Critical Care Surge Response Strategies for the 2020 COVID-19 Outbreak in the United States

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About This Report

The coronavirus disease 2019 (COVID-19) pandemic is placing extraordinary strains on the U.S. medical system, most especially hospitals. Hospitals are searching for ways to ramp up their surge capacity to provide critical care for the sickest COVID-19 patients. This report presents a range of strategies for creating critical care surge capacity in the nation's hospitals. The report is accompanied by a user-friendly, Microsoft Excel–based tool that allows decisionmakers at all levels—hospitals, health care systems, states, regions—to estimate current critical care capacity and rapidly explore strategies for increasing it.

The Excel tool and related user guide can be accessed at www.rand.org/t/TLA164-1.

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Summary

The coronavirus disease 2019 (COVID-19) outbreak is creating unprecedented stresses on hospital and health care systems around the globe. Hospitals, health care systems, states, and regions need to urgently assess their resources, identify potential bottlenecks, and create strategies for increasing critical care surge capacity, the resources needed to care for the sickest patients with the novel coronavirus.

In late March 2020, the United States surpassed China as the country with the greatest numbers of confirmed COVID-19 cases (Lin, 2020), and it is estimated that up to 60 percent of the population in the United States could be infected over the course of the pandemic if social distancing measures are not properly observed (Dara and Afessa, 2005; Harvard T. H. Chan School of Public Health, 2020). The majority of COVID-19 cases are mild, and patients recover with little or no need for medical care. However, in a cohort of COVID-19 patients in China, Wu and McGoogan, 2020, reports that 15 percent of cases were considered severe, and 5 percent were considered critical. In Italy, 54 percent of COVID-19 patients required hospitalization, and up to 18 percent required intensive care unit (ICU) care (Chow and Saliba, 2020; Morris, 2020). As in Italy, many U.S. hospitals and health systems frequently operate at or near capacity even during normal times (Mishra, 2001), and recent analyses suggest that the U.S. critical care system will be seriously strained—and possibly overwhelmed—during the coming weeks and months (Abir, Cutter, and Nelson, 2020; Murthy, Gomersall, and Fowler, 2020).

In order to function appropriately, ICUs need *space, staff, and stuff* (Carmona, 2006). Bottlenecks or gaps in any one of these three can significantly limit the number of patients receiving critical care. The numbers of ICU beds, critical care nurses, respiratory therapists (RTs), and ventilators are limited in the United States. Thus, meeting the need for critical care capacity in the coming weeks and months will require "out-of-the-box" thinking: creative and nimble strategies for adapting, substituting, conserving, reusing, and reallocating equipment, space, and supplies (Hota et al., 2010), as well as robust efforts by those outside the health care system to address regulatory, supply chain, and other barriers.

In this report, we present a list of strategies for creating critical care surge capacity based on a review of literature on experiences during past outbreaks and the current COVID-19 pandemic, a survey of frontline clinicians conducted in collaboration with the American College of Emergency Physicians, and two telephone roundtables with leading emergency and critical care physicians and public health and preparedness experts from around the country. The strategies are organized into two tiers:

- Tier 1 includes *contingency capacity strategies*: adapting medical care spaces, staff constraints, and supply shortages in a way that increases capacity without significant impact on medical care delivery (Hick, Barbera, and Kelen, 2009). Strategies might

include converting stepdown, post-anesthesia care unit (PACU) beds or operating rooms (ORs) to ICU beds, drawing on emergency department and/or PACU nurses not on shift for ICU care, and borrowing, purchasing, or acquiring additional ventilators from stockpiles.

- Tier 2 includes *crisis capacity strategies*: changes that likely will have significant impact on routine care delivery and operations. Strategies might include turning regular hospital beds into ICU beds, using open ICU beds in the Veterans Health Administration and other federal/noncivilian facilities, using ICU beds in mobile hospitals, and reopening shuttered hospitals. They might also include providing just-in-time training, changing staffing and supervisory ratios, and altering standards of care.

To illustrate the possible impact of these strategies on capacity, we used data on the ten Federal Emergency Management Agency (FEMA) regions to estimate the number of patients accommodated, given the number of available critical care doctors and nurses, RTs, ventilators, and hospital beds.

In our analysis, we found that the number of ventilators is the most common limiting factor, followed by the number of critical care doctors. The number of nurses, RTs, or beds was not the limiting factor in any FEMA region. As expected, moving from baseline up to the first and second tier increases critical care surge capacity. But the degree of increase in such capacity depends on both the amount of resources available and the specific combinations. In most situations, Tier 2 options produce considerably more capacity than Tier 1 options, but in some cases, there is little additional gain.

We conclude the report by identifying considerations and decisions for hospitals and state, regional, and federal decisionmakers. We also provide links to a variety of other resources, and this report is accompanied by a user-friendly, Microsoft Excel–based tool that allows decisionmakers at all levels—hospitals, health care systems, states, and regions—to estimate current critical care capacity and rapidly explore strategies for increasing it. The tool and a brief guide to its use can be found at www.rand.org/t/TLA164-1.

Acknowledgments

1. Background

The coronavirus disease 2019 (COVID-19) virus is creating unprecedented stresses on hospital and critical care systems around the globe. Unknown to the world only months ago, the virus was first reported in Wuhan Province, China, at the end of December 2019. The timeline of key events around the U.S. COVID-19 outbreak is depicted in Figure 1.1. The situation in China has improved, but it has been worsening steadily in Europe. Italy has been hardest hit, with 69,176 cases and 6,820 deaths as of March 24, 2020 (Worldometer, 2020a). In late March, the United States exceeded the number of confirmed COVID-19 cases in China (Lin, 2020), with significant community transmission occurring week to week since the first case was confirmed in the country on January 20, 2020 (Centers for Disease Control and Prevention [CDC], 2020). It is estimated that up to 60 percent of the U.S. population could be infected over the course of the pandemic and that the number of cases will peak at different times in different states (Dara and Afessa, 2005; Harvard T. H. Chan School of Public Health, 2020). For example, cases in California increased rapidly the week of February 18, and there was a rapid increase in cases in New York, which became an outbreak epicenter, the week of March 17.

Figure 1.1. Timeline of Key Events in the COVID-19 Outbreak

January 3, 2020
National Health Commission of the People's Republic of China notifies the World Health Organization (WHO)

January 6, 2020
China Centers for Disease Control (CDC) emergency response activated (Level 2)

January 15, 2020
China CDC response upgraded to Level 1

January 30, 2020
WHO declares public health emergency of international concern

January 31, 2020
US Secretary of Health and Human Services declares a public health emergency

March 1, 2020
President proclaims that the COVID-19 outbreak in the United States constitutes a national emergency

March 11, 2020
WHO declares COVID-19 outbreak a pandemic

March 18, 2020
President signs Defense Protection Act

March 19, 2020
State Department issues Level 4 "Do Not Travel" Advisory

Policy

Not to Scale

Health

December 29, 2019
Cases of pneumonia linked to Huanan Seafood Wholesale Market in Wuhan, China

January 13, 2020
First confirmed case outside of China

January 10, 2020
China CDC publicly shared the gene sequence of the novel coronavirus

January 8, 2020
China CDC announces novel coronavirus as causative pathogen for outbreak

January 20, 2020
First case confirmed in United States (US)

February 29, 2020
First death in US

March 17, 2020
Cases confirmed in all 50 states

The majority of people with COVID-19 can be managed at home. But among 44,000 cases in China, about 15 percent were considered severe, and about 5 percent were considered critical (Wu and McGoogan, 2020). In Italy, 54 percent of COVID-19 patients required hospitalization, and up to 18 percent required intensive care unit (ICU) care (Chow and Saliba, 2020; Morris, 2020). Unfortunately, as in Italy, many U.S. hospitals and health systems frequently operate at or near capacity (Thompson, 2020). Moreover, access to critical care varies considerably across the country (Tsai, Jacobson, and Jha, 2020). Only half of U.S. hospitals deliver critical care services, with the majority of ICU beds (94 percent) located in metropolitan hospitals (Halpern and Tan, 2020). Further, almost half of the hospitals in the United States do not have critical care physicians (Halpern and Tan, 2020). Given that COVID-19 can lead to respiratory failure requiring mechanical ventilation, there is growing concern that there will be shortages and a mismatch between available critical care resources and projected demand posed by the COVID-19 pandemic (Abir, Cutter, and Nelson, 2020; Murthy, Gomersall, and Fowler, 2020).

Under just about any scenario, the U.S. health care system will be strained, if not overwhelmed. A model from the Harvard T. H. Chan School of Public Health calculates a capacity gap of inpatient hospital beds at 1,373,248 (274 percent of available capacity) and of ICU beds at 295,350 (508 percent of available capacity) to accommodate a 40 percent prevalence in the U.S. population after six months without an approach to "flattening the transmission curve" (Tsai, Jacobson, and Jha, 2020). Alternatively, if the transmission curve is flattened with successful social distancing measures, the need for inpatient and ICU beds would be reduced (Tsai, Jacobson, and, Jha 2020; see Figure 1.2).

