CHEST

Surge Capacity Logistics

Care of the Critically Ill and Injured During Pandemics and Disasters: CHEST Consensus Statement

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BACKGROUND: Successful management of a pandemic or disaster requires implementation of preexisting plans to minimize loss of life and maintain control. Managing the expected surges in intensive care capacity requires strategic planning from a systems perspective and includes focused intensive care abilities and requirements as well as all individuals and organizations involved in hospital and regional planning. The suggestions in this article are important for all involved in a large-scale disaster or pandemic, including front-line clinicians, hospital administrators, and public health or government officials. Specifically, this article focuses on surge logistics—those elements that provide the capability to deliver mass critical care.

METHODS: The Surge Capacity topic panel developed 23 key questions focused on the following domains: systems issues; equipment, supplies, and pharmaceuticals; staffing; and informatics. Literature searches were conducted to identify studies upon which evidence-based recommendations could be made. The results were reviewed for relevance to the topic, and the articles were screened by two topic editors for placement within one of the surge domains noted previously. Most reports were small scale, were observational, or used flawed modeling; hence, the level of evidence on which to base recommendations was poor and did not permit the development of evidence-based recommendations. The Surge Capacity topic panel subsequently followed the American College of Chest Physicians (CHEST) Guidelines Oversight Committee's methodology to develop suggestion based on expert opinion using a modified Delphi process.

RESULTS: This article presents 22 suggestions pertaining to surge capacity mass critical care, including requirements for equipment, supplies, and pharmaceuticals; staff preparation and organization; methods of mitigating overwhelming patient loads; the role of deployable critical care services; and the use of transportation assets to support the surge response.

CONCLUSIONS: Critical care response to a disaster relies on careful planning for staff and resource augmentation and involves many agencies. Maximizing the use of regional resources, including staff, equipment, and supplies, extends critical care capabilities. Regional coalitions should be established to facilitate agreements, outline operational plans, and coordinate hospital efforts to achieve predetermined goals. Specialized physician oversight is necessary and if not available on site, may be provided through remote consultation. Triage by experienced providers, reverse triage, and service deescalation may be used to minimize ICU resource consumption. During a temporary loss of infrastructure or overwhelmed hospital resources, deployable critical care services should be considered.

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ABBREVIATIONS: MCC = mass critical care

Summary of Suggestions

Stockpiling of Equipment, Supplies, and Pharmaceuticals

1. We suggest hospital support services, including pharmacy, laboratory, radiology, respiratory therapy, and nutrition services, also be included in the planning of critical care surge.

2. We suggest equipment, supplies, and pharmaceutical stockpiles specific to the delivery of mass critical care (MCC) be interoperable and compatible at the regional level and ideally at the state/provincial level, so as to ensure uniformity of response capabilities, coordinated training, and a mechanism for exchange of material among facilities.

3. We suggest facilities should ensure adequate availability of disaster supplies through facility-based caches, with vendor agreements and understanding of supply chain resources and limitations.

4. We suggest the existing MCC hospital target lists for basic equipment, supplies, and pharmaceuticals remain relevant for institutions seeking to plan for MCC response.

5. We suggest regional and hospital stockpiles include equipment, supplies, and pharmaceuticals that can be used to accommodate the needs of unique populations that are likely to require critical care in centers other than specialty care centers, including pediatric, burn, and trauma patients.

Staff Preparation and Organization

6. We suggest hospitals use adaptive measures to compensate for reduced staffing, such as additional shifts, workload, and changes in shift structure/time, should be planned in collaboration with the critical care staff representatives.

7. We suggest hospital staff preparation for response to a disaster is vitally important to the successful outcomes of such events and should include emphasis on role definition, integration with the incident command system, and the ability to perform cross-trained functions.

8. We suggest hospital staff preparedness to support critical care surge response include knowledge of the following: standard operating procedures, role definition, use of hospital incident command system, cross-training of additional staff, and training in the use of situational awareness tools, particularly those that can assist in decision-making regarding critical care surge planning, operations, response, and recovery.

9. We suggest once a disaster or pandemic has occurred, hospitals should implement measures to mitigate preventable causes of staff shortage, including sheltering of staff and their families, provision of mental health support, measures to mitigate fatigue, access to transportation services, and maintenance of a safe working environment.

10. We suggest critical care nurse-to-patient ratios in an event requiring critical care surge be determined by provider experience, available support (ancillary staff), and clinical demands.

11. During a disaster or pandemic, we suggest critical care physician oversight and direction of the clinical care teams who provide critical care

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services, including scheduled patient assessment and treatment plan evaluation. If direct oversight is unavailable, a means of remote consultation should be used.

12. Should expert consultation (eg, pediatrics, trauma, burn, or critical care) not be available locally, we suggest every effort be made by hospitals to ensure that such expertise be provided at a minimum through remote consultation.

13. We suggest hospitals consider the utilization of technology (eg, telemedicine) as an important adjunct to the delivery of critical care services in a disaster to serve as a force multiplier to support response to disaster events. Where no such systems are currently in place, development of a telemedicine or other electronic platform to support patient care delivery is suggested.

Patient Flow and Distribution

14. We suggest decisions regarding in-hospital placement of critically ill patients during an MCC (after initial survey and treatment) be performed by an experienced clinician who makes similar triage decisions on a daily basis.

15. Early discharge of ICU patients to the general ward is a complex process, requiring critical care expertise. To enable rapid admission of critically ill patients to the ICU immediately after termination of ED/operating room workup and treatment, we suggest discharge of ICU patients (when possible) during preparation for an impending MCC be given priority simultaneous to decisions made about initial ED patient distribution.

Deployable Critical Care Services

16. We suggest deployable critical care services be considered a temporary alternative to critical care when loss of hospital infrastructure limits provision of critical care.

17. We suggest deployable critical care services are not definitive critical care facilities but may be used as a temporizing measure for delivery of critical care in a disaster setting. Expansion of critical care resources in the hospital environment, with temporary facilities for lesser acuity patients, is preferred over provision of deployable critical care when possible.

18. We suggest deployable critical care services may serve as temporary critical care locations provided there is a clear plan for patient transfer, within a few hours to days, to a definitive treatment location.

19. In crisis surge response, we suggest less intensive treatment of moderately injured patients be prioritized over the deployment of temporary critical care services when it would result in improved outcomes for larger numbers of patients.

Using Transportation Assets to Support Surge Response

20. We suggest surge capacity plans include predetermined standards that define minimal ongoing critical care capability in order to define the framework for decisions regarding patient transfer as the demands on the system gradually increase during a disaster or pandemic.

21. We suggest priority be given to transfer of assets to patients, particularly when transfer of patients to definitive care is limited by dangerous conditions (including considerable risk posed by available transportation options).

22. Transportation used for patient evacuations may also be used to bring in assets (eg, specialty providers and equipment), particularly when access/transport capacity is the limiting factor in patient movement.

Introduction

Successful management of a disaster or pandemic requires implementation of preexisting plans to minimize loss of life and prevent event expansion and secondary illness and injury. These plans are strategic documents and policies that should be developed in preparation for a surge during a disaster or pandemic and should be accompanied by rigorous training to ensure best outcomes. Many facilities do not incorporate critical care in their disaster plans or have critical care expansion plans that are separate from their all-hazard response plan. However, critical care is an important component of the hospital response to a disaster,[1-3] and managing surges in the ICU cannot be accomplished in isolation. A systems perspective, which includes all the organizations and persons involved as well as intensive care, is necessary. Planning should take into account the 12 disaster scenarios most likely to involve large numbers of critically ill or injured patients as outlined by the US Department of Homeland Security National Preparedness Guidelines.[4] Critical care surge capacity is defined as the maximal number of critical casualties that can receive adequate critical care for as long as required, regardless of patient placement, after recruiting all critical care assets. In a companion article in this guideline, we examine issues related to surge operations, describing the conduct of mass critical care (MCC).[5] The suggestions in this article are important for all who are involved in a disaster or pandemic with multiple critically ill patients, including frontline clinicians, hospital administrators, and public health or government officials. Although it is important for all providers to be familiar with all aspects of surge capacity logistics, Table 1 provides an overview of the suggestions of most interest to various stakeholders. In this article, we specifically focus on surge logistics: the elements that provide the capability to deliver MCC in disaster events (Table 2).

