areas of the hospital. Table 17.1 details the nonrespiratory medical equipment that is essential for emergency mass critical care. The Mass Critical Care Task Force project, Definitive care for the Critically Ill During a Disaster, has also published guidance on ancillary equipment planning for surge positive pressure ventilation.

Personnel

Staffing of ICUs during an emergency is an additional challenge. There are shortages of fully trained critical care staff (nurses, respiratory therapists, pharmacists, intensivists) even at baseline [27–29]. Some studies have shown that 10–60 % of staff may not report for work in the event of a disaster. More staff may be absent if the disaster is an epidemic, or if the disaster impacts family life, including closure of schools, daycare, etc. [30]. These concerns suggest that staffing for a significant critical care surge will require modification of existing staffing models. Off-duty staff may be recalled to the hospital to properly care for a surge of patients. Staff trained in anesthesia, either anesthesiologists or other ancillary staff, will likely possess airway and ventilator management skills that could make them a reasonable source of supplementary critical care personnel. Transferring individual staff within and throughout local hospitals will minimize the chance that one particular unit or hospital may become overwhelmed. Identifying which hospitals may be able to share staff will enable credentialing and training to occur prior to a disaster.

If recalling off-duty staff or utilizing staff from other units or hospitals does not meet staffing needs in a disaster, "tiered staffing" has been recommended. A tiered staffing model has been described by the Working Group on Emergency Mass Critical Care and the Mass Critical Care Task Force [3, 7]. These team-based models incorporate non-critical care trained clinicians and nurses to provide the general medical management of the patients, allowing intensivists to focus on airway and ventilator management as well as other critical care related issues. The working group recommends that when tiered staffing is implemented, each non-critical care clinician should be responsible for up to six patients, and each intensivist should be able to oversee four non-intensivists. Each intensivist would thus be able to care for 24 patients [3]. When utilizing tiered staffing, expectations of staff brought from other clinical areas should be clearly delineated.

Table 17.1 Suggested nonrespiratory medical equipment for emergency mass critical care[a]

Devices	Reusable/ consumable	Duration of use	Minimum number per 10 treatment spaces for 10 day[b]	Comments
Hemodynamic support				
CVC	Consumable	Duration of need	13	Multilumen percutaneously inserted, nontunneled CVCs or PICCs (with skilled operators) are acceptable; assumption: average of 1 CVC per patient; some patients many not require CVCs and some may require multiple CVCs during a 10-day period
CVC ancillary supplies (e.g., administration sets, insertion site dressings, flush)	Consumable	Per institutional preference	Sustained-use equipment: 13 × units of equipment per patient × 10/ duration of use (d); daily consumable equipment: 13 × units of equipment per patient per day × 10 day	
Peripheral IV equipment	Consumable	4 day	65	
IV crystalloid solution	N/A	4–5 L on day 1, 2–3 L on days 2 and 3; 1–2 L/day thereafter	200 L	Crystalloid choice is dependent on institutional practice; volume may be reduced if institution prefers hypertonic saline solution
IV pump (multilumen)	Reusable	Duration of need	10	Patients requiring additional pumps may be too ill to support during extreme shortages
Miscellaneous equipment				
Disposable bath package	Consumable	2–3 day	35	
Nasogastric/orogastric tubes	Consumable	Duration of need	13	Route for enteral nutrition and medications in ventilated patients; if there are insufficient enteral

(continued)

Table 17.1 (continued)

Devices	Reusable/ consumable	Duration of use	Minimum number per 10 treatment spaces for 10 day[b]	Comments
				feeding pumps, bolus feeding by gravity is an acceptable alternative
Nasogastric/orogastric tube ancillary supplies (e.g., securing tape, syringe, ophthalmic lubricating ointment)	Consumable	Per institutional preference	Sustained-use equipment: 13 × units of equipment per patient × 10/ duration of use (d); daily consumable equipment: 13 × units of equipment per patient per day × 10 day	
Optional equipment				
Continuous heart rate and rhythm monitor	Reusable	Duration of need	10	May consider at least one device capable of cardioversion (for nonpulseless but unstable arrhythmias)
ECG cable/leads	Reusable	(consumable)	Duration of need	10 or 13
ECG patches	Consumable	Duration of need	100	
Sequential compression device	Reusable	Duration of need	10	Dependent on institutional practice and patient VTE risk and risk of adverse event from chemical VTE prophylaxis
Sequential compression boots	Consumable	Duration of need	13	
Patient monitoring				