Figure 1.2. Critical Care Bed Demand and Suppression Strategies Modeled for the United States
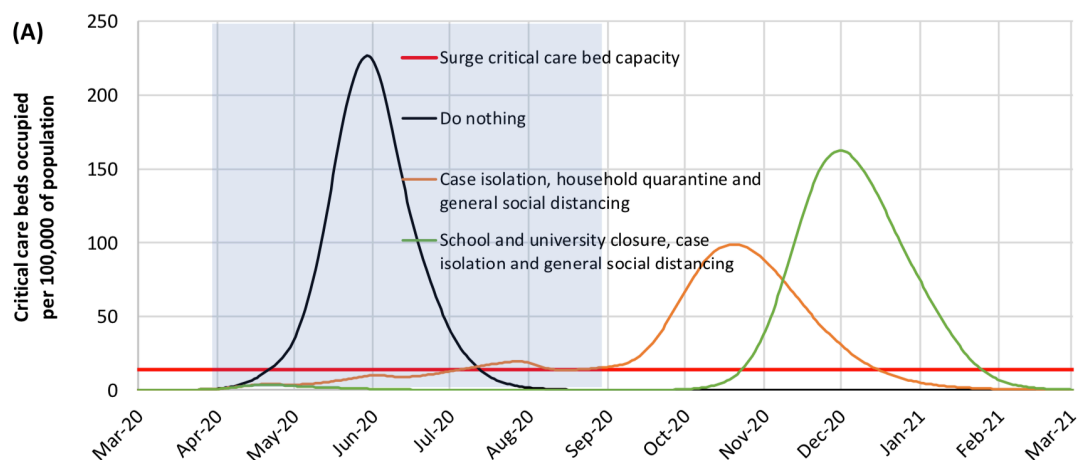
SOURCE: Ferguson et al., 2020, p. 19. Used with permission.

Meeting the need for critical care capacity in the coming weeks and months will require outside-the-box thinking: creative and nimble strategies for using available staff and resources. This need becomes all the more urgent as (inevitably) some health care workers contract COVID-19. It will also require creative efforts to adapt, substitute, conserve, reuse, and reallocate equipment, space, and supplies (Hota et al., 2010). It will also require robust efforts by those outside the health care system to address regulatory, supply chain, and other barriers. Information on COVID-19 disease characteristics and critical care needs are included in Box 1.1.

The purpose of this report is to summarize a variety of evidence-based and promising strategies for creating and expanding critical care surge capacity in the nation's hospitals. We assembled these strategies using a review of literature on experiences during past outbreaks (e.g., severe acute respiratory syndrome [SARS] 2003, H1N1, Middle East respiratory syndrome [MERS], Ebola), a survey of frontline emergency physicians conducted in collaboration with the American College of Emergency Physicians (ACEP), and two roundtables conducted via conference calls with leading emergency and critical care physicians and public health and preparedness experts from around the country (additional information on methods is provided in the appendix). The report is accompanied by a user-friendly, Microsoft Excel–based tool that allows decisionmakers at all levels—hospitals, health care systems, states, regions—to estimate current critical care capacity and rapidly explore strategies for increasing it using their own data and surge assumptions (Abir et al., 2020).

Box 1.1. COVID-19 Disease Characteristics and Critical Care Needs

All age groups are susceptible to COVID-19 infection. However, worldwide, the death rate for individuals ages 80 and older who are infected by the COVID-19 virus is significantly higher than for all other age groups (Worldometer, 2020b). Further, those with comorbidities, such as cardiovascular disease, diabetes, chronic respiratory disease, hypertension, and cancer, have an increased mortality risk (Worldometer, 2020b).

A study from Wuhan, China, evaluating the clinical course of 136 patients hospitalized with COVID-19 infection, showed that the median time from first symptom to dyspnea was 5.0 days, to hospital admission was 7.0 days, and to acute respiratory distress syndrome (ARDS) was 8.0 days. Of the hospitalized patients in this study, 26.1 percent required transfer to the ICU because of complications, such as ARDS, arrhythmia, and shock. Of the 36 patients in the ICU, four (11.1 percent) received high-flow oxygen therapy, 15 (41.7 percent) received noninvasive ventilation, and 17 (47.2 percent) received mechanical ventilation (four were switched to extracorporeal membrane oxygenation). Further, studies show that about 20–30 percent of COVID-19 hospitalized patients with pneumonia have required mechanical ventilation (Specht, 2020; Wu and McGoogan, 2020).

In other studies, among ICU patients with COVID-19, 11–64 percent received high-flow oxygen therapy, and 47–71 percent received mechanical ventilation (Wang et al., 2020; CDC, 2020). A small proportion have also been supported with extracorporeal membrane oxygenation (3–12 percent; Wang et al., 2020; CDC, 2020).

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2. Essential Components of Critical Care Capacity

To function appropriately, ICUs need *space, staff, and stuff* (Carmona, 2006). The number of ICU beds (Halpern and Tan, 2020), critical care nurses, respiratory therapists (RTs), and ventilators are limited in the United States (Kliff et al., 2020). For hospitals and communities to effectively respond to the anticipated surge in the critical care needs for COVID-19 patients, a balance between space, staff, and stuff (i.e., resources) needs to be achieved (Figure 2.1).

Figure 2.1. Depiction of the Balance Needed Between Space, Staff, and Stuff for an Effective Critical Care Surge Response
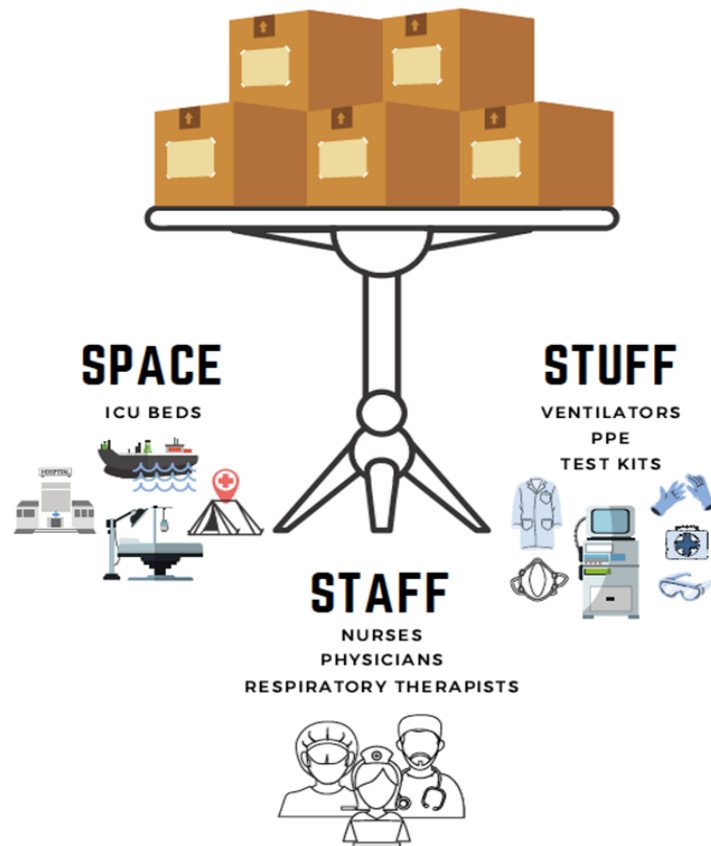
NOTE: PPE = personal protective equipment.

Baseline Capacity

At baseline, critical care in U.S. hospitals is delivered in ICUs, including adult medical, cardiac, surgical, neurosurgical, pediatric, and neonatal ICUs. The required staff to take care of critically ill patients includes RTs, critical care nurses, and critical care physicians, among others

(Box 2.1). Many ICU patients need to be placed on mechanical ventilators for respiratory support. However, ventilator supplies vary considerably across communities (Rubinson, Vaughn, et al., 2010).

Box 2.1. Key Facts About Critical Care Capacity in the United States

- Approximately 97,000 ICU beds (Halpern and Tan, 2020)
- 94 percent of ICU beds are located in metropolitan areas (Halpern and Tan, 2020)
- Physician-to-patient ratio is 1:10 (Ajao et al., 2015; Dara and Afessa, 2005)
- Nurse-to-patient ratio is between 1:1 and 1:2 (Ajao et al., 2015)
- RT-to-patient ratio ranges from 1:4 to 1:14 (Parker et al., 2013; Ajao et al., 2015; California Society for Respiratory Care, 2016; West et al., 2016)
- 62,000 ventilators (20.5 per 100,000 people; Halpern and Tan, 2020; Rubinson, Vaughn, et al., 2010)

Surge Capacity

Even in the early stages of the pandemic in the United States, frontline providers expressed concerns about the ability to marshal the types and quantities of space, staff, and stuff needed to meet the projected demand for critical care. To understand these concerns, we collaborated with ACEP to administer an online survey on March 13, 2020, to 32,056 members in the United States and abroad, querying about baseline and COVID-19 surge needs. A total of 337 surveys were completed by participants from urban (146), suburban (130), and rural (61) hospitals.