Materials and Methods

The Surge Capacity topic group met in June 2012 and developed 23 key questions focused on the following domains: systems issues; equipment, supplies, and pharmaceuticals; staffing; and informatics. Four literature searches were conducted to identify studies upon which evidence-based recommendations could be made. Searches were limited to between January 1995 and October 2012; English-language articles were included and non-English-language articles excluded (e-Appendix 1). A total of 1,440 articles were identified. The articles were reviewed for relevance to the topic by two topic editors (S. E. and J. L. H.). The lead topic editor (D. H.) was responsible for "deconflicting" the results where initial consensus was not achieved. Seven hundred twenty-seven articles were deemed relevant to the subject of surge capacity planning and response. Most reports were small scale, were observational, or used flawed or limited modeling; hence, the level of evidence on which to base recommendations was poor and did not permit the development of evidence-based recommendations. The Surge Capacity topic panel subsequently followed the American College of Chest Physicians (CHEST) Guidelines Oversight Committee's methodology to develop suggestions based on expert opinion through a modified Delphi process.[8] e-Appendix 1 contains key questions, key suggestions, and corresponding search terms and results.

Results

Stockpiling of Equipment, Supplies, and Pharmaceuticals

1. We suggest hospital support services, including pharmacy, laboratory, radiology, respiratory therapy, and nutrition services, also be included in the planning of critical care surge.

2. We suggest equipment, supplies, and pharmaceutical stockpiles specific to the delivery of MCC be interoperable and compatible at the regional level, and ideally at the state/provincial level, so as to ensure uniformity of response capabilities, coordinated training, and a mechanism for exchange of material among facilities.

3. We suggest facilities should ensure adequate availability of disaster supplies through facility-based caches, with vendor agreements and understanding of supply chain resources and limitations.

4. We suggest the existing MCC hospital target lists for basic equipment, supplies, and pharmaceuticals remain relevant for institutions seeking to plan for MCC response.

5. We suggest regional and hospital stockpiles include equipment, supplies, and pharmaceuticals that can be used to accommodate the needs of unique populations that are likely to require critical care in centers other than specialty care centers, including pediatric, burn, and trauma patients.

Policies should enable programs to optimize critical care resources available to a hospital. The existing framework for optimizing resources includes substitution, conservation, use of less-resource-intensive therapies, and, in the worst-case scenario, reuse or reallocation of scarce resources.[5] Stockpiling of equipment, supplies, and pharmaceuticals prior to a disaster or pandemic increases hospital surge capacity. A current focus on just-in-time inventory management limits stockpiling and requires constant vigilance and advocacy to ensure that key supplies are available. Thus, the development and oversight of equipment, supplies, and pharmaceutical stockpiles to deliver MCC is an integral function of local, regional, state or province, or national health-care emergency management programs. The ability to deliver effective critical care hinges on the maintenance of adequate supplies of narcotics, sedatives, antibiotics, vascular access supplies, and laboratory reagents that often are targeted for reduced stocking. Regional discussions of stockpiling based on the hazards faced by the community are central to the planning process. A coordinated approach to planning, purchasing, and stockpiling can lead to a much more robust and effective response than any single-facility efforts. Mechanisms for coordination of supply and staff during an event are detailed in the "Surge Capacity Principles" article by Hick et al[5] in this consensus statement. Regional stockpiles of critical medical supplies (particularly those used routinely and those that are likely to be required before outside supplies can arrive) at multiple medical facilities can be used to enhance critical care surge preparedness.[9]

TABLE 1] Primary Target Audiences for Suggestions

Suggestion Number	Primary Target Audience		
	Clinicians	Hospital Administrators	Public Health/ Government
1		✓	
2			✓
3		✓	
4		✓	
5		✓	✓
6	✓	✓	
7	✓	✓	
8	✓	✓	
9	✓	✓	
10	✓	✓	
11	✓	✓	
12	✓		✓
13		✓	
14	✓	✓	
15	✓	✓	
16		✓	
17		✓	
18		✓	
19		✓	
20		✓	
21		✓	
22		✓	

Critical care surge capabilities rely on support from pharmacy, laboratory, radiology, respiratory therapy, and nutrition services; hence, these should be included in all plans. Critical care experts should discuss with their pharmacy and central supply the quantities that should be readily available and determine arrangements should these supplies become exhausted.[10] Up to one-fifth of the patients admitted to hospitals after a major disaster may present with respiratory complications[11,12]; thus, respiratory care should also be involved in the institutional plans for operating a significantly greater number of ventilators than usual. Similarly, pharmacy and radiology usual practices may be altered during disasters, and laboratories may need to limit routine services to focus on critical testing.[13-16]

Health-care facilities should also have local plans to institute substitution, conservation, adaptation, reuse, and reallocation of scarce resources.[17,18] For drugs, these plans may require input from pharmacists and specialist clinicians. For example, infectious disease specialists may need to work in concert with pharmacists when antibiotic substitution or conservation strategies are contemplated.[19-22]

Successful implementation of conservation strategies relies on education and training as well as on preparation. For example, conservation of oxygen depends on implementation of standard operating procedures regarding the indications for supplemental oxygen and training to target oxygen saturation to > 89% rather than to > 95% as well as on the choice of liquid oxygen and compression-driven ventilators.[23] Inconsistent or even conflicting approaches can be avoided if national societies or bodies, such as the US Food and Drug Administration, provide basic templates and guidance so that individual institutions are not required to conduct these efforts independently.

Individual hospitals can optimize the use of stockpiled equipment, supplies, and pharmaceuticals if systems for pre-event preparation, cache monitoring, updating, and oversight and coordination policies during an event are used.[18] In general, the existing target lists of ancillary equipment for surge positive pressure ventilation (Table 3), medical equipment for critical care surge (Table 4), and pharmaceuticals (Table 5) remain relevant for institutions seeking to plan for pandemic and disaster response.[17,18,25] Similar target lists for pediatric critical care surge can be found in a dedicated article by the Task Force for Pediatric Emergency Mass Critical Care.[24]

Mechanical Ventilation Surge: Ventilatory support is an absolute necessity for survival in critically ill patients and may be the single most important therapy that dictates outcome. Moreover, ventilators are expensive and likely to be the limiting factor in any hospital's ability to accommodate a large MCC surge. Currently, US hospitals own approximately 65,000 full-feature ventilators and 100,000 less-advanced ventilators[26] to serve 93,955 ICU beds.[27] Hospitals working individually are unlikely to have enough ventilators stockpiled to double their ventilatory capacity in accordance with crisis surge requirements. Vendors will also be unable to supply a large number of ventilators on short notice. We suggest that health-care coalition surge objectives be consistent with individual hospital surge goals[5] and include the capability to surge at least up to the limit of the total number of ventilators available to coalition partners.[28]

A practical solution to this shortfall is to undertake a regional count of ventilators and a map of ventilation capacity per zone. A region's MCC operational plan would be built around that map, which outlines

