ICU preparedness in pandemics: lessons learned from the coronavirus disease-2019 outbreak

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Purpose of review
The worldwide SARS-CoV-2 pandemic has taken a heavy toll on ICUs worldwide. This review expounds on lessons learned for ICU preparedness during the pandemic and for future mass casualty events.

Recent findings
In the 21st century, there have already been several outbreaks of infectious diseases that have led to mass casualties creating ICU strain, providing multiple opportunities for hospitals and hospital systems to prepare their ICUs for future events. Unfortunately, the sheer scale and rapidity of the SARS-CoV-2 pandemic led to overwhelming strain on every aspect of ICU disaster preparedness. Yet, by analyzing experiences of hospitals throughout the first 7 months of the current pandemic in the areas of infection control, equipment preparedness, staffing strategies, ICU spatial logistics as well as acute and postacute treatment, various important lessons have already emerged that will prove critical for successful future ICU preparedness.

Summary
Preemptive planning, beginning with the early identification of staffing resources, supply chains and alternative equipment sources, coupled with strong infection control practices that also provide for the flexibility for evolving evidence is of utmost importance. However, there is no single approach that can be applied to every health system.

Keywords
coronavirus disease-2019, disaster response, ICU preparedness, pandemic preparedness, SARS-CoV-2

INTRODUCTION

In May 2011, the WHO commissioned a review of the impact of preparedness guidelines in relation to the H1N1 pandemic of 2009. At the time the chairman of that review committee wrote that, 'the world is ill-prepared for a severe pandemic or for any similarly global, sustained, and threatening public health emergency' [1,2]. Eleven years later, the SARS-CoV-2 pandemic has shown the truth of that prescient comment. It has laid bare vulnerabilities in local and system-level preparedness even though there were countless lessons to be incorporated from previous outbreaks of similar viruses: SARS-CoV-1 in 2003, H1N1 in 2009 and again in 2017 [3].

Indeed, in 2012, the National Academy of Sciences in the United States (US) released a Crisis Standards of Care with intent to provide hospitals a framework for design and implementation of disaster preparedness plans [4▪]. This was followed by scientific organizations culminating in the US National Influenza Pandemic Preparedness Plan in 2017 [5]. But in early March 2020, the Society for Critical Care Medicine (SCCM) conducted a survey of over 150 000 critical care providers to assess ICU preparedness in light of the looming pandemic and nearly all respondents reported they had significant concerns regarding their institutions' preparedness with over half reporting significant impacts as a result [6]. Seven months into the current SARS-CoV-2 pandemic, there are already many important lessons to be learned of which the following review hopes to elucidate, so that ICUs can continue to prepare for future disasters.

INFECTION CONTROL

Adequate personal protective equipment (PPE) is a key pillar of ICU preparedness. The WHO

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KEY POINTS

- During this pandemic, ICUs have encountered enormous strain on a scale not seen in a century in all areas of disaster preparedness: physical space, staffing, equipment and resources, and hospital systems input, throughput, and output.
- Rigorous infection control measures and frequent education and training of ICU staff is a key component of preparedness.
- The identification of key staff, resources, supply chains, and space is important for any preparedness plan from inception.
- ICU preparedness plans must be flexible and have the capacity to adapt to changing guidelines and strain as the pandemic continues to evolve.
- Continuing assessment of ongoing preparedness activities and outcomes of procedures are essential and should play a large role in disaster planning policy for ICUs as there is no 'one size fits all' approach.

recommends standard PPE include medical masks, gowns, gloves, eye protection (face shields or goggles); aerosol-generating procedures (i.e. endotracheal intubation, noninvasive ventilation or heated high-flow supplemental oxygenation, cardiopulmonary resuscitation, bag-mask ventilation, bronchoscopy) require particulate respirators, such as N95 or FFP2-certified respirators and fluid-resistant gowns. Additionally, for those that fail respirator mask fit testing, powered air-purifying respirators are needed. These all present logistical challenges. Modifying nursing tasks by moving intravenous line pumps and other devices outside rooms can also minimize infection risk as well as limit PPE use. Similarly, altering dosing or the use of certain medications can also be considered to minimize risks and PPE supply demand.