The most-cited concerns were shortages in diagnostic kits, a shortage of negative pressure room capacity, and a shortage of N95 masks (see Table 2.1). The following responder comment illustrates the concern about a lack of PPE:

> We are already critically low on masks. We get one paper mask at the beginning of the shift and told to put it on and not take it off. They worry we will infect ourselves if we take it off. So, no eating or drinking is allowed on a 12-hour shift to try to conserve masks.

Others noted that hospitals are routinely stretched thin (Abir, Cutter, and Nelson, 2020; Derlet and Richards, 2000), even more so given that the COVID-19 outbreak comes on the heels of a challenging flu season. As one respondent put it:

> Our hospital is already at capacity with holding [patients] in the ED [emergency department]. Nursing homes aren't taking patients so we can't empty the floors. We are short-staffed even without pandemic surge and mass hysteria. Our physicians at baseline are seeing more than we are comfortable seeing on a regular basis and hysteria, threat of litigation, endless updates are making working on the front lines even more challenging.

The situation is even more difficult in small critical access hospitals, which typically lack the resources of larger urban hospitals. As one respondent noted:

> We are a 25-bed critical access hospital with nine beds in the ED. We have no ICU facilities. The ED MD is the de facto critical care doc. It would not take too

many patients to overwhelm our capabilities. The Level 1 receiving hospital, an hour north, has been full for most of the winter. If their ICU fills up we'll be scrambling indeed.

Because the crisis falls on a system that is already stretched thin, creating the critical care capacity needed for the surge in COVID-19 patients will require creative thinking about the allocation and use of space, staff, and stuff.

Table 2.1. Survey Responses to the Question: "What Areas Are You Currently Challenged with in the Setting of the COVID-19 Outbreak? Check All That Apply."

Area of Concern	Percentage
Shortages in COVID-19 diagnostic kits	79
Negative pressure room capacity for isolation of suspected or confirmed cases	74
Shortages in N95 masks	70
Screening patients in triage	64
Keeping track of guidance around criteria for testing for COVID-19	58
Increased patient volume due to worried well patients presenting to the ED	54
ED critical care capacity for treating suspected or confirmed cases with severe illness	53
Getting calls from the community with questions about COVID-19	51
Controlling public messaging around COVID-19	48
Training staff around proper PPE use	41
Provider work absenteeism	23
Suspected or confirmed COVID-19 transfers from other EDs	17

NOTE: These questions were asked on March 13, 2020.

3. Strategies to Create Critical Care Surge Capacity

Surge response strategies must work both to increase the supply of resources and to decrease the demand on the system (Hota et al., 2010). According to prior research, strategies for increasing care capacity include adaptation, substitution, conservation, and reuse/reallocation (Hota et al., 2010). Lessons from past responses to pandemics indicate that hospitals should prioritize training and deploying reserve staff and acquiring the needed material to expand ICU capacity within current physical space (Gomersall et al., 2006).

According to data gathered from a review of the literature related to hospital response to past pandemics and response to the COVID-19 outbreak, as well as from our study's roundtables, we have generated a two-tiered list of strategies for creating critical care surge capacity, adapted from Hick, Barbera, and Kelen, 2009. Tier 1 includes *contingency capacity strategies*: adaptations to medical care spaces, staffing constraints, and supply shortages that are not anticipated to significantly affect routine care delivery (Hick, Barbera, and Kelen, 2009). Tier 2 includes *crisis capacity strategies*: adaptations likely to have a significant impact on routine care delivery and operations. We emphasize that the Tier 2 strategies are intended to be dramatic, befitting their use in crisis situations, and we draw on both published literature and on-the-ground experience in New York City, the first city in the United States to face crisis conditions. The tiered surge strategies for space, staff, and stuff are presented in Table 3.1 and are described in the following sections. Note that the strategies outlined in Table 3.1 are not exhaustive. Given the fluid nature of the evolving pandemic, and depending on the critical care resource demands on given hospitals and health systems, more-conservative or more-aggressive approaches could be indicated.

Table 3.1. Tiered Critical Care Surge Strategies for Space, Staff, and Stuff

	Tier 1 Surge Strategies	Tier 2 Surge Strategies
Space		
Beds	• Convert stepdown, post-anesthesia care unit (PACU) beds or operating rooms (ORs) to ICU beds • Double up patients in ICU rooms	• Convert regular hospital beds to ICU beds (e.g., by moving regular floor patients to makeshift hospitals, such as in university dorms and hotels, to make room for critical care patients) • Use open ICU beds in federal/noncivilian facilities, including hospital ships and Veterans Health Administration (VHA) facilities, for civilians • Use ICU beds in mobile hospitals • Reopen shuttered hospitals
Staff		
Nurses	• Draw on off-shift ED and/or PACU nurse pool for ICU care • Recruit off-shift ICU nurses from the VHA and other federal facilities	• Provide "just-in-time" training for floor nurses and have them provide critical care under supervision of a critical care nurse (e.g., two floor nurses per one ICU nurse) • Implement crisis standards of care for ICU nurse–to-patient ratios (from the standard 1:1 or 1:2 to 1:3) • Use upper-level nursing students to assist with care for less-sick patients to free up floor nurses for critical care
RTs	• Increase ventilator-to-RT ratios	• Draw on off-shift OR nurse anesthetists to work independently or under RT supervision
Physicians	• Draw on off-shift ED and/or anesthesiologist physicians and surgeons with critical care experience for ICU care • Recruit off-shift ICU physicians from the VHA and other federal facilities from the same or different localities	• Have hospitalists provide critical care under supervision of a critical care physician (e.g., two hospitalists per one ICU physician)
Stuff		
Ventilators	• Purchase domestically available ventilators • Borrow ventilators from other hospitals in the region • Acquire ventilators from stockpiles	• Use one ventilator for multiple patients (i.e., "ventilator splitting")

Space Strategies

The ideal setting for critical care is an ICU. Table 3.2 outlines the numbers and types of ICU beds across the United States and the numbers of some of the other hospital spaces that can be used for critical care (Halpern and Tan, 2020). A capacity gap of inpatient hospital beds at 1,373,248 (274 percent of available capacity) and of ICU beds at 295,350 (508 percent of available capacity) has been predicted during the COVID-19 outbreak (Tsai, Jacobson, and Jha, 2020). Prior research proposes that, after beds to house critical care patients have been exhausted

in ICUs and PACUs, beds in other hospital locations should be repurposed for critical care in the following order: (1) use of step-down units and large procedure suites, (2) use of telemetry units, and (3) use of hospital floor beds (Halpern and Tan, 2020; Rubinson, Hick, et al., 2008). In addition, ORs in the United States are equipped with critical care resources, including anesthesia machines that can be used as ventilators, and can be considered for use to increase ICU capacity (Schlifke, 2020).

Academic hospitals usually have dedicated medical, surgical, cardiac, pediatric, and neonatal ICUs (Halpern and Pastores, 2015). The surge in need for critical care resources will require the breakdown of these silos so that critical care capacity can be adapted to meet the needs of the current pandemic. Further, hospitals need to break down not just silos around physical space but also around staffing. Staff should be pooled and mixed to allow for "more-expert" providers in the context of COVID-19 to be shared across ICU types. For example, medical ICU nurses can help support cardiac surgical intensive care physicians, who are more used to managing post-operative patients.

As one roundtable participant put it:

> One of the other things is to break down the barriers of segregated ICUs, so that patients can go to any kind or any labeled ICU whether it's medical, surgical, respiratory, trauma, neurosurgical.

Many hospitals and health systems are following the recommendation of the American College of Surgeons, which recommends minimizing, postponing, or canceling elective and non-urgent operations until the demand on current health care infrastructure posed by a sudden surge in critical care needs for patients with COVID-19 infection is more fully elucidated (American College of Surgeons, 2020). By canceling elective surgeries, hospitals not only can expand ICU space, but also can increase critical care staffing by leveraging anesthesiologists and surgeons to provide critical care, nurse anesthetists to provide ventilator support for intubated patients, and PACU nurses to provide critical care nursing for critically ill COVID-19 patients.

Space surge strategies can be more effective if coupled with patient cohorting strategies. One study of critical care surge strategies for H1N1 patients recommended grouping sicker patients in the main ICUs and placing less critically ill, less complex patients in "satellite" spaces in the hospital (Hota et al., 2010). Careful patient selection based on disease severity and complexity for different ICU bed locations might help mitigate challenges with ICU staff supervising non-ICU staff in the care of critical patients.

Table 3.2. Intensive Care Unit Bed and Other Special Care Bed Capacity in the United States

Type of Bed	Total Number of Beds (Across 2,704 Hospitals)
Total acute care hospital beds	534,964
ICU beds	96,596
Medical-surgical	46,795
Cardiac	14,445
Pediatric	5,137
Neonatal	22,901
Other	7,318
Burn beds	1,118
ICU units (spaces with multiple beds)	5,039
Observation, step-down, progressive beds	25,157

SOURCE: Adapted from Halpern and Tan, 2020.