TABLE 2] An Overview of the Critical Care Surge Planning Process

Process
Key elements
1. Management
2. Human resources
3. Alternative physical spaces
4. Equipment and technology
5. Processes for surge
Key principles
1. Central authority
2. Readiness to act for all categories of surge
3. Response built on partnerships
4. Tiered escalation response
5. Operational capabilities will be scalable, flexible, and adaptable
Objectives and critical tasks
1. Establish a steering committee
Identify a senior management sponsor as well as at least one champion from all key hospital stakeholders (eg, medicine, nursing administration, ED, ICU, unions).
2. Establish a critical care surge resource team
Identify a physician gatekeeper to cochair the steering committee with the executive who will lead and be accountable for managing surge events with support from a resource team comprising representatives from ICU nursing leadership and frontline staff.
3. Complete a comprehensive hospital assessment
Map patient flow through the hospital, monitor patient flow through the hospital, track surge events when they occur, and track access to critical care. Use all these data to understand the system and provide feedback to hospital areas to drive improvement.
4. Conduct a campaign to educate the organization about surge
For a surge plan to be effective, it is critical for the entire organization to understand the process and its role in managing surge.
5. Establish a critical care communication system
Implement a traffic light system that communicates patient status: green (ready for ICU discharge), yellow (possible discharge in 24-36 h), red (ongoing life support required). ICU patient status should be updated at least bid. This improves flow by enabling planning by all clinicians involved and allows for easy identification of patients for ICU discharge through reverse triage if a sudden surge event occurs.
6. Identify essential services and functions required to sustain the critical care service
This involves understanding the key activities required to admit, care for, and discharge patients from the ICU in addition to identifying potential alternate areas with the functionality to permit critical care in the event of a surge.
7. Develop a resilient human resources system
This process is aimed at developing a robust human resources network to provide critical care during a surge and includes maintaining a staff inventory based on skill set, cross-training critical care extenders, and planning how to staff during surges.
8. Planning to use alternate spaces during a surge
Merely identifying alternate spaces where critical care can be provided will not be effective. A concrete policy and plan (and agreements with the affected area) must be in place to allow this to be executed.
9. Planning for surge equipment and supply needs
The delivery of critical care outside of the ICU requires equipment and supplies that are not usually available in most areas outside the ICU. Ideally, prestocked carts with ICU supplies (with or without any additional equipment required) are created and can easily be moved into the alternate space to quickly prepare the area for providing critical care. Prestocked carts also enable the ICU staff to be familiar with the supplies and equipment they will have in advance of deployment to an unfamiliar work environment.

(Continued)

TABLE 2] *(continued)*

Process
10. Developing a decantation process
In moderate or major surges, it may be necessary to deescalate services and decant the hospital and ICU to facilitate new ICU admissions. It is essential that a plan about how to undertake a decant, including establishing partnerships with community groups such as home care, nursing homes, and transportation services, is in place.
11. Understand how patient volumes in noncritical care affect the ICU
ICUs are not islands unto themselves in the health-care system. Therefore, it is important for ICU leaders to understand both how other services (eg, surgery) affect the ICU and how the function of the ICU affects other hospital services and their targets and priorities.
12. Evaluation, exercises, and reassessments
Having established the hospital's surge plan and process, hospitals must have an ongoing evaluation of how it functions during common minor surges in order to refine the system, exercises for moderate and major surges to test the plan, and a process to reassess the plans at regular intervals to update them when planning assumptions or when critical enablers change.

(Adapted from Christian et al[6] and the Ontario Ministry of Health and Long-Term Care.[7])

shortfalls and target goals for the regional ventilator stockpile. With clear targets, hospitals and coalitions will likely be motivated to stockpile ventilators to meet these goals. Thus, facilities should first assess their capacity to use anesthesia machines, noninvasive ventilation machines, and transport ventilators for potential redeployment. Although simple pressure-triggered ventilators may play some role when lung compliance is normal, in most disasters and pandemics, they will be of very limited utility.[29] Stockpiled mechanical ventilators must meet unique needs, which should be considered before selection (Table 6).

Facilities should also map their ability to provide mechanical ventilatory support. The first question is which hospital areas are capable of supporting mechanical ventilation: The availability of physical space, air and oxygen supply, expired gas clearance, and negative pressure for suction should all be examined. The second question is whether the hospital infrastructure is capable of supporting the planned surge. The existing infrastructure should be studied not only in terms of the power requirements and oxygen supply but also in light of the most likely regional hazards. For example, during Hurricane Katrina, hospitals suffered generator power outages[30] and had to move ancillary departments (eg, biomedical engineering, central supplies) because their location had exposed them to flooding.[31] During the Lebanon war, a hospital within the missile striking zone had to convert ED areas into operating rooms because the latter were not designed to withstand artillery and missile attack.[32]

Mechanical ventilation of a patient places implicit constraints on the system; it is highly demanding in terms of staff (both time and training), equipment, and consumable supplies. Depending on the type of disaster or pandemic, the surge of mechanical ventilation is expected to last at least several weeks.[33-36] Initiation of mechanical ventilation during a pandemic or disaster is a weighty decision. Once initiated, withdrawal of ventilation, although ethically defensible, may be legally challenging,[37,38] depending on the jurisdiction. Those making decisions to intubate patients during an MCC event should be aware of the immediate and long-term implications of their decisions[39] and seek alternative options where possible.[40] Decisions regarding manual ventilation should be made per event and should take into account the time and physical costs of manual ventilation, the inherent risk of close contact with the patient for the staff, ventilator and staff availability and training, and the time manual ventilation is likely to be required.

Staff Preparation and Organization

6. We suggest hospitals use adaptive measures to compensate for reduced staffing, such as additional shifts, workload, and changes in shift structure/time, should be planned in collaboration with the critical care staff representatives.

Delivery of critical care depends on the availability of sufficiently trained medical, nursing, and ancillary staff. Because acute care hospitals operate around the clock, the available personnel may be doubled or even tripled rapidly through recruitment of off-shift staff. This arrangement generally suffices for treatment of the initial wave of patients. However, a continued response is likely to consume the available reserves of rested personnel within 24 to 48 h. Because the critical care needs in a disaster or pandemic are more prolonged

TABLE 3] Suggested Ancillary Equipment for Surge Positive Pressure Ventilation

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Positive pressure ventilation equipment				
Airways	Consumable	Multiple use	15 (range of adult sizes 4-5)	Assumptions: 40% of patients will arrive already intubated Turnover of 50% of patients within 10 d Will be used for problem intubation and to prevent biting on tube
Manual resuscitator with face mask	Consumable or reusable	Duration of ventilation	13	For intubation, patient transport, airway care, and emergency loss of medical gas or ventilator power source
T-piece resuscitators	Reusable	…	…	…
Ancillary respiratory equipment[b]				
Airway care				
Closed-circuit suction catheter	Consumable	Duration of ventilation	13	Crucial for respiratory-transmitted epidemics
Endotracheal tube	Consumable	Duration of ventilation	16	7.5-8.0 mm adequate for most adults Assumption: Extras for intubation failures and equipment malfunctions
Tube guide	Consumable (but can be reused)	One time	16	…
Endotracheal tube securing device	Consumable	Duration of ventilation	16	Tape acceptable
Single-use suction catheter	Consumable	One time	300	For postextubation suctioning Assumption: 50% survival, and 50% of survivors extubated within 10 d Four catheters per patient
Yankauer suction catheter	Consumable	Multiple use	13	For suctioning oropharyngeal secretions periintubation, while intubated, and when needed after extubation Kept with patient's equipment during entire mechanical ventilation requirement
Suction trap and hoses (regulator to trap and trap to suction device)	Consumable (can be reused if required)	Duration of ventilation	13	…
Vacuum source and suction regulator	Reusable	Duration of ventilation	10 (if possible)	Multiple patient management processes require vacuum source

(Continued)