An extensive supply chain is critical. Reuse, recycling, and reconditioning of PPE is likely not only possible but required. Fit testing should be regularly performed prior to outbreaks as facial contours can change over time. Assuming appropriate PPE supplies, the procedure of donning and doffing requires urgent attention and training. Trained observers are ideal as the risk of self-contamination increases when doffing. Additionally, surface decontamination is especially important on surfaces, such as plastic and stainless steel. Proper disposal of soiled objects and terminal sterilization of vacated rooms is critical.

Another important infection control measure has been restricting family visitation. Although the emotional toll to patients and their loved ones cannot be underestimated, the risk of either introducing community-acquired SARS-CoV-2 infection into an ICU (placing both noninfected patients and staff at risk) or reverse transmission back into the community is of even greater concern. Most hospitals and hospital systems have, thus appropriately restricted civilian visitation instead relying on video conferencing or other interfaces [2]. In the same vein, hospitals have adapted universal masking guidance for all staff and visitors along with mandatory objective and subjective screening at entry points.

But as more becomes known about the virus throughout this pandemic, guidelines have rapidly changed. Close planning and open communication with trained infection control personnel is important for clarification and education for all essential staff [7▪]. In the same vein, when a vaccine becomes available to healthcare providers, ICUs must advocate that their staff be given high prioritization status for vaccination, given the heightened degree of exposure faced.

SURGE CAPACITY

The sheer volume of critically ill patients infected with SARS-CoV-2 has at times overwhelmed hospital systems and experience requires extensive ICU surge capacity planning. Most crucial, hospital systems must have a rapidly scalable disaster response encompassing four key elements: physical space, medical staffing, equipment, and the system itself (often referred to as the four 's': space, staffing, stuff, systems) [2,7▪]. ICUs should also be able to expand baseline capacity by 20% in disaster situations [8]. At the beginning of the pandemic, the initial approach taken was largely similar to that of previous outbreaks and even with high-consequence pathogens such as Ebola: containment. Negative-pressure, single-patient rooms, specialized separate quarantine units, and biocontainment units were utilized. However, in almost every large medical center that was inundated with critically ill patients, surge capacity had to be rapidly augmented and increased. Thus far, evidence has shown that of those infected with SARS-CoV-2, approximately 5% will require ICU-level care [9,10,11▪▪].

One approach to rapidly increasing ICU bed capacity has been to drastically reduce elective surgical procedures thereby increasing the number of ICU-level beds available, which in turn can relieve the strain from specialized ICUs to transfer non-SARS-CoV-2-infected patients. An additional approach employed by one hospital system in an urban setting in the United States was to distribute critical SARS-CoV-2 patients throughout ICUs as each unit had a certain number of negative-pressure rooms. This allowed ICUs to become accustomed to the heightened care these patients required, allowed staff time to perfect infection control measures and techniques, and allowed large numbers of staff to develop a certain comfort level [7■].

A second approach has been to have surge or 'pop-up' units, little used wards, or step-down facilities that can be rapidly converted into ICU-level locations to care for infected patients. Staffing becomes an issue with these units but the ability to separate infected patients from other areas of the hospital proved to be advantageous. Additionally, the general approach of cohorting proved successful during the H1N1 pandemics and again for SARS-CoV-2, as no hospital possesses enough negative-pressure rooms to accommodate the volume of patients nor can correctly predict the amount of ICU beds that will be required [12]. Possible ICU-level rooms include operating rooms, step-down units, or postanesthesia recovery units. However, an important consideration that cannot be ignored with the conversion of anesthesia ventilator units is that ventilators used in these units are not the same as standard ICU ventilators and need trained anesthesia providers [13].

The rapid surge and incorporation of new ICU-level care rooms and facilities also requires efficient ICU bed management. This demands a multidisciplinary approach with key stakeholders including hospital administration, nursing, physicians, respiratory, ancillary staffing in close communication. For large hospital systems, a centralized coordinating center may be of benefit. Lastly, another aspect of ICU surge capacity is to evaluate, which non-pandemic conditions ordinarily managed in an ICU can be managed in step-down units or monitored floors. For example, some hospitals routinely admit diabetic ketoacidosis, certain postoperative, and certain cardiac patients to the ICU whereas others do not. It must also be clear to clinicians, through a formal declaration, when a crisis standards of care context exists in the hospital coupled to a very high level of situational awareness of patient load, resources, and shifting policies [3].