During the project roundtables, we heard from hospital representatives that hospitals might move noncritically ill patients to makeshift hospitals and unconventional treatment settings: essentially, turning the main hospital facility into an ED and ICU. Prior research has identified such alternate locations as convention centers, exhibition halls, empty warehouses, airport hangars, schools, sports arenas, and hotels as "facilities of opportunity" (Koenig and Schultz, 2010).

Many patients who are critically ill with certain respiratory conditions (e.g., tuberculosis, COVID-19) are cared for in negative pressure rooms to decrease the risk of disease transmission to providers. For COVID-19 patients, negative pressure rooms are especially important when performing aerosolizing procedures (e.g., endotracheal intubation or bronchoscopy). However, if the number of negative pressure hospital rooms are limited, high-efficiency particulate air (HEPA) filters can be installed in exhaust ducts as an infection control measure (Halpern and Tan, 2020).

During our roundtables, critical care practitioners described challenges with the limited number of negative pressure hospital rooms. Some hospitals have converted inpatient floor beds into HEPA and negative pressure ICU rooms, but some roundtable participants do not believe that enough negative pressure capacity can be created. As one participant noted:

> We've already abandoned the idea that these patients are still going to go into negative pressure rooms. We're still prioritizing people who we think are higher risk [for these spaces].

Specific input from roundtable participants regarding strategies to help increase critical care space capacity is included in Table 3.3.

Table 3.3. Strategies from Roundtable Participants for Creating Space Capacity

Space Surge Strategy	Expert Input
Repurposing existing space	"To increase critical care bed capacity, we have closed down all elective surgical cases that would require either blood or ICU care beds postoperatively, so we did that a week ago in preparation. And we are also starting to consolidate elective areas like bariatric surgery and so forth to increase our capacity . . . we have [been] able to increase our ICU capacity by about 38 to 40 beds by doing that."
	"We think we can double our ICU capacity by working with our endoscopy and other procedural area spaces as well as the PACU."
	"That's our plan for partly expanding our ICU space into our post-anesthesia space that is a recovery space which has actually had walls and good gases. We can't have folks who need aerosolizing procedures in that space because it's an open space; however, it becomes a great space to care for a large number of people on ventilators."
	"Facilities has been able to convert all 25 [hospital floor] rooms . . . to make them [negative] pressure rooms."
Expanding telemedicine to allow ICU physicians to advise non-ICU physicians in community hospitals (i.e., tele-ICU consults)	"We really do need community hospitals to do critical care as well, and that's going to be challenging."
	"I do some telemedicine at nights for some community hospitals and what I find is that 95 percent of it doesn't involve cameras, most of it is talking to nurses and, you know, putting in orders and the like, so even if you don't have video capabilities, like cameras in the room, there is a lot you can do remotely just with your EMR [electronic medical record], you know, in terms of remotely helping with patient care."
	"But, you know, having remote telemedicine capabilities in your hospital would be a great thing because you'd need to don and doff less, just because you can camera in and look at the ventilator. Some places, you can see the ventilator online as well. All that would help."
Expanding capacity outside of the hospital walls	"So, the shuttered hospitals have been the primary place that folks have looked for increasing critical care capacity. Some of the other less traditional places have been mostly focused on getting everybody else out of the hospital . . . This is a nontraditional place to put patients who are non-COVID."
	"My bias is that we try desperately to do all the critical care within existing hospitals. You know, that's where we have labs. That's where we have medical gases. That's where we have medical supply chain, our concentration of PPE. I think trying to transplant that in the middle of a crisis to a different care setting, and having health care providers become familiar [with] that—trying to give some sort of lab, and food service, and waste handling resource is extraordinarily challenging in the worst of the times. So, my thought is that we try and offload as much of the floor-level medical care, that's what I think we try to repurpose or relocate."
	"We have not [thought about using mobile hospitals] and it's largely because technically if we were to recruit mobile hospitals, it's really the staffing issue that becomes the crux, and not necessarily the facility at this time for us. So, we haven't pursued that at this point."
Addressing patient outflow	"Build COVID SNFs [skilled nursing facilities], COVID sub-acute facilities so that we fix the outflow obstruction to help us expand our capability."

Staff Strategies

Using American Hospital Association (AHA) 2015 data and literature, Halpern and Tan, 2020, finds that although there are potentially 28,808 critical care doctors with hospital privileges and 19,996 full-time-equivalent critical care physicians, as well as 34,000 critical care advanced practice providers in the United States, 48 percent of acute care hospitals lack critical care physicians. An analysis conducted by the Society for Critical Care Medicine highlighted that the deficit of critical care providers will be significant in the context of projected critical care needs for COVID-19 (Halpern and Tan, 2020). Strategies to increase critical care staff capacity need to include plans for redeploying staff, shifting care team models, and coordinating volunteers.

Critical care providers in our roundtables anticipate that RTs will be a major bottleneck:

> Yeah, I think that's going to be, in terms of staffing, one of our tightest things, it's the place we can't expand by bringing in people from other subspecialties, etc., and we're always very tight. We're just going to have to learn how to work with fewer of them. They're [RTs] going to have to cover more units, which is going to be difficult cause of all the [patient] proning going on, and the PPE.

During our roundtables, we heard from participants that some hospitals are recruiting senior medical students and nursing students to help with more-routine care delivery in order to free up licensed staff to help manage critical care needs. Prior research has supported the use of medical students during disasters, including using medical students to enhance the Medical Reserve Corps (Kaiser et al., 2011).

Previous public health emergencies have highlighted limitations in the current processes for emergency credentialing of volunteer health care providers (Schultz and Stratton, 2007). The H1N1 outbreak provides a recent example of how this strategy was used in many emergency departments to expand their ability to meet the resource demands critical to response (Sugerman et al., 2011). The Emergency System for Advance Registration of Volunteer Health Professionals Program, provided by the Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response, is a tool designed to facilitate emergency credentialing of volunteer health care workers. However, our research revealed little evidence that it is being used during the current outbreak. In addition, the Medical Reserve Corps can help identify local medical volunteers to assist with care delivery during a crisis (Medical Reserve Corps, undated). Such volunteers can help reduce the workload of hospital floor physicians and nurses so they can assist with care for critically ill patients, similar to using medical and nursing students to care for less-sick patients.

It is important to factor staff absenteeism into critical care staffing calculations, whether because of a need for quarantine after contracting COVID-19, a fear of contracting the disease, or other reasons. Hospital-associated transmission is suspected as the mechanism for COVID-19 infection among health care providers (Wang et al., 2020). Some studies have estimated 10–40 percent absenteeism among health care workers during a pandemic (Thanner et al., 2011). These

studies also found that, even with high transmission rates, absenteeism ranges from 2.5 percent to 4.2 percent (Thanner et al., 2011).

During our roundtables, we heard several concerns about older staff being vulnerable to the disease and the possibility that this would contribute to absenteeism:

> Another problem we have is a lot of our nurses are older. So, the risk is of nosocomial transmission, it's a much more real concern.

Other participants were not as concerned with physician absenteeism:

> Honestly, I don't think it's going to change things . . . I think that it would be different if this were Ebola, but I think people, maybe a small percentage of my colleagues won't come to work, or . . . just refuse to do this. And, certainly it's understandable for some people if they have comorbidities or are older, but I think people are going to work.

Some of the concerns regarding older ICU physician vulnerability to COVID-19 can be mitigated by leveraging these providers for conducting tele-ICU consultations.

The Society of Critical Care Medicine recommends the tiered staffing model shown in Figure 3.1 to extend ICU-trained staff (physicians, advanced practice providers, nurses) by overseeing and directing non-ICU trained staff (Halpern and Tan, 2020). Given that respiratory failure from COVID-19 will be a primary driver of critical care resource use (Murthy, Gomersall, and Fowler, 2020), anesthesiologists and pulmonologists could serve as intensivist extenders (i.e., staff who can work effectively under supervision of fully qualified intensivists; Halpern and Tan, 2020). Emergency medicine providers and surgeons with critical care experience could also serve in this role. Progressive care nurses (those who provide direct care or influence care for acutely ill patients who are moderately stable with an elevated risk for instability), burn care nurses, and PACU nurses could augment critical care nursing capacity (Cain and Miller, 2019). Further, nurses trained in pediatric intensive care often provide care for adult patients with congenital medical conditions and therefore could potentially take care of some adult patients with critical illness. Similarly, nurses trained in neonatal intensive care could extend their scope of practice to some pediatric patients. In academic hospitals, staffing teams can leverage critical care fellows and upper-year residents from various specialties to expand critical care staff capacity.

Specific strategies from roundtable participants to help increase critical care staff capacity are included in Table 3.4.