TABLE 3] *(continued)*

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Fingertip for suction	Consumable	Duration of ventilation	13	...
Circuits				
Circuit for use with HME	Consumable	Duration of ventilation	9	Assumption: HME acceptable for approximately 70% of patients
Circuit for use with heated humidifier without wire	Reusable	Duration of ventilation	4[c]	Requires additional consumable items (see humidifier section)
Circuit for use with heated humidifier with wire	Reusable	Duration of ventilation	4[c]	...
Expiratory limb filter in ventilator circuit				
HEPA style filter	Consumable	12-48 h, depending on type of humidifier	100 (does not include 35 HME with filter; see humidifier section)	For contagious respiratory secretions Benefit uncertain Consider risk of occlusion with water or secretions and risk of contagion during replacement vs potential benefit when maintained closed
Humidifiers				
HME (with or without filter)	Consumable	3-5 d per patient (without filter) 2 d per patient (with filter)	25 (without filter) or 50 (with filter capability if suspicious for contagious respiratory secretions)	Recommend: absolute humidity $\geq$ 30 mg/L, dead space $<$ 75 mL Assumption: acceptable for approximately 70% patients
Heated humidifier, no heated wire circuit	Reusable	Duration of ventilation	4[c]	Meets needs of all patients but adds expense of a durable item and additional consumables and requires electricity
Water traps	Consumable or reusable	Duration of ventilation	4[c]	Needed for heated system without wire Consumables could be cleaned and reused
Heated humidifier, with heated wire circuit	Consumable	Duration of mechanical ventilation	4[c]	...
Chamber	Consumable	Duration of ventilation	4	Needed for either heated system Some companies still supply a reusable chamber
Sterile water	Consumable	2 L every 24 h	80 L	Needed for either heated system Water is heavy, expensive, and requires large storage area
Medical gas				

(Continued)

TABLE 3] *(continued)*

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Compressed air	Permanent	Duration of ventilation	…	Air compressors make air on site as long as electrical power is available. Present at most hospitals.
Compressed oxygen	Finite quantity that requires resupply	Duration of ventilation if 50-55 psi oxygen not available	…	Number of cylinders limited by space and cost.
50-55 psi line with quick connections from source to ventilator	Reusable	Duration of ventilation	10 air 10 oxygen	…
Liquid oxygen	Finite quantity that requires resupply			If distribution from supplier to hospital remains functional, provides significant oxygen capacity Hospital piping may limit high flow if most or all oxygen stations are used
Oxygen reservoir for low-flow oxygen use by mechanical ventilator (if applicable)	Consumable	Duration of ventilation if 50-55 psi oxygen not available	13	…
Oxygen regulators	Reusable	Duration of ventilation	1 per ventilator	50-55 psi regulator for gas cylinders if ventilator is pneumatically driven
Monitoring devices				
Pulse oximeter	Reusable	Intermittent patient checks	10	Individual pulse oximeters required because of the potential infection control challenges for staff performing oximetry rounds
Pulse oximetry probe	Consumable	Duration of stay	26	Disposable probes preferable for contact-transmissible diseases Assumption: some probes will fall off patient after a period of time
Capnograph	Reusable	Duration of stay	10	Ongoing verification of tube location, adequacy of ventilation, suggests cardiac output
Capnograph tubing	Consumable	Duration of stay	26	Assumption: $ETCO_2$ monitored on day 1 and then as needed
Capnograph fluid trap	Consumable	Duration of stay	52	Assumption: $ETCO_2$ monitored on day 1 and then as needed
Point-of-care diagnostic devices				
12-lead ECG	Reusable	Duration of admission	1 (per ICU)	Will require additional consumables

(Continued)

TABLE 3] *(continued)*

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Glucometer	Reusable	Duration of admission	1	Will require additional consumables
Portable ultrasound	Reusable	Duration of admission	1 (per ICU)	For bedside assessment and ultrasound-guided procedures
Point-of-care blood analyzers	Reusable	Duration of admission	1 (per ICU)	Blood gas analysis, basic electrolyte and lactate levels, thromboelastography
Respiratory medication delivery				
MDI adapters	Consumable	Duration of ventilation	13	For patients needing bronchodilators
Updraft nebulizer (Hudson RCI; Teleflex Inc)	Consumable	Duration of ventilation	4	For patients needing nebulized medications not available in MDI form

Pediatric-specific equipment, although not presented in order to limit the complexity of the suggestions, should be considered. Some devices may be used interchangeably for adults and most pediatric patients (eg, 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.[24] $ETCO_2$ = end tidal CO_2; HEPA = high-efficiency particulate air; HME = heat and moisture exchanger; MDI = metered-dose inhaler; psi = pounds per square inch. (Adapted with permission from Rubinson et al.[15])

[a] Consumable equipment for 10 patient care spaces for 10 d assumes 30% patient turnover due to clinical improvement and death.

[b] Does not include endotracheal intubation/tracheostomy equipment. Pharmaceuticals and intubation equipment should be available.

[c] Numbers will depend on decision to use a circuit with or without a heated wire. If HMEs are stockpiled exclusively, then existing heated humidifiers can still be assigned for patients with copious secretions or high minute ventilation.

than the response in other sections of the hospital,[4,5,41-44] the likelihood of depleting staff reserves is greater in the ICU. Planning ahead for phased staff callbacks (eg, staged callbacks when a disaster is declared so that all staff do not respond at once) and automatic consideration of staffing needs for 12, 24, and 48 h postevent to determine need and coverage and make appropriate plans (eg, notifying patients of clinic closures and rescheduling to allow staff to provide inpatient care) can greatly facilitate safe and effective coverage for the duration of the surge.

Preparation:

7. We suggest hospital staff preparation for response to a disaster is vitally important to the successful outcomes of such events and should include emphasis on role definition, integration with the incident command system, and the ability to perform cross-trained functions.

8. We suggest hospital staff preparedness to support critical care surge response include knowledge of the following: standard operating procedures, role definition, use of hospital incident command system, cross-training of additional staff, and training in the use of situational awareness tools, particularly those that can assist in decision-making regarding critical care surge planning, operations, response, and recovery.

9. We suggest once a disaster or pandemic has occurred, hospitals should implement measures to mitigate preventable causes of staff shortage, including sheltering of staff and their families, provision of mental health support, measures to mitigate fatigue, access to transportation services, and maintenance of a safe working environment.

Adaptive measures to compensate for reduced staffing, such as additional shifts, workload, transition-to-care teams, and changes in shift structure, should be planned in collaboration with the critical care staff (Table 7). Routine services that affect the ability to effectively respond to the pandemic or disaster (eg, elective surgery, clinic services) can be curtailed in order to reassign staff to pandemic- or disaster-relevant duties.[32] New divisions of labor may be required and should be based on the skill sets required rather than traditional roles or functions of providers. The use of care teams, that is, combinations of providers who cumulatively possess the required skill set, should be considered.[17,25,45] Additionally, administrative and teaching responsibilities should be curtailed during surge operations

TABLE 4] Suggested Medical Equipment for Critical Care Surge

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Oxygen delivery				
Oxygen, air regulators, flow meters	Reusable	Duration of stay	13	...
Nasal prongs	Consumable	Duration of need	13	...
Face masks	Consumable	Duration of need	13	...
Face mask with reservoir	Consumable	Duration of need	13	Preferably administered with water
Intubation equipment				
IV access				
IV crystalloid solution	N/A	4-5 L, day 1 2-3 L, days 2 and 3 1-2 L/d thereafter	200 L	Crystalloid choice depends on institutional practice Volume may be reduced if institution prefers hypertonic saline
Peripheral IV (alcohol, swabs, catheter, tape, regular and blood administration sets, needleless caps)	Consumable	4 d	65	...
CVC	Consumable	Duration of need	13	Multilumen percutaneously inserted, nontunneled CVCs or PICCs (with skilled operators) are acceptable Assumption: average one CVC per patient Some patients many not require CVCs and some may require multiple CVCs during a 10-d period
CVC ancillary supplies (eg, chlorhexidine; needles; syringes; lidocaine; sterile gloves, robes, sheets, masks, and caps; gauzes; sterile sets for insertion; stitches; sterile blades; insertion site dressing administration sets; 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 d	...
IV pump (multilumen)	Reusable	Duration of need	20	Patients requiring additional pumps may be too ill to support during extreme shortages

(Continued)