STAFFING

Around the world, the pandemic created a need for intensivists who often exceeded supply [14■]. As the previously mentioned SCCM report makes clear, the majority of ICUs normally function at or near capacity and in the United States, the number of ICU beds has been shrinking. Although many different approaches have been used to adjust to this, an important lesson from the pandemic is that institutions must first be aware of their current staffing resources. This not only includes critical care providers in ICUs but also those with prior critical care training and/or airway management skillsets (i.e. emergency medicine and anesthesiology physicians as well as hospitalists with procedural competency). With these being known, provider staffing in ICUs can be significantly augmented [4■]. One important approach taken by an urban medical center was the reassignment of pediatric critical care providers and nurses to caring for adult patients. This increased staffing capacity by a substantial amount [15]. Additionally, in many hard-hit areas, this care was further supplemented by employing noncritical care providers under direction of an intensivist. This approach creates a tiered-staffing structure, an idea that had been explored by SCCM previously in creating guidance for pandemics [4■].

An important piece of provider staffing has also been the rapid evolution of telemedicine. One hospital system created a tele-ICU infrastructure that provided care not only to hospitals within the system but also to other facilities hard hit by the virus within several weeks [14■]. This allowed for expansion of care but also provided staffing relief as the quick expansion of multiple units for surge can easily overwhelm staff and lead to infections among healthcare workers on the frontlines [16]. Telemedicine, if employed properly and allowing for an adaptive approach to critical care by utilizing individual hospitals' resources and unique approaches, has proven to be an effective, essential, and efficient portal for delivery of quality care.

Given the rise in the volume of patients, the nurse : patient ratio will likewise need to be increased; some places reported increases of 1 : 1.5 to 1 : 3 [17]. Although critical care-trained nurses should focus on actual bedside patient care, they can be supported by noncritical care nurses in medication and equipment preparation outside patient rooms. They also can serve as trained observers for PPE donning and doffing.

EQUIPMENT/RESOURCES

With the SARS-CoV-2 pandemic affecting nearly every region of the world simultaneously, equipment and supplies has been of paramount concern. During any disease outbreak, requirements for PPE increase but the current pandemic has placed enormous strain on global supply chains. Within hospitals and hospital systems, stockpiles must be coordinated and alternative means of supplies obtained rapidly. Given the risks posed with contamination from multiple surfaces as well as the costs associated with sterilization, single-use items are preferable [17]. However, reusable PPE is becoming more feasible to accomplish and conservation is made possible by the use of cohorting patients and incorporating warm/hot zones that permit entry and reentry of medical staff without having to doff and re-don PPE. The highest priority must be given to adequate PPE for frontline staff in emergency rooms and ICUs.

In addition to PPE supply chain considerations, it is also crucial to secure supply chains for essential medications (e.g. sedatives, paralytics, intravenous fluids) that are frequently used in ICUs. The same consideration applies to mechanical ventilators, noninvasive ventilation machines, high-flow oxygen cannulas, dialysis machines, and vascular access devices.

PHARMACEUTICAL TREATMENTS

ICUs will likely be the location where experimental or repurposed therapeutic are first trialed in hospital systems. Thus, they must develop ways of allocating what will likely be limited supplies, through patient lotteries or equivalent means in qualifying patients. Additionally, they should give consideration as to whether they will participate in clinical trials during a public health emergency.

FUTILE CARE

Prior to the COVID19 pandemic, SCCM had been raising awareness of the societal problem of futile care and indeed many interventions undertaken for COVID-19 patients would be deemed futile care. Futile care in a nonpandemic setting is problematic enough but, in a pandemic, when hospital capacity is compromised, it rises to the utmost level of importance. It is critical to determine, which interventions would be futile ahead of time based on patient characteristics and objectively adhere to those determinations. Such criteria should also be applied to acceptance criteria for interhospital transfers [18].