Noninvasive BP cuff	Consumable	Duration of patient stay	1 small; 10 standard; 3 large adult; 1 thigh	Consumable cuff or cuff cover is acceptable; proportions of sizes may vary based on anticipated patient sizes
Thermometer	Reusable or	consumable	Duration of patient stay	I:3 disposable probes
Temperature measurement site based on institutional preference				
Urinary catheter with collection bag	Consumable	Duration of need	13	

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[a]Pediatric-specific equipment, while not presented to limit the complexity of the suggestions, should be considered. Some devices may be used interchangeably for adults and most pediatrics (e.g., mechanical ventilators approved for adult and pediatric use). Amounts of pediatric-specific equipment should be determined by regional analysis of need in consultation with pediatric experts. *N/A* not applicable, *CVC* central venous catheter, *PICC* peripherally-inserted central venous catheter, *VTE* venous thromboembolism

[b]Equipment for ten patient care spaces for 10 days assumes: 30 % patient turnover (clinical improvement and deaths)

A final issue related to staffing is that of navigating the EMR. Systems and order sets often differ both between and within hospital, and staff may be very familiar with EMR functionality in their home hospital or unit but not in the ICU to which they are reassigned. Identification and EMR-specific training of non-critical care staff who may be re-assigned to ICUs in the event of a disaster is imperative to avoid medical errors related to the EMR.

Evacuation

Although planning for surge critical care within conventional hospital space presents real challenges, an even more complex task is the planning and execution of an evacuation of critically ill patients. An evacuation may take place either horizontally or vertically. A horizontal evacuation refers to the removal of patients and staff from an *area* of the hospital that is no longer safe, either because of structural damage, security concerns or loss of hospital resources (electricity, medical gases, etc.) A vertical evacuation refers to removal of staff and patients from the entire hospital in the event that the entire hospital is no longer safe. The patient, equipment, and patient records must be transported in unusual conditions from the hospital, to transport, and then into another care environment, likely with a different set of clinicians. The hazards and opportunities for error inherent in this required sequence of events are numerous.

During the 1990s as many as 20 hospitals were evacuated each year in the USA [31]. In May of 2011, a tornado in Joplin, Missouri struck St. John's Regional Medical Center, killing four people in the hospital and on the hospital grounds. The hospital was evacuated in the immediate aftermath of the storm and subsequently demolished because it was structurally unsound [32]. More recently, two major hospitals in New York City were evacuated during and after hurricane Sandy after power was lost and back-up generators were compromised. No one was injured during these evacuations, even though they took place at night, without power, and during a hurricane. The Veterans Affairs Hospital in New York City was also evacuated because of Hurricane Sandy, although the decision to evacuate was made prior to the storm's arrival. These examples and others suggest that hospital evacuation can occur safely with appropriate planning [33, 34].

In general, evacuation will be necessary if significant damage has occurred to the hospital building or if conditions at or near the hospital are expected to worsen to the point that damage is likely. In either event, an evacuation decision is made based on an assessment of the risk associated with sheltering in place versus the risk associated with moving complex critically ill patients [35]. The difficulty of determining when to evacuate was illustrated clearly during and after Hurricane Sandy, when three hospitals required evacuation, but only one evacuated prior to the storm [33, 34].

Evacuation planning requires addressing two major sets of issues: those related to the disaster itself and those related to the patients who need to be evacuated. With regard to the disaster itself, planning and decision-making will vary based on whether it is a one-time event, such as a power-outage or tornado, or an ongoing event, such as an earthquake with aftershocks. The urgency of the evacuation will also impact planning and implementation. Will the event require immediate, rapid response to an immediate threat or can the evacuation be done in a more controlled fashion as with a predicted storm or dwindling resources without ability to re-supply? The care needs and stability of the patients for transport must also be assessed. Appropriate portable equipment must be assigned to each patient along with skilled staff to accompany the patient during transport [36].

When evacuating a large facility, both portable equipment and staff will likely be in short supply. Critical care transport teams, who often transfer critically ill patients in routine situations, may be of some help if the disaster is limited geographically, but they are also likely to be overwhelmed by high demand. Equipment and staff initially assigned to the evacuating hospital will need to return to the hospital after successful transport of one patient, to prepare the next patient and care for those who remain.

Transport of the critically ill has grown more complex as the amount of equipment routinely used to care for them has increased. In a disaster, the complexity may be compounded by damage to the hospital physical plant, necessitating alternative routes of egress or traversing of stairs. To accomplish transport safely, use of specially designed evacuation litters or sleds is recommended. Each hospital should determine the number of evacuation sleds needed to evacuate their facility in a timely fashion and should facilitate acquisition and storage of these key items. Guidelines have been published to assist hospitals in determining their needs [37]. Finally, the importance of drills cannot be overemphasized. Practicing evacuations prior to an actual emergency, even on a limited scale, provides real-time experience to hospital staff and helps identify areas of concern to be addressed in an organized fashion.