TABLE 4] *(continued)*

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Chest drain				
Chest drains (chlorhexidine, Y-connectors, insertion set, tubing, chamber, sterile water, negative pressure valve and connectors)	Consumable	Duration of need	6	Assumption: some patients may require more than one drain, and others may require none
Patient warming/cooling				
Regular blankets	Reusable	10 d	13	...
Insulating blankets	Consumable	Duration of need	13	...
Bair Hugger (3M)	Reusable	Duration of need	2	...
Bair Hugger blankets	Consumable	Duration of need	13	...
HOTLINE (Smiths Medical)	Reusable	Duration of need	2	...
High-flow IV lines, high-flow three-way connectors, hot line sets	Reusable	Duration of need	26	Highly depends on the type of event anticipated
Pressure bags (for blood/fluid)			10	...
Miscellaneous equipment				
Disposable bath package	Consumable	2-3 d	35	...
Nasogastric and orogastric tubes	Consumable	Duration of need	13	Route for enteral nutrition and medications in ventilated patients If there are insufficient enteral feeding pumps, bolus feeding by gravity is an acceptable alternative
Nasogastric and orogastric tube ancillary supplies (eg, securing tape, syringe, feeding bags, draining bags)	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 d	...
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)

(Continued)

TABLE 4] *(continued)*

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
ECG cable and leads	Reusable (consumable)	Duration of need	10 or 13	...
ECG patches	Consumable	Duration of need	100	...
Sequential compression device	Reusable	Duration of need	3	Depends on institutional practice and patient VTE risk and risk of adverse event from chemical VTE prophylaxis
Sequential compression boots	Consumable	Duration of need	13	Depends on institutional practice and patient VTE risk and risk of adverse event from chemical VTE prophylaxis
Patient monitoring				
NIBP 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
Manual sphygmomanometer	Reusable	Duration of patient stay	1 small 2[b] standard 1[b] large adult 1 thigh	Assumes that these are backup to NIBP cuffs[b]; if NIBP not available suggest quantity increase to same as NIBP
Thermometer	Reusable or consumable	Duration of patient stay	16 disposable probes	Temperature measurement site based on institutional preference
Urinary catheter, water-based alcohol 30%, sterile insertion set, collection bag	Consumable	Duration of need	13	...
Nursing care				
Blankets, sheets, pillows, diapers	Reusable	Duration of patient stay	20	...
Protective equipment (ie, gloves, masks, robes)	Consumable	Duration of need		Quantity variable depending on isolation needs of scenario (trauma vs pandemic)
Scissors	Consumable	Duration of need	13	...
Plasters	Consumable	Duration of need	30	...
Stoma care equipment	Consumable	Duration of need	10	Assumes one patient with a stoma
Blood culture tubes/bottles (aerobic and anaerobic)	Consumable	Duration of need	130	Assumes admission culture set and one set for repeat peripheral and line cultures
Shaving equipment	Consumable	Duration of need	50	Assumes 50% male occupancy

(Continued)

TABLE 4] *(continued)*

Device	Reusable/Consumable	Duration of Use	Minimum Number per 10 Treatment Spaces for 10 d[a]	Comment
Pressure sore dressings	Consumable	Duration of need	30	...
Bags for patient belongings	Consumable	Duration of need	13	...
Boxes for hearing aids/false teeth	Consumable	Duration of need	5	...
Tubes for blood tests	Consumable	Duration of need	200 of each type required	Assumes laboratory tests every 12 h Variable types based on hospital laboratory system
Urinalysis containers	Consumable	Duration of need		...
Forms for sending tests	Consumable	Duration of need		Variable per hospital process
Pens, markers	Consumable	Duration of need	13	...
Patient identification tags	Consumable	Duration of need	13	...
Isolation/allergy signs	Consumable	Duration of need	13	...
Needles	Consumable	Duration of need	3,000	...
Syringes	Consumable	Duration of need	3,000	...
Three-way connectors	Consumable	Duration of need	120	...
Caps for IV lines	Consumable	Duration of need	300	...

CVC = central venous catheter; N/A = not applicable; NIBP = noninvasive (automatic) BP; PICC = percutaneous inserted central catheter. (Adapted with permission from Rubinson et al.[15])

[a] Equipment for 10 patient care spaces for 10 d assumes 30% patient turnover (clinical improvement and deaths).

[b] Pediatric-specific equipment, although not presented to limit the complexity of the suggestions, should be considered.[24] Some devices may be used interchangeably for adults and most pediatrics (eg, 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.

TABLE 5] Suggested Pharmaceuticals

Preventive Therapeutics	Acute Care	Event Specific
DVT prophylaxis	IV fluid solutions	Chemical (activated charcoal, atropine, pralidoxime, silver sulfadiazine, GCSF, pupillary dilators, etc)
GI hemorrhage prophylaxis	Nutrition	Antivirals steroids (topical, systemic)
Treatment of reactive bronchospasm (inhalational agents)	Antibiotics	
Infection control (ie, antiseptics)	Vasopressors	
Vaccines (tetanus, hepatitis)	Sedatives	
Eye care	Analgesics	
Oral hygiene	Neuromuscular blockers	
	Anticoagulants	
	Diuretics	
	Antiarrythmics	

GCSF = granulocyte colony-stimulating factor. (Adapted with permission from Sprung and Kesecioglu.[18])

(including cancellation of meetings not related to the incident), policies should be in place about rescinding vacations and leave, and documentation requirements should be altered to free up time for direct patient care.

Nursing Staff:

10. We suggest critical care nurse-to-patient ratios in an event requiring critical care surge be determined by provider experience, available support (ancillary staff), and clinical demands.

Increased nurse-to-patient ratios provides improved safety and better outcomes for patients.[46] Although controversial, high nurse-to-patient ratios have been associated with a lower risk for ventilator-associated pneumonia[47] and lower mortality rates in neonatal ICUs.[48] Patient care is increasingly compromised at higher ratios of patients to staff, with data suggesting a 7% increase in adverse outcomes for each patient above 4:1 in general medical surgical care.[49]

However, when providing care during a disaster or pandemic, it is not feasible to maintain the typical 1:1 or 1:2 North American ICU nurse-to-patient ratios. Hence, strategies such as the use of care teams with noncritical care trained nurses off-loading tasks within their skill set from the critical care nurses should be used to mitigate the potential for harm. A similar model has been proposed by project XTREME (Cross-Training Respiratory Extenders for Medical Emergencies) where respiratory extenders are employed during emergencies to compensate for high patient-to-respiratory therapist ratios.[50] Although the benefits and limits of skilled task off-loading and nurse-to-patient ratios in disasters are unclear, there will be a tipping point beyond which higher ratios will lead to such poor outcomes that delivery of critical care confers no benefit. This supposition has led hospitals planning for radiation-related casualties to plan a nurse-to-patient ratio not to exceed 8:1.[51]

Physician Staff:

11. During a disaster or pandemic, we suggest critical care physician oversight and direction of the clinical care teams who provide critical care services, including scheduled patient assessment and treatment plan evaluation. If direct oversight is unavailable, a means of remote consultation should be used.

12. Should expert consultation (eg, pediatrics, trauma, burn, or critical care) not be available locally, we suggest every effort be made by hospitals to ensure that such expertise be provided at a minimum through remote consultation.

13. We suggest hospitals consider the utilization of technology (eg, telemedicine) as an important adjunct to the delivery of critical care services in a disaster to serve as a force multiplier to support response to disaster events. Where no such systems are currently in place, development of a telemedicine or other electronic platform to support patient care delivery is suggested.