Figure 3.1. Tiered Critical Care Staffing to Expand Capacity

MD with training in intensive care

Non-ICU MD

Respiratory therapists (RTs), advanced practice providers (APPs), anesthesiologists, certified registered nurse anesthetists (CRNAs)

ICU nurses

Non-ICU nurses or advanced practice providers (APPs)

24 x   24 x   24 x   24 x
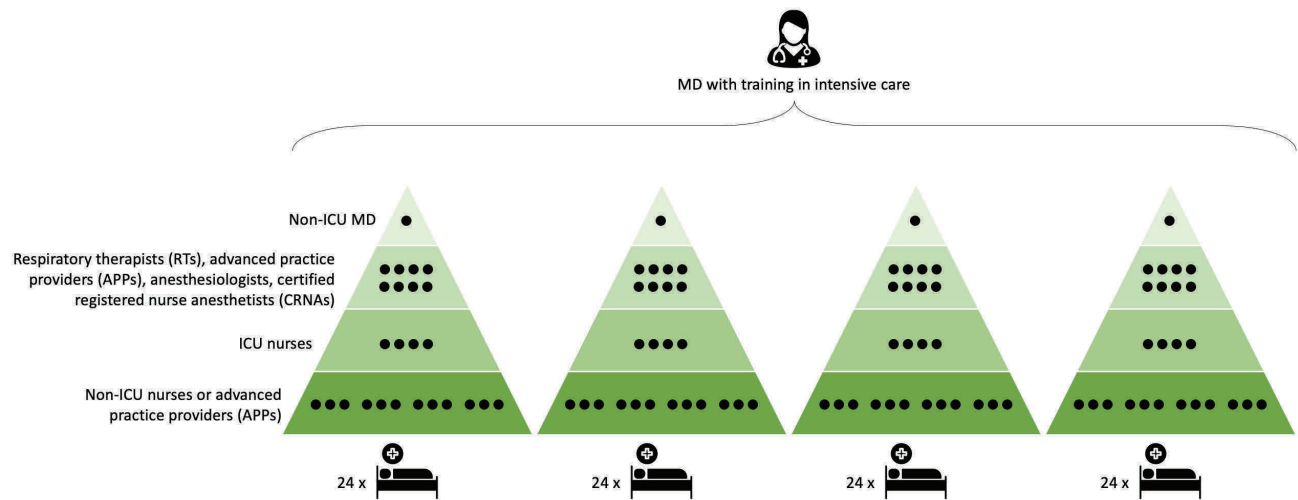
SOURCE: Adapted from Halpern and Tan, 2020.

Table 3.4. Strategies from Roundtable Participants for Creating Staff Capacity

Space Surge Strategy	Expert Input
Use of physicians from other departments with critical care expertise	"In terms of staffing, it's going to be our intensivists, our fellows, and then the anesthesiologists . . . because they are not doing elective surgeries, [they] have agreed to assist with staffing."
Use of physician extenders to provide critical care under supervision of ICU doctors	"Some pulmonologists who didn't do critical care for a long time have agreed [to] come back and help us out. Surgeons, internists, all sorts of people are volunteering to help out in some capacity. So I think some of it will be us giving them more direction and them carrying it out." "I absolutely think so [regarding critical care physicians and supervising noncritical care physicians and nurses to provide critical care]. I think that's the way that it will be if we have to double or triple patient capacity."
Expanding staff through recruitment from outside agencies	"In terms of the National Defense Medical System, we finally deployed the U.S. Public Health Service. Being very aggressive and looking at all options to enhance the workforce and staffing; having state boards of nursing reach out to retired nurses who have active licenses that are for whatever reason not currently employed within the health care system; looking at the Medical Reserve Corps and how we can optimize those groups of volunteer professionals and engage them in helping with staffing."
Consider alternate team-based staffing models	"One medical resident and one anesthesia resident sort of combine their skill sets where one is, sort of, very procedurally savvy and the other is more like helping with the medications and the fine points of managing the patients and then the intensivist would have to spend less time in that unit if they're running another one. That's sort of mixing your skill sets."

Stuff Strategies

The H1N1 pandemic revealed a need for a clearer understanding of the number and geographic distribution of ventilators in the United States. Models for pandemic planning indicated a huge demand for this resource (Toner and Waldhorn, 2010). A 2015 study assessing the capacity of the health care system to use additional mechanical ventilators at various capacity levels (i.e., conventional, contingency, and crisis) suggests limited capacity in the United States (Ajao et al., 2015). Gomersall et al., 2006, p. 1007, suggests that "equipment purchases should be proportionate to availability of reserve staff" as opposed to the estimated number of patients in need of mechanical ventilation.

The New York State Department of Health recently approved a *ventilator splitting* protocol (i.e., the use of one ventilator for two patients) developed by NewYork–Presbyterian Hospital (Siegel, 2020). Although this approach is clinically controversial and drew criticism from several medical associations (American Society of Anesthesiologists, 2020), it is one strategy that hospitals are considering to increase ventilator capacity. And hospitals rely on large storage tanks for liquid oxygen, requiring planning to ensure the availability of medical-grade oxygen and appropriate trucks for delivery (Devereaux et al., 2008; Manuell, Co, and Ellison, 2011).

Further, different types of ventilators previously being used in non-ICU settings are being used to meet the increased demand. These include anesthesia machines primarily used in the OR setting, transport ventilators, home ventilators (including those used for patients requiring chronic ventilation that can be repurposed for ICU patients with minimal ventilator support requirements), and ventilators used for noninvasive ventilation, which are capable of pressure control ventilation for the critically ill.

Specific input from roundtable participants regarding strategies to help increase critical care stuff capacity are included in Table 3.5.

Table 3.5. Strategies from Roundtable Participants for Creating Stuff Capacity

Stuff Surge Strategy	Expert Input
Acquiring new PPE	"A lot of our PPE we're purchasing, and . . . trying to gather more including donations."
	"We've also set up a website to help coordinate the community donations and other facility donations."
	"We're looking at some novel supply chain approaches. We're working with Home Depot right now as a potential for getting some N95 masks as well as some direct lines . . . from overseas."
Reusing PPE	"The main issue is trying to reduce our use rate. So, reusing masks, and trying to have people use only one, and determine which infection prevention is needed in terms of surgical versus N95, and that's challenging because it's a change in culture and in recommendations to health care providers."
	"We're in the process of securing a large amount of the cloth surgical masks to have as a backup. We're also getting UV [ultraviolet] sterilization of masks to be reused as well."
Using one ventilator for two patients (i.e., ventilator splitting)	"I've only looked at it theoretically . . . The concept is to have several patients with similar tidal volume and similar pressures that the ventilator circuits are split and that you're ventilating multiple patients with a single ventilator."

Bringing It All Together in Systems: The Fourth "S" of Surge

Ultimately, creating adequate critical care surge capacity in response to the COVID-19 pandemic will require a balance between creating the needed space, staff, and stuff and identifying bottlenecks in each area to be urgently addressed. To do this, the role of systems and networks needs to be closely evaluated and leveraged to ensure that regions across the United States optimize the efficiency with which critical care resources are allocated and/or shared.

The importance of resource awareness. First, striking the balance among critical care space, staff, and stuff requires that each hospital and health system know its inventory and resources, including whether it has the capacity to share unused resources with (or transfer them to) hospitals with greater needs for critical care resources at any point during the outbreak. This resource awareness should not only be at the hospital and health system levels, but also at a regional level so that state government and regional Federal Emergency Management Agency (FEMA) leadership can assist with determining the areas of greatest need and can help facilitate resource sharing among hospitals. When Italy realized the extent of community spread of COVID-19, it began using an ICU network to increase its capacity to care for and distribute patients (with and without COVID-19) with critical care needs (Grasselli, Pesenti, and Cecconi, 2020). Regionalization of critical care resources and surge strategies should be considered as the United States prepares for a surge in critical care needs for COVID-19 patients.

Real-time resource tracking is key. Roundtable participants emphasized the need for *real-time* information sharing to increase situational awareness of critical care surge capabilities and resource needs among hospitals and across regions:

> [I] don't know if it can be adopted at this point in time but, I think there needs to be a mandate . . . for all health care facilities to have a real-time automated capacity reporting process through the states. So, we really have a better feel for where there is capacity within systems. In terms of a public health emergency, that the state departments of public health can play an active role in the potential distribution of critical care patients. I think that's more of an intermediate and a long-term recommendation, but I think that's incredibly important.

EMR systems might help. Roundtable members identified a possible role for electronic health records in such information sharing:

> You know, I don't know to what extent we've engaged the electronic health records, and the degree to which the federal government could ask them to open API [application programming interface] so that real-time bed capacity, at least between places that are on some of those dominant EHRs [electronic health records] in the market, could be seen . . . The technology makes it much, much easier and these API's can be created. It's also been a permissions issue between facilities. So that's another lever for federal government.

The importance of whole-of-community partnerships. Furthermore, there is an urgent need to identify "community alternate care site partners" (Koenig and Schultz, 2010). Alternate care sites could include community primary care clinics, urgent care centers, ambulatory surgical centers, and long-term care facilities (Rebmann et al., 2011). Key partners include home health agencies, local governance, medical examiners' offices, nonprofit organizations, pharmacies, public health departments, and needs agencies (Mazowita, 2006). These partners should be part of a "whole-of-community" response, which a roundtable participant indicated would be important for identifying critical care surge capacity solutions in communities:

> There are plenty of places that aren't having that community approach still largely [using an] approach on the health system capacity level. So, the feds could support and resource that, push that.