Resource Allocation

Even with the most comprehensive response plans, during a disaster demand for critical care services and equipment may significantly exceed supply. If patients cannot be transferred to other facilities with additional critical care capability, and alternate equipment is not available, hospitals should have in place a mechanism for the fair allocation of limited resources. Absolute scarcity of resources necessitates a shift in the providers' focus from the need of the individual patient to optimizing the survival of the greatest number of individuals. It is essential that all options for expanding existing resources be exhausted before implementing a scarce resource allocation plan, given the significant ethical concerns associated with any deviation from usual standards of care. As would be expected, planning for the allocation of scarce critical care resources in this context is extremely challenging, as it opens the possibility of withholding critical care treatment from patients who might receive it under usual circumstances.

Several authors have published guidelines that focus on resource allocation [5, 38–41]. These guidelines attempt to answer whether it is ethically permissible to withhold or withdraw treatment from one patient to allocate that resource to another patient who may be more likely to survive. The published protocols [5, 40] have different strengths and weaknesses. Each addresses what criteria may be used to allocate ventilators or other similar resources, but they vary in complexity and associated efficiency. Choosing a protocol to implement in advance of a mass casualty event may reassure those involved in triage decision-making that every effort has been made to provide efficient, fair use of critical care resources. Although several allocation strategies may be ethically and morally permissible, the Institute of Medicine has outlined basic norms and processes that should be adhered to in developing a protocol for a given institution or community [42].

In general, a resource allocation plan should specify inclusion criteria, a prioritization tool, and a description of the triage team structure [40]. The inclusion criteria are designed as criteria for admission to a critical care unit. Respiratory failure will likely be the most common criteria used, however hemodynamic collapse and need for vasopressors could also be a criteria, if support cannot be provided in other areas of the hospital.

If exclusion criteria are utilized, categories related to the severity of illness or injury and the patients overall prognosis may be included. Those who support using exclusion criteria suggest that if patients are severely injured and not expected to survive, they may be excluded from admission to the ICU, as resources provided to support them prior to death would be better utilized for patients who are expected to survive but require critical care support to do so. Some suggest that severe co-morbidities may also be taken into account when developing exclusion criteria, although this category may be more problematic than others.

A triage tool should be applied to all patients regardless of their reason for requiring critical care, and is helpful to not only exclude patients from the ICU, but also prioritize patients for care. One option is to use an illness severity score such as the Sequential Organ Failure Assessment (SOFA) score, and categorize patients according to their score. A SOFA score >11 has been associated with >90 % mortality in some contexts and has been suggested by some to be an acceptable criterion for withholding critical care [43]. An important caveat to the use of SOFA scores is that the mortality associated with a particular score may vary depending on the type of disease process. This fact was illustrated during the H1N1 influenza outbreak, during which a SOFA score of 11 only resulted in a mortality rate of 59 %, not the predicted 90 % mortality [44].

Finally, when an allocation system is in place, it is important to continually reassess patients, as their status for inclusion or exclusion may change given underlying co-morbidities and response to treatment. Reassessment may suggest that resources should be re-allocated to ensure that the greatest number of victims be given the highest chance for survival. Equally important in the triage process is the need for transparency and accountability for triage teams. The difficult process of resource allocation must take place openly and via protocol to relieve the pressure felt by individuals tasked with making these difficult decisions and to ensure that all involved understand the process as it unfolds.

Conclusion

Provision of critical care in a disaster is a complex enterprise. Although daunting, the successful development and testing of a disaster plan for each ICU is necessary given the possibility of disaster occurring at any time. Planning should begin with a hazard vulnerability analysis and should follow an all-hazards model. This approach will allow the majority of resources to be focused on those disasters that are most likely to occur, while ensuring that all major concerns are addressed. The disaster plan should focus on the increased use of physical space, increased staffing and hospital resources available, and input should be sought from all units and staff that will be involved in a disaster response. The possibility of evacuation must be considered, both horizontal (from one unit or hospital wing to another) and vertical (out of a hospital building completely). Evacuation of critically ill patients is a complex enterprise, but recent history suggests it can be done without significant increase in morbidity or mortality. Finally, although priority should be placed on expanding capacity, planners must also develop structures for allocation of resources when surge capacity is exhausted and evacuation is not possible.

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