Daily patient management by a critical care expert has been shown to decrease hospital and ICU patient lengths of stay and mortality.[52,53] However, it is highly likely that in some areas, critical care experts will not be available locally. Telemedicine consultation in the

TABLE 6] Operating, Performance, Safety, and Maintenance Features to Be Sought in Stockpiled Mechanical Ventilators

Ventilator Criteria	Mandatory Features	Optional Beneficial Features
Operating features		
Power source	AC with battery backup ≥4 h duration using standard evaluation of battery duration based on (mean + 1 SD) patient requirements for ARDS should be at least 4 h duration at: Assist-volume control 16-L minute ventilation 35 breaths/min 15 mL/cm H_2O compliance 20 cm H_2O/L/s resistance 10 cm H_2O PEEP Low-flow oxygen source at 4 L/min and 10 L/min Not 50-55 psi oxygen or medical air source 1:2 I:E time	Pneumatic operable (as additional power source option) External battery option >10 h on defined battery settings and total weight of kitted material remains <30 lb Battery recharge from null to full by AC source within 4 h Range of external and internal power tolerances: Voltage AC: −25% to +15% of nominal value DC: −15% to + 25% of nominal value Frequency: AC: −5% to +5% of nominal value
US FDA approved for pediatric use	Pediatric and infant approved	...
Modes of ventilation	CPAP volume control (assist/control and SIMV)	Pressure control
Control of settings	Respiratory rate PEEP V_T Flow or I:E ratio F_{IO_2} (on 50-55 psi source O_2)	Trigger mode Trigger sensitivity Alternative ventilation modes Flow waveform
Range of flow	Minimum of ≤10 L/min Upper limit ≥80 L/min	...
PEEP	Internal PEEP PEEP compensation	PEEP upper limit ≥20 cm H_2O
Oxygen titration	Room air to F_{IO_2} 1.0 on 50-55 psi oxygen source	...
Operate without 50-55 psi oxygen source	Able to operate on oxygen concentrator or low-flow oxygen source	...
Measurements	Measure and display inspiratory V_T Peak inspiratory pressure	Inspiratory plateau pressure (static pressure) Auto PEEP Expired V_T
Oxygen sensor		Built-in oxygen sensor
Performance features		
Ease to set up/set ventilation settings/troubleshoot	Ability to read screen: At a distance In sunlight In low ambient light	Color coding of connections Unique connections for equipment with specific functions Laminated quick reference and troubleshooting guide Software interface to assist operator setup device

(Continued)

TABLE 6] *(continued)*

Ventilator Criteria	Mandatory Features	Optional Beneficial Features
Oxygen consumption	Time to empty 680-L E tank: Assist-volume control 16-L minute ventilation 35 breaths/min 15 mL/cm H_2O compliance 20 cm H_2O/L/s resistance 10 cm H_2O PEEP F_{IO_2} 1.0 and 0.5 1:2 I:E ratio $>$38 min $F_{IO_2} = 1.0$ $>$104 min $F_{IO_2} = 0.5$ Time to empty 680-L E tank: Assist-volume control 6-L minute ventilation 12 breaths/min 30 mL/cm H_2O compliance Resistance 20 cm H_2O/L/s resistance 5 cm H_2O PEEP F_{IO_2} 1.0 and 0.5 1:2 I:E ratio $>$100 min $F_{IO_2} = 1.0$ $>$280 min $F_{IO_2} = 0.5$	...
Sustained use	Documented evidence of sustained performance for: 2,000 h Assist-volume control 16-L minute ventilation 35 breaths/min 15 mL/cm H_2O compliance 20 cm H_2O/L/s resistance Documented evidence of sustained performance for (may be a separate machine for both 2,000-h evaluations): 2,000 h Assist-volume control 8-L minute ventilation 60 breaths/min Compliance 3 mL/cm H_2O Resistance 200 cm H_2O/L/s Reference contacts for three or more clinical institutions where equipment used $\geq$2 wk continuously	...
Standards	...	Meets *Standard Specification for Ventilators Intended for Use in Critical Care 1* (ASTM F1100-90) Meets *Lung Ventilators for Medical Use: Part 3 Emergency and Transport Ventilators* (ISO 10651-3)
Safety features		

(Continued)

TABLE 6] *(continued)*

Ventilator Criteria	Mandatory Features	Optional Beneficial Features
Alarms	Audible and visible alarms Disconnect, apnea, high pressure, low source gas pressure	Wi-Fi or similar wireless technology included and demonstrated to reliably communicate through common hospital patient room walls At least one receiver per 10 ventilators Receiver is capable of interfacing with any third-party pulse oximeter using standard wireless communication Visible alarm remains lit until reset by operator Multiple types of audible alarms denoting various severities of problems
Stockpiling features		
General durability	Fluid spill resistance Mechanical shock (similar to 4-ft drop, military standard) Mechanical vibration EMC and electrical safety testing Storage temperature and humidity: −20°C to 60°C, 0 to 95% RH Operating temperature and humidity: 5°C to 40°C, 0 to 95% RH	...
Recalls	Vendor must disclose all recalls on ventilator and equipment in the past 3 y	...
Vendor and support contract	Company will continue to produce ventilator model for at least 5 y and continue to support model 10 y after order is completed Able to produce all ventilators within 18 mo from order; if unable to meet this criterion, estimated ramp-up/surge period and time frame for delivery must be stated 24 h, 7 d/wk direct phone access to senior-level technician Vendor responsible for maintaining call coverage Warranty Provide any storage life data, if available	Warranty period starts at first contact with patient Ability to produce all ordered ventilators within 9 mo of order
Maintenance	≥1 y for battery and all equipment interval maintenance; also include battery replacement if needed	All usual maintenance activities can be performed with ventilator in kit All usual maintenance activities can be performed with kits in stockpiled configuration
Purchasing costs	≤$13,000 (2014 USD) Cost must include kitted ventilator, end-user training program, maintenance, and all necessary equipment (ancillary supplies) to ventilate one patient on both 50-55 psi and low-flow oxygen	...
End-user training program	Laminated instruction materials attached	Interactive training through Internet or DVD, with data demonstrating training effectiveness (subject to evaluator review for merit of data)

(Continued)

TABLE 6] *(continued)*

Ventilator Criteria	Mandatory Features	Optional Beneficial Features
Kit	Rigid case Weight of kit with ventilator and all ancillary equipment needed to ventilate one patient ≤30 lb Wheels provided on case	Weight of kit with ventilator and all ancillary equipment needed to ventilate one patient ≤20 lb
Additional approvals/clearances	...	FDA-approved closed-loop technology included with the ventilator (eg, oxygen conservation, ventilator-patient interaction feedback, automated setting modification) Full Joint Air Worthiness Certificate Full Fleet Air Worthiness Release Aeromedical Certification Letter from US Army

AC = alternating current; ASTM = American Society for Testing and Materials; DC = direct current; EMC = electromagnetic compatibility; FDA = US Food and Drug Administration; I:E = inspiratory:expiratory; ISO = International Standards Organization; PEEP = positive end-expiratory pressure; RH = relative humidity; SIMV = synchronized intermittent mechanical ventilation; V_T = tidal volume; USD = US dollars. See Table 3 legend for expansion of other abbreviation. (Adapted with permission from Rubinson et al.[15])

aftermath of an MCC was first described > 25 years ago.[54] Expert critical care telemedicine consult has been shown to improve best practice adherence, lower the rate of preventable complications,[55] improve survival in sicker ICU patients,[56] reduce hospital length of stay, and reduce ICU mortality in general (adjusted OR, 0.40; 95% CI, 0.31-0.52).[55]

Facilities that do not usually provide significant critical care should be prepared to manage patients in place for up to several days until transfer becomes possible. Hospitals that routinely provide critical care may also be challenged with populations that require more specialized care (pediatrics, burn, etc) because the usual receiving facilities for these patients become overwhelmed or incapacitated.

Within the United States, only 9.3% of the acute care hospitals provide pediatric critical care.[57] Between 20% and 30% of the pediatric population lives > 50 miles from a hospital with a pediatric ICU, a level I or II trauma center, or a burn center.[58] There is both state and regional variation in geographic access to burn centers in the United States, and routine referrals to a burn center may require hours of transport by ground or rotary air vehicles.[59] Similar inequalities are described elsewhere.[60,61] Under these circumstances, consultation with critical care experts at other facilities can contribute greatly to safe and effective in-place management.[62] Key facilities should be identified and these relationships established prior to an event, including mechanisms to provide interregional consultation when required. Key supply and educational elements required to care for specialty populations should be identified and addressed preevent. For instance, baby formula and diapers for pediatric patients may be overlooked.[24]

Where critical care physicians are available, consultation and rounds may be modified and other services restricted (clinic, pulmonary, and other nonurgent testing) to provide care for critically ill patients. This may involve off-loading some physician responsibilities onto others. For example, hospitalists may provide most of the day-to-day management, whereas critical care physicians provide overall supervision and input for patients with worsening laboratory or physiologic parameters, complicated ventilator management issues, shock, or a requirement for emergency procedures.