However, several participants cautioned against unwarranted assumptions about partner resources, such as those of the VHA:

> We do have a [VHA] available to us—but they're not usually geared up to take ICU patients, we usually take theirs. A lot of them aren't resourced the way we are, so we don't depend on them.

Expanded use of telemedicine can improve coordination among sites and staff. The role of telemedicine was emphasized to create additional critical care capacity during the roundtables. For those hospitals and health systems without existing telemedicine platforms or whose telemedicine platforms are overwhelmed by the demand, the Centers for Medicare & Medicaid Services and the U.S. Department of Health and Human Services are permitting the use of any

messaging platform (including FaceTime, Zoom, or others, so long as they are not publicly viewable; Centers for Medicare & Medicaid Services, 2020).

Input from roundtable participants regarding strategies to help increase critical care system and whole-of-community capacity is included in Table 3.6.

Table 3.6. Specific Strategies from Experts on Creating Critical Care System and Whole-of-Community Surge Capacity

Critical Care System and Whole-of-Community Surge Strategy	Expert Input
Engaging key stakeholders in surge response	"That has pivoted in the last week to a whole of community approach and the essential nature of . . . responding to this together. So, if the hospital systems start to work collaboratively with the public health departments, and with the public hospitals, and with nontraditional players. The real estate briefing for us every day is one of the most fascinating pieces along with the . . . supply chain folks because you know having space that we acquire that we then convert that was never a hospital before."
	"The production capacity is mostly not [available] in [our] city, so it's harder to get them to the table. I think as the bridge . . . rather than let market forces just drive up the price of things, to work in partnership with the production capacity strikes me as crucial at this point."
Allocating scare resources	"This whole idea of if it gets [down] to . . . triage . . . now, every intensivist is considered a triage officer and then if the state approves it, we will have these triage committees that will . . . decide who gets removed from ventilators."
	"It may end up meaning that you may simply have to remove patients form the ventilator . . . if there's somebody more viable coming in."

4. Assessing Critical Care Capacity Created by Various Surge Strategies

The surge-capacity creation strategies described in Chapter 3 can be implemented at the individual hospital, health care system, state, or regional level. Next, we illustrate how surge capacity can be created regionally by examining the impact of implementing various surge strategies in the ten FEMA regions (Jan, 2020), depicted in Figure 4.1. We draw on AHA data (AHA, 2020), American Medical Association data (American Medical Association, 2020), and other data on critical care space, staff, and stuff.

Figure 4.1. U.S. FEMA Regions
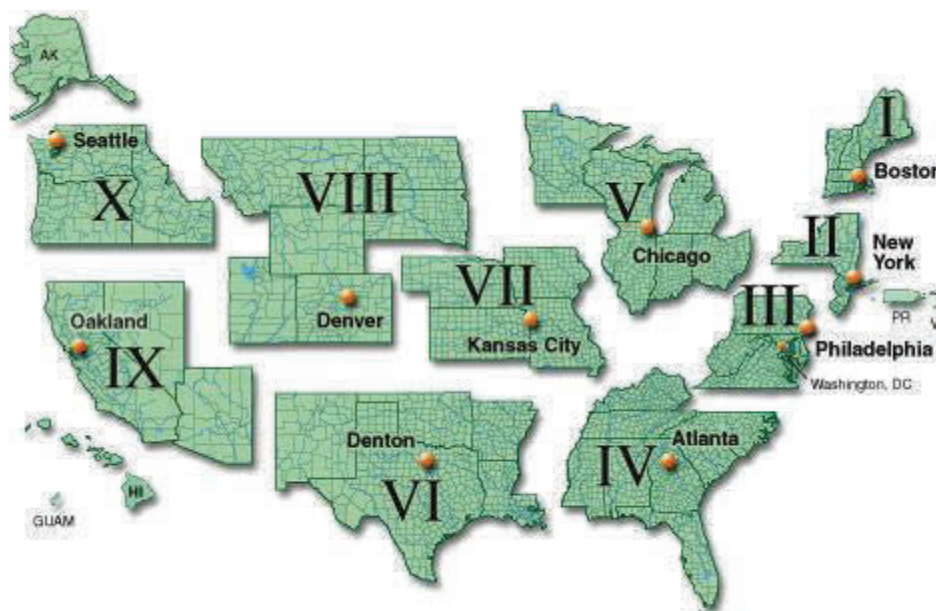
SOURCE: FEMA, 2019.

The total number of patients accommodated is calculated using a simple tool based on a Microsoft Excel model that we developed. A copy of the model and simple user instructions are available at www.rand.org/t/TLA164-1. These critical care capacity estimates can inform cross-regional critical care resource sharing—from regions with less demand to those with more demand. We encourage hospital leaders and state and regional officials to use this tool to examine critical care capacity creation strategies using assumptions based on data from their communities.

Data limitations required us to make the following important assumptions:

- **ICU beds.** For the baseline case, we counted cardiac ICU, medical/surgical ICU, and other ICU beds as reported from the 2018 AHA survey. For Tier 1 and Tier 2, *we assumed that all the hospital beds*, as reported in the same AHA survey (AHA, 2020), *could be made available to care for critical care patients*.
- **Ventilators.** Data on the number of ventilators by FEMA region are not publicly available; thus, we assumed that the total number of ventilators in the nation are distributed across FEMA regions proportional to the number of ICU beds in each region. Tier 1 and Tier 2 surges assume that additional ventilators will be acquired from the use of older hospital ventilators, Strategic National Stockpile ventilators, and anesthesia machines (Halpern and Tan, 2020).
- **Critical care doctors.** We assumed that the baseline ICU physician-to-patient ratio is 1:10, according to available literature; *we assumed hospitals can surge to 1:24*, within the recommendations from the Society of Critical Care Medicine for pandemic critical care (Halpern and Tan, 2020) and by soliciting subject-matter expert input from within and outside the project team. According to this expert input, *we also assumed that 50 percent of emergency physicians and anesthesiologists are off-shift on any given day and that they can independently manage critical care patients with a 1:24 physician-to-patient ratio*. This percentage availability is based on the fact that elective surgeries have been canceled at many hospitals (making anesthesiologists available and assuming that—at least partially—ED staffing for less-sick patients will be supplemented by community and family medicine physicians and physician volunteers). We also assumed that 50 percent of hospitalists are off-shift on each day and that they *each can manage 12 critically ill COVID-19 patients under the supervision of an ICU physician*. We assumed that *each ICU physician is able to supervise two hospitalists (i.e., a tiered staffing strategy)*. The total ICU physician patient load is within the surge load recommended by the Society of Critical Care Medicine for provision of critical care during the COVID-19 pandemic (Halpern and Tan, 2020). Note that we used a modified version of the Society of Critical Care Medicine's tiered staffing model based on subject-matter expert input. We assumed that clinicians can *simultaneously* manage patients *and* supervise other clinicians. This clearly assumes a huge burden on these clinicians, but input from subject-matter experts suggests that many are already doing this in the nation's most-affected hospitals.
- **Critical care nurses.** Baseline nurse-to-patient ratios in ICUs are typically 1:1 or 1:2, according to available literature (Ajao et al., 2015). *We assume hospitals can surge to 1:4*. According to subject-matter expert input from within and outside the project team, *we assumed that 50 percent of non-ICU nurses are off-shift on any given day and that they each can manage two critical care patients under the supervision of an ICU nurse*. This percentage availability of floor nurses is based on the assumption that care of less-sick patients in hospital wards can be supplemented with volunteer community nurses and/or nursing students in the last year of training so that floor nurses can help with critical care. We assumed *each ICU nurse is able to supervise two non-ICU nurses*.
- **RTs.** According to the literature, the baseline number of ventilators managed by one RT can vary from four to 14 or more (Ajao et al. 2015; California Society for Respiratory Care, 2016; West et al., 2016). According to subject-matter expert input from within and outside the project team, *we assumed that 50 percent of OR nurse anesthetists are off-shift on any given day and that they each can manage 12 ventilators under the*

supervision of an RT. We assumed *each RT is able to supervise three nurse anesthetists*. The total ICU RT ventilator load is within the surge load recommended by the Society of Critical Care Medicine (Halpern and Tan, 2020).

- **Model does not account for time.** For simplicity's sake, the model does not account for the amount of time needed to move to higher tiers. Nor does it account for the average amount of time resources are likely to be tied up (e.g., length of time on ventilators).
- **Geographic fungibility of resources.** For the purposes of estimation, we assumed that all resources within a region are *fungible*: that is, a physician in one of the region's hospitals could be redeployed to any other hospital in the region. This assumption renders the calculations tractable, simple, and transparent, and allows us to illustrate the basic logic of capacity creation. But readers are advised that this *might lead to significant overestimates of overall regional capacity*.

Specific numeric assumptions for each tier are summarized in Table 4.1. It is important to note that the strategies examined here include some, but not all, of the capacity creation strategies described in the previous chapter.