EXTRACORPOREAL MEMBRANE OXYGENATION

Extracorporeal membrane oxygenation (ECMO) deserves a special note here. It is a resource-intensive, potentially life-saving modality not universally distributed throughout the world but rather located in specific centers. ECMO has previously been used successfully during pandemics – most notably during the 2009 H1N1 pandemic as a salvage therapy – and technology has improved dramatically [19▪]. Indeed, even as a salvage therapy in the last pandemic regional ECMO networks developed organically [20]. As such, the WHO's initial interim guidance for SARS-CoV-2 suggested that regions with access to ECMO be an option for patients with refractory hypoxemia despite maximal critical care support. In fact, limited data that is thus-far available has shown relatively positive results [21]. However, regionalization and coordination are often lacking. Moreover, as the current pandemic has shown, when the overall burden of disease vastly overtakes and surpasses available resources, ECMO utilization becomes less important. But underlying this entire approach is the notion that ECMO guidance and criteria must be created in advance and objectively applied [22]. The initiation of ECMO should be discussed early and with a multidisciplinary team.

Importantly, data has traditionally shown that patients with severe respiratory failure (acute respiratory distress syndrome or ARDS) in general fare better when these patients are transferred to ECMO-capable facilities [23]. However, during a pandemic, a regional allocation system must be set in place and regularly meet to report on capacity, transfer capabilities, as well as standardizing procedures and keeping clear communication with community hospital settings [19▪]. In preparedness plans for the continued management of this pandemic and future disaster events, ECMO resources should be included.

POSTACUTE CARE CONSIDERATIONS

Patients admitted to ICUs with severe disease as a result of SARS-CoV-2 infection invariably end up requiring mechanical ventilation as a result of ARDS and/or septic shock. But more patients are also surviving to recovery – a recovery that is often burdensome and lengthy. Many hospitals have involved palliative care teams in the care of patients admitted to ICUs, and this has helped tremendously with communication and advocacy given the visitation restrictions put in place. As patients are severely deconditioned from prolonged critical illness and from being on a ventilator, their postacute care needs will likely include a lengthy stay in a skilled nursing facility, inpatient rehabilitation facility, long-term care hospital, or home care – almost 50% of ICU patients in general require these services [24▪,25,26].

Early on it was also recognized that nursing facilities could be used to offload ICU patients who no longer needed that level of care and could rapidly embark on recovery [24▪]. But issues presented themselves immediately: skilled nursing capacity at the start of the SARS-CoV-2 pandemic was estimated at 85%, evidence again of inadequate surge capacity. And there have been outbreaks at skilled nursing facilities, notably in the United States in Washington State where 25% of Life Care Center's residents died as a result of a SARS-CoV-2 outbreak [27]. Just like in hospitals, no-visitation policies had to be enacted and group activities canceled. Moreover, some patients that are transferred out of ICUs likely still have the capability to transmit disease.

Thus, prior to discharge to a facility, admissions criteria need to be clear. Designated COVID rehabilitation centers and non-COVID centers should have standardized preadmission testing strategies. The current discharge processes vary among facilities with some requiring negative SARS-CoV-2 testing even if patients were admitted to a hospital with a negative test. PPE adequacy for facility staff is also an important consideration that needs to be addressed on the same level as providers in acute-care hospitals [28]. Lastly, post-ICU care clinics specifically designed to help patients cope with recovery from critical illness are an important consideration, reinforced by the SARS-CoV-2 virus' ability to cause 'long haul symptoms' even in those with mild infection.

CONCLUSION

The global SARS-CoV-2 pandemic has exposed systemic healthcare vulnerabilities at all levels and ICU preparedness activities have had to adapt both tactically and strategically. What has also been made clear is that in the realms of staffing, space, stuff, systems, and infection control, there is no 'one size fits all' approach [9,10]. ICUs need to have plans that are malleable to specific situations, resources, and unique issues. Wellbeing and safety of staff is and should be paramount to ensuring readiness and preparedness of ICUs [15]. As this pandemic continues to evolve and as outbreaks will continue to occur, pandemic preparedness should remain at the top of disaster preparedness planning.

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Conflicts of interest

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■■ of outstanding interest

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