Pharmacy Staff: Medication errors account for more than three-fourths of serious medical errors that occur during normal ICU operations.[63] During a disaster or pandemic, serious medication errors are likely to increase because of increased workload and medications from alternative supplies or with more than one brand name.[64] Pharmacists play an important role on interdisciplinary ICU teams as medication safety experts.[65] There is strong evidence substantiating reductions in adverse drug events when pharmacists are involved in the care of ICU patients.[66] A two-tiered approach is advisable for the delivery of pharmacy services during an disaster or pandemic wherein pharmacists with critical care training and experience

TABLE 7] Methods of Augmenting Critical Care Manpower Surge

Event Phase	Management
Preparation	Map all critical-care trained staff in the hospital
	Define staff skill sets required
	Maintain an inventory of staff skill sets
	Redesign the division of labor (ie, divide according to the skills required)
	Cross-train additional staff
	Teach MCC standard operating procedures
	Train to integrate with the hospital incident command system
	Develop situational awareness tools
Acute	Recall resting staff
	Curtail nonessential activities (eg, elective surgery and clinic services) and redeploy staff to support critical care
	Extend working hours
Chronic	Shelter staff and their families
	Mitigate fatigue (ie, ensure rest)
	Provide transportation services
	Maintain a safe working environment
	Provide staff mental health support
	Have critical care extenders work within a care team model

MCC = mass critical care.

direct the efforts of less trained or experienced pharmacists and pharmacy technicians.[25]

Patient Flow and Distribution:

14. We suggest decisions regarding in-hospital placement of critically ill patients during an MCC (after initial survey and treatment) be performed by an experienced clinician who makes similar triage decisions on a daily basis.

15. Early discharge of ICU patients to the general ward is a complex process, requiring critical care expertise. To enable rapid admission of critically ill patients to the ICU immediately after termination of ED/operating room workup and treatment, we suggest discharge of ICU patients (when possible) during preparation for an impending MCC be given priority simultaneous to decisions made about initial ED patient distribution.

Triage during a pandemic or disaster is intended to provide the best care possible to as many patients as possible.[67] Awareness of the existing resources and alternative resource options as well as prior experience in matching patients to resources enable optimization of resource use. Thus, professionals performing daily triage decisions are best equipped to optimize resource use during a disaster or pandemic. The selection and function of triage officers as well as the performance of triage are described in the "Triage" article by Christian et al[68] in this consensus statement. Methods to avoid overtriage during a pandemic or disaster may include strict criteria to decrease admissions and facilitate discharges as well as cancellation of scheduled procedures. Reverse triage is the main tool used to open additional conventional ICU beds.[69,70]

Avoidance of Overtriage: Imposing strict admission criteria has been shown to decrease overtriage. A relatively small reduction of sensitivity from ≥95%[30] to 90%[31-36] in field triage of individual patients can halve the volume of injured patients transported to level I trauma centers.[71] Several large organizations thus have endorsed prehospital mass casualty triage tools,[72,73] and rigorous triage criteria have been implemented successfully in field hospitals during MCC situations.[74] However, during actual mass casualty events, triage systems often have not been applied and may not perform consistently as an isolated strategy to optimize the use of existing resources.[75] The greatest benefit is gained from triage during a disaster or pandemic when it is performed by experienced providers. The Royal London trauma center experienced 33% overtriage from bombing sites where experienced helicopter emergency medical service providers functioned as triage officers vs 85% from other locations.[43] Hence, it is important to include experienced critical care physicians in the patient distribution process in both accepting patients into and transferring them out of the ICU.

Service Deescalation and Engineered Failure: Canceling scheduled procedures can provide staff and space for disaster and pandemic patients in operative and postoperative areas.[76] However, canceling procedures can have potentially negative consequences for both the patients[77] and the hospitals[32,77-79] involved. Disasters may reach a point where the time and resources invested in certain treatments (eg, extracorporeal membrane oxygenation) are too great to continue to provide them because many more moderately injured patients can benefit from stabilization and prevention of complications than can benefit from advanced critical care interventions in the setting of severe organ failure.[38] Deescalation and engineered failure are discussed in detail in the "Surge Capacity Principles" article by Hicks et al[5] in this consensus statement.

Reverse Triage: Reverse triage is the identification of patients for whom expedited discharge is safe and ethical. To enable immediate rapid admission of critically ill patients to the ICU in a disaster, discharge of ICU patients during preparation for impending MCC should be given priority simultaneously with decisions about initial ED patient distribution. Reverse triage can be a significant contributor to conservation of ICU surge capacity.[69,70,80,81] In addition to the benefits of improved surge capacity, minimizing patient length of stay in the ED through more-rapid admission to the ICU may improve patient outcomes. Delays of > 6 h in transfer from the ED to the ICU have been associated with increased mortality (12.9%-17.4%) and length of hospital stay.[82] Reverse triage requires preparation of relevant plans and procedures and a priori staff training.

Reverse triage may not be effective in all situations[81]; the more efficiently an ICU is run at baseline, the less reverse triage is likely to be beneficial or possible. Optimally, there should be daily evaluation of the potential for discharge to intermediate or floor-level care so that when a disaster occurs, a discharge list is already available. Availability of intermediate care and floor care beds is critical to the success of ICU reverse triage, and modifications of admission criteria to these units should be agreed on in advance to permit maximum flexibility in transfers and care delivery. The discretion of the critical care physician in these times is critical to safe and successful reverse triage.

Deployable Critical Care Services

16. We suggest deployable critical care services be considered a temporary alternative to critical care when loss of hospital infrastructure limits provision of critical care.

17. We suggest deployable critical care services are not definitive critical care facilities but may be used as a temporizing measure for delivery of critical care in a disaster/pandemic setting. Expansion of critical care resources in the hospital environment, with temporary facilities for lesser acuity patients, is preferred over provision of deployable critical care when possible.

18. We suggest deployable critical care services may serve as temporary critical care locations provided there is a clear plan for patient transfer, within a few hours to days, to a definitive treatment location.

19. In crisis surge response, we suggest less intensive treatment of moderately injured patients be prioritized over the deployment of temporary critical care services when it would result in improved outcomes for larger numbers of patients.

Deployable critical care services (eg, field hospitals) have traditionally been used by the military but have only recently been integrated into the civilian setting in response to disasters. Commonly described interventions in the civilian setting include surgical intervention, hemodialysis, and treatment of chronic diseases.[83,84] Contrary to military field hospitals, which primarily focus on trauma, mobile hospitals, when deployed in the civilian setting, should prepare to manage a dynamic case mix that may include both surgical and nonsurgical patients as well as adult and pediatric populations.[84] Nursing staff requirements may be higher than those required within a conventional medical facility.[85] Organizational aspects may be adapted from the experience of professional organizations already working within specific specialties (eg, the Renal Disaster Relief Task Force established by the International Society of Nephrology).[86-89]

Although it is feasible to provide life support in an austere environment, such as a deployed facility, sophisticated critical care is most effectively provided in a tertiary-care hospital, with a number of supports such as consultant subspecialty physicians, interventional radiology, surgical services, microbiology, and laboratory services, among others. Life support without these other services and supports can at best be a temporary measure and will not ultimately serve patients well. Deployable critical care may be a packaged field hospital with advanced capabilities but could also include critical care expertise and materials inserted into a hospital structure deficient in these services (Fig 1).