For each FEMA region, Table 4.2 relates the quantities of critical care doctors and nurses, RTs, ventilators, and beds to the estimated number of patients who could be accommodated simultaneously. The estimates compare the number of patients who can be accommodated without extraordinary capacity-creation strategies (i.e., baseline capacity) with the number accommodated when hospitals employ the Tier 1 and Tier 2 strategies described in this report.

Quantities of staff extenders (i.e., those requiring supervision) are provided in red text. In addition, the input (e.g., doctors, nurses, ventilators) whose volume is the limiting factor is shaded in yellow. Figure 4.2 provides a more simplified depiction of the estimates, focusing only on the estimated number of patients who can be cared for concurrently.

Table 4.1. Summary of Numeric Assumptions

Resource	Baseline	Tier 1	Tier 2
ICU beds created[a]	No	Yes	Yes
ICU doctor-to-patient ratio	1:10	1:24	1:24
ICU nurse-to-patient ratio	1:2	1:4	1:4
RT-to-patient ratio	1:8	1:12	1:12
Patient-to-ventilator ratio	1:1	1:1	1:1
Borrowed fully capable staff[b] from other departments or hospital wards			
Doctors	No	Yes	Yes
Nurses	No	No	No
RTs	No	No	No
Borrowed extenders[c] from other departments or hospital wards			
Doctors	No	No	Yes
Nurses	No	No	Yes
RTs	No	No	Yes
Physician supervisor–to-extender ratio	No	No	1:2
Nurse supervisor–to-extender ratio	No	No	1:2
RT supervisor–to-extender ratio	No	No	1:3
Physician extender–to-patient ratio	No	No	1:12
Nurse extender–to-patient ratio	No	No	1:2
RT extender–to-patient ratio	No	No	1:12
Additional ventilators acquired	No	Yes	Yes

[a] Assumes all hospital beds can be converted into ICU beds.
[b] Fully capable staff are those who can care for critical care patients independently.
[c] Borrowed extenders are those who can care for critical care patients under the supervision of fully capable staff.

Table 4.2. Estimates of Surge Creation Using Data from FEMA Regions (Limiting Factor Shaded)

FEMA Region	Surge-Creation Tiers	Staff and Standards of Care (Extenders in Red)			Stuff and Space		Total Number of Patients Cared for Concurrently
		Critical Care Doctors	Critical Care Nurses	RTs	Ventilators	Beds	
I	Baseline[a]	513	7,317	1,570	2,219	2,327	2,219
	1[b]	513	7,317	1,570	7,159	42,173	7,159
	2[c]	1,822 + 1,064	7,317 + 11,585	1,570 + 18	7,159	42,173	7,159
II	Baseline	736	17,842	3,428	4,948	5,574	4,948
	1	736	17,842	3,428	15,961	93,802	15,961
	2	2,999 + 1,477	17,842 + 28,249	3,428 + 18	15,961	93,802	15,961
III	Baseline	810	18,168	4,423	6,043	6,882	6,043
	1	810	18,168	4,423	19,493	102,135	19,440
	2	2,985 + 1,982	18,168 + 28,766	4,423 + 32	19,493	102,135	19,493
IV	Baseline	1,119	35,775	9,184	13,260	15,194	13,260
	1	1,119	35,775	9,184	42,774	212,570	26,856
	2	4,649 + 3,639	35,775 + 56,644	9,184 + 59	42,774	212,570	42,774
V	Baseline	1,108	28,416	7,547	10,555	12,363	10,555
	1	1,108	28,416	7,547	34,048	163,964	26,592
	2	4,832 + 3,123	28,416 + 44,991	7,547 + 71	34,048	163,964	34,048
VI	Baseline	625	22,321	6,060	9,778	10,694	9,375
	1	625	22,321	6,060	31,541	135,292	15,000
	2	2,980 + 2,662	22,321 + 35,342	6,060 + 38	31,541	135,292	31,541

| FEMA Region | Surge-Creation Tiers | Staff and Standards of Care (Extenders in Red) | | | Stuff and Space | | Total Number of Patients Cared for Concurrently |
		Critical Care Doctors	Critical Care Nurses	RTs	Ventilators	Beds	
VII	Baseline	342	8,812	2,321	3,353	3,906	3,353
	1	342	8,812	2,321	10,815	54,089	8,208
	2	1,177 + 893	8,812 + 13,953	2,321 + 28	10,815	54,089	10,815
VIII	Baseline	218	6,170	1,574	2,092	2,227	2,092
	1	218	6,170	1,574	6,749	36,463	5,232
	2	1,068 + 609	6,170 + 9,770	1,574 + 16	6,749	36,463	6,749
IX	Baseline	866	21,305	5,648	7,435	7,715	7,435
	1	866	21,305	5,648	23,985	120,588	20,784
	2	4,205 + 2,276	21,305 + 33,733	5,648 + 22	23,985	120,588	23,985
X	Baseline	263	5,808	1,554	2,317	2,434	2,317
	1	263	5,808	1,554	7,475	31,554	6,312
	2	1,275 + 1,077	5,808 + 9,195	1,554 + 10	7,475	31,554	7,475

NOTE: Quantities of staff extenders (i.e., those requiring supervision) are provided in red text. The input (e.g., doctors, nurses, ventilators) whose volume is the limiting factor is shaded in yellow.
[a] Baseline = conventional capacity.
[b] Tier 1 = contingency capacity.
[c] Tier 2 = crisis capacity.

Figure 4.2. Visual Display of FEMA Region–Level Estimates of Number of Patients Cared for Concurrently Under Baseline, Tier 1, and Tier 2 Scenarios
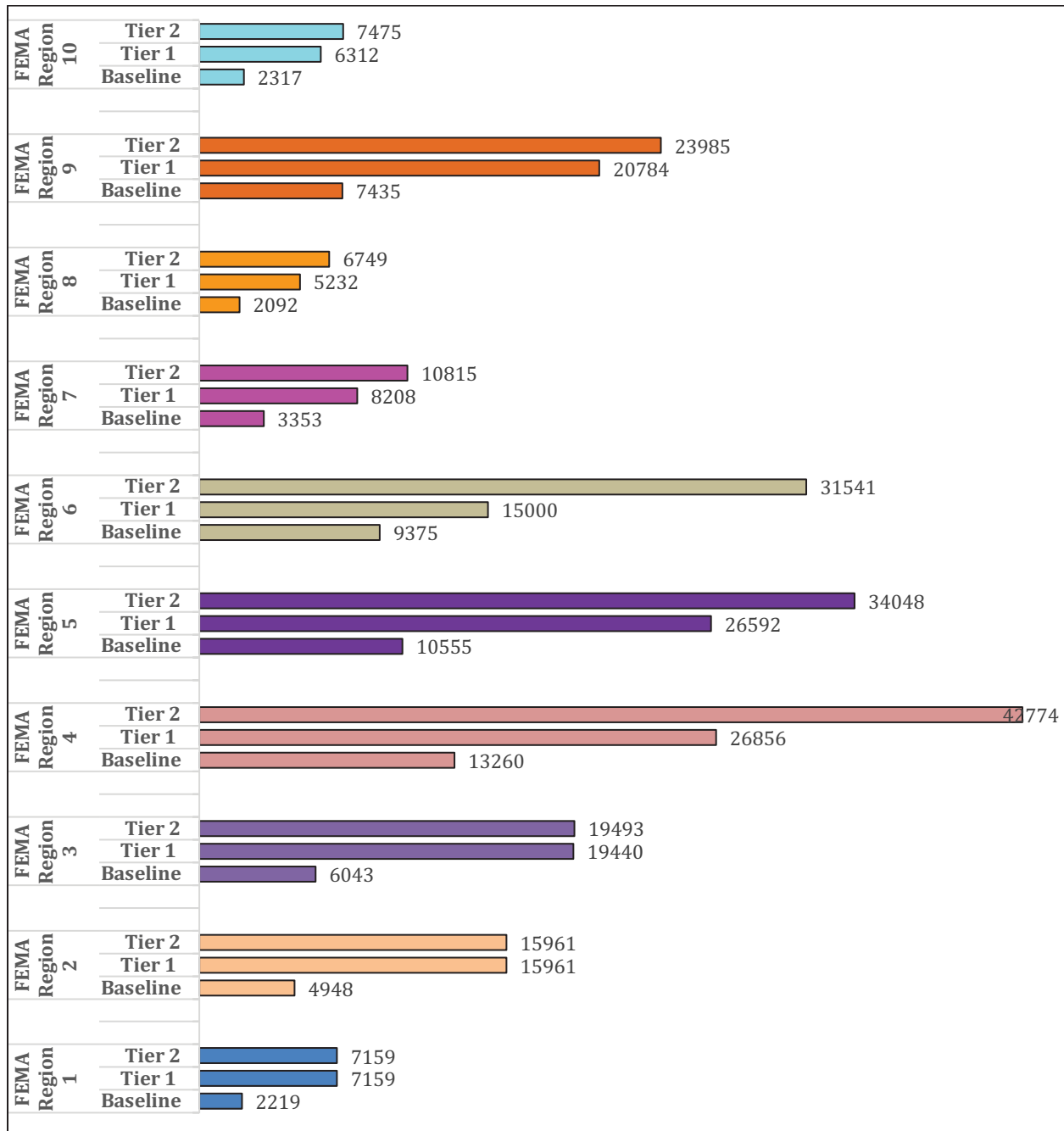
Within the limitations of the assumptions that we needed to make, the specific estimates are less important than the overall patterns observed. As noted above, the overall number of patients who can be cared for is limited by whichever resource (staff or stuff) is most limited (shaded yellow in Table 4.2). In the majority of cases, ventilators are the limiting factor. Because we

assume one ventilator per patient, the total number of patients accommodated in these cases, therefore, equals the number of ventilators. In a few instances, doctors are the limiting factor, but in no case is the number of nurses, RTs, or beds the limiting factor.

As expected, moving from lower to higher tiers increases capacity in most cases. But the amount of increase depends on the specific combination of resources available in each region. For instance, the limiting factor (box shaded in Table 4.2) in Region IV in the baseline condition is ventilators. Thus, adding ventilators in Tier 1 increases the number of patients accommodated from 13,260 to 26,856. The number of doctors then becomes the limiting factor, which is addressed by adding physician extenders in Tier 2, for an increase to 42,774 patients accommodated. In Region I, adding ventilators in Tier 1 also increases patient capacity (from 2,219 to 7,159). However, the move from Tier 1 to Tier 2 does not produce any estimated increase whatsoever because it is already limited by the number of ventilators in Tier 1, and moving to Tier 2 does not increase that resource.

5. Next Steps and Policy Recommendations

In this report, we identified several strategies for enhancing critical care capacity in hospitals, organized into two tiers. Tier 1 strategies are designed for contingency situations that involve using adaptations to medical care spaces, staffing constraints, and supply shortages in a way that increases capacity without having a significant impact on delivered medical care. Tier 2 strategies are implemented in catastrophic situations and have a significant anticipated impact on standards of care (Hick, Barbera, and Kelen, 2009). The FEMA region critical care capacity estimates we created using Tier 1 and Tier 2 strategies demonstrate how the RAND Critical Care Surge Response Tool can be used to provide information about capacity and potential bottlenecks. However, implementing these strategies requires a wide variety of specific considerations. Decisions will vary considerably from community to community and will require location-specific data for optimal usability. Next, we provide a short list of key considerations and decisions for hospitals and for state, regional, and federal entities based on this report's literature review, the ACEP survey, expert roundtables, and the study team's expert opinion.

Hospitals should consider the following:

- Use the RAND Critical Care Surge Response Tool (Abir et al., 2020) or similar resources to assess critical care bottlenecks in space, staff, and stuff in your facility and identify the most-effective surge strategies to address those bottlenecks.
- Have tiered critical care surge capacity plans in place ahead of time so that critical care surge capacity efforts can be escalated as indicated.
- Cancel elective procedures to free up critical care space, staff, and stuff.
- Develop an inventory of staff who might play unconventional roles in your COVID-19 response.
- Identify candidates for critical care just-in-time training.
- Leverage telemedicine technology to provide tele-ICU consultation capabilities to community hospitals with less critical care capability.
- Communicate and collaborate with community (e.g., businesses, public health entities, first-responder agencies, nursing homes) and regional partners (e.g., health care coalitions) to create critical care surge capacity.

State, regional, and federal entities should consider the following:

- Facilitate communication and coordination among hospitals, health care systems, and public health entities.
- Develop regional resource-sharing protocols to facilitate proportional distribution according to needs.
- Maintain updated registries of resources and resource shortfalls, and disseminate those data among hospitals and health systems to maintain regional situational awareness of resources.

- Institute emergency credentialing policies for health care worker volunteers (e.g., waivers).
- Identify and address liability barriers to critical care capacity creation.
- Identify supply chains for PPE, ventilators, and other critical care resources.
- Institute policies to combat price-gouging by suppliers of PPE, ventilators, and other critical care resources.
- Provide guidance on crisis standards of care and rationing of critical care resources.

In addition, readers are encouraged to refer to preexisting planning checklists (see Box 5.1).

Box 5.1. Selected Resources on COVID-19 Critical Care Capacity

- Centers for Disease Control and Prevention, "Interim Clinical Guidance for Management of Patients with Confirmed Coronavirus Disease (COVID-19)," webpage, updated April 3, 2020. As of April 16, 2020: https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html
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Appendix. Research Methods

In this appendix, we briefly describe the methods used to produce this report. All data collection was declared exempt by the RAND Human Subjects Protection Committee.

Methods

Peer-Reviewed and Gray Literature Review

We used PubMed and Google to conduct relevant searches regarding pandemic critical care capacity surge and conducted a targeted review of past RAND reports and relevant websites. Search terms used included critical care, intensive care unit, surge capacity, hospital, pandemic, and disaster.

ACEP All-Member Survey

In partnership with RAND, ACEP administered an all-member survey on March 13, 2020. The survey link was administered to 32,056 members electronically through ACEP's Microsoft Dynamic Customer Relationship Manager platform. The questions were developed by emergency and critical care experts at RAND and ACEP and are shown in Figure A.1. A total of 337 respondents filled out the survey. Descriptive analyses of responses to questions 1 through 4 were conducted using Microsoft Excel. Responses to the optional question 6 were qualitatively analyzed to identify themes across respondents. There were six responses missing for question 1 and six responses missing for question 2. One response was excluded because the respondent marked both "None of the above" and "All of the above" for question 4 (the respondent's answers to other questions were retained, however). Given the project timeline, it was not possible to conduct follow-up activities to ensure a representative sample. Thus, findings from the survey should be viewed as suggestive but not conclusive.

Figure A.1. ACEP COVID-19 Survey

1. **What is the location of your primary practice ED?**
   Rural
   Suburban
   Urban

2. **What is the nature of your primary place of practice?**
   Academic
   Community
   Other

3. **What areas are you currently challenged with in the setting of the COVID-19 outbreak? Check all that apply.**
   Screening patients in triage
   Negative pressure room capacity for isolation of suspected or confirmed cases
   Shortages in N95 masks
   Training staff around proper personal protective equipment (PPE) use
   Shortages in COVID-19 diagnostic kits
   Keeping track of guidance around criteria for testing for COVID-19
   ED critical care capacity for treating suspected or confirmed cases with severe illness
   Provider work absenteeism
   Increased patient volume due to worried well patients presenting to the ED
   Suspected or confirmed COVID-19 transfers from other EDs
   Getting calls from the community with questions about COVID-19
   Controlling public messaging around COVID-19
   All of the above
   None of the above

4. **What areas are the current challenges in your ED regarding provision of critical care? Check all that apply.**
   Physician staffing
   Nurse staffing
   Respiratory therapy staffing
   Ventilator capacity
   ED boarding of critical care patients
   All of the above
   None of the above

5. **Would you be willing to participate in this survey on a weekly basis?**
   Yes
   No

6. **Please share any additional comments you may have:**

Roundtables

We conducted two 1.5-hour roundtables via conference call: one on March 20 and one on March 21, 2020. The first roundtable included five critical care physicians from a national critical care research network. The second roundtable included eight emergency care and disaster preparedness and response experts from institutions around the country. We targeted well-known thought leaders in the field. Roundtable participants were selected to represent geographic variability, but we focused on urban perspectives.

We used a semistructured interview guide to guide the discussions (Figure A.2). The discussions were recorded and transcribed by members of the team. We used the *rapid analysis* technique to analyze the transcripts: i.e., a team-based method of ethnographic inquiry using triangulation and iterative data analysis to develop actionable information from an insider's perspective in order to inform policy (Beebe, 2001; Hamilton, 2013). Three team members developed a template to summarize the notes from the roundtables, structured by questions from our interview guides, and analyzed the findings. This analysis involved taking each set of transcripts and extracting responses into the structured rapid analysis template in the form of summary statements and illustrative quotes using the qualitative analysis software Dedoose (Dedoose, 2020). The final condensed matrix of themes was summarized to report results.

Figure A.2. Semistructured Roundtable Discussion Guide

1) What is the current status of ICU bed capacity at your institution?

2) What are some strategies to increase critical care bed capacity?

3) What is the current status of ICU staffing (doctors, nurses, respiratory therapists) at your institution?
   a. Staff morale issues

4) What are some strategies to increase critical care staffing capacity?

5) What is the current status of ventilators and other critical care resources at your institution?
   a. PPE

6) What are some strategies to increase ventilator and other critical care capacity?

7) What other critical care surge needs do you anticipate?

8) What can state and federal government do to help increase critical care surge capacity in the coming weeks?

Abbreviations

ACEP	American College of Emergency Physicians
AHA	American Hospital Association
ARDS	acute respiratory distress syndrome
CDC	Centers for Disease Control and Prevention
COVID-19	coronavirus disease 2019
ED	emergency department
EMR	electronic medical record
FEMA	Federal Emergency Management Agency
HEPA	high-efficiency particulate air
ICU	intensive care unit
MERS	Middle East respiratory syndrome
OR	operating room