The most likely application of deployable critical care outside the military is in the use of limited surgical, dialysis, and other capabilities in an area that has a compromised health-care infrastructure; difficulty transferring patients out; and a large number of cases of crush or other orthopedic injury, such as had occurred in Haiti[88,90] and after other massive earthquakes.[9,83,91] Oxygen generation,[92,93] potable water,[94-96] water suitable for dialysis,[97] power sources,[31,98,99] infection control, and diagnostic support[88,100] are all key limiting factors in the delivery of these types of services. Hospital infrastructure destruction and failure during disasters is common.[30,31,101,102] Under these circumstances, the use of a deployable critical care facility or assets while awaiting evacuation of patients or awaiting infrastructure recovery is a

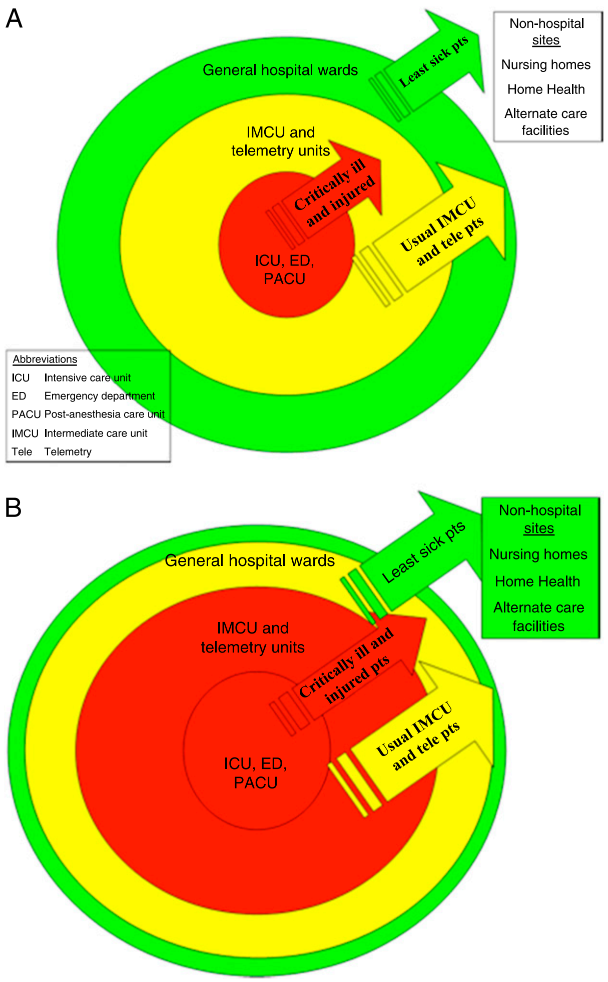

Figure 1 – *A and B, The sequence of surge during a disaster or pandemic illustrating that critical care services should be expanded within existing hospital facilities and that lower acuity patients should be transferred out to temporary facilities rather than attempting to provide critical care in field hospitals. (Adapted with permission from Rubinson et al.[15])*

reasonable temporary measure. Awareness of regional and national assets and their deployment time frame is critical for the success of these strategies.

Finally, during crisis circumstances in general and in disasters involving infrastructure compromise in particular, definitive care options for critically ill patients may become severely limited.[103] When hospital resources are overwhelmed, delivery of critical care to a few consumes a disproportionately large part of hospital staff and supply resources. There may come a time when these resources would be better used for patient stabilization, care, and prevention of organ failure in a less seriously injured but larger group of patients. These decisions about triaging resources may affect select patients, treatments, or the entire ICU. Additional discussion is presented in the "Surge Capacity Principles" article by Hicks et al[5] and "Triage" article by Christian et al[68] in this consensus statement, with the ethical foundation for such decisions also addressed.[38]

Using Transportation Assets to Support Surge Response

20. We suggest surge capacity plans include predetermined standards that define minimal ongoing critical care capability in order to define the framework for decisions regarding patient transfer as the demands on the system gradually increase during a disaster or pandemic.

21. We suggest priority be given to transfer of assets to patients, particularly when transfer of patients to definitive care is limited by dangerous conditions (including considerable risk posed by available transportation options).

22. Transportation used for patient evacuations may also be used to bring in assets (eg, specialty providers and equipment), particularly when access/transport capacity is the limiting factor in patient movement.

Transportation and transfer of critically ill patients is addressed in the "Evacuation of the ICU" article by King et al[104] in this supplement. Most ground and aeromedical transport platforms can only accommodate a single patient and although beneficial, require significant resources. There are also very few critical care transport-capable crews and units available in a given region. Even national assets designed for patient evacuation cannot provide true ongoing critical care to more than a few patients.[105] In certain situations, appropriate personnel and equipment can safely provide ongoing care in nondedicated transport units, but there are significant issues with equipment not being designed for transfer and prehospital use and with training that may affect patient safety.

In addition, according to one estimate, about 7% of adult intensive care patients at any given time may be too ill to survive transport.[106] Adverse events are common during critical patient transports, the most common being equipment malfunctions. Interhospital transport of critically ill patients has been associated with worse patient outcomes, particularly in pediatric populations.[107]

Given these risks, the scarcity of trained transport teams and vehicles for critical care transport, and the complex logistics involved in transporting critically ill patients, in many cases it may be better to bring resources to groups of patients rather than move large numbers of patients to the resources. The Task Force did not reach consensus regarding specific exclusions from this suggestion (eg, situations involving clear danger to patients or staff or infrastructure damage that would preclude continued delivery of critical care). However, bringing providers to unfamiliar facilities to work with unfamiliar equipment also poses risks that should be balanced against the advantages of continuing care in place. It is thus important to seek ways to augment the surge response through use of available transportation assets and concurrent planning for dual use of existing transport resources. Regional coordination of the movement of supplies, staff, and patients in these cases can be critical to success.

Areas for Research

Demographic data of critical care requirements based on the overall population served, specific caseloads, and ICU cases and needs over time is an area that needs to be explored. Methodological assessment of achieved vs required surge would rely on standard ICU management report forms and data forms per patient. At the ICU management and institutional levels, forms based on the framework proposed for critical incident reporting could be used to study the events post hoc.[108] For the individual patient, a well-known tool such as the Therapeutic Intervention Scoring System-28 could be initially converted into a required and provided checklist, with subsequent changes being made as experience is gained with data collection. Such forms would ensure uniform collection of data on the need for vs actual provision of ventilation and monitoring, ICU procedures, and consults. Until such evidence becomes available, careful analysis of community risks, facility role, and availability of regional resources should inform individual facility planning for surge capacity.

Conclusions

The critical care response to a disaster is more prolonged than the response in other sections of the hospital, which necessitates preplanning and training for staff augmentation and redistribution of resources. The limits of effective nurse-to-critical patient ratios in a disaster setting have yet to be elucidated, but lower ratios are clearly beneficial. Critical care physician oversight is crucial whether through direct or long-distance consult (eg, telemetry, telephone), particularly, but not only, for specialized critical care. Interregional consultation relationships should be established a priori to facilitate such consults.

Critical care surge relies on the principles of substitution, conservation, adaptation, reuse, and reallocation of resources. However, it also depends on the presence of stockpiles, ancillary services, and regional collaboration between facilities. Ventilators and their consumable supplies will be the limiting factor when critical care surge is required; thus, regional coalitions should outline operational plans and coordinate hospital efforts to achieve predetermined ventilation goals. Triage by an experienced provider, reverse triage, and service deescalation may all be used to minimize ICU resource consumption. In extreme crises, deescalation may mean prioritization of less advanced care to a greater number of individuals over delivery of critical care to a few. Until such decisions are made, during temporary loss of infrastructure or overwhelmed hospital resources, deployable critical care services should be considered a bridge to definite care. Despite the difficulties inherent to medical practice in such circumstances, it is generally better to convey resources to patients than vice versa.

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Additional information: The e-Appendix can be found in the Supplemental Materials section of the online article.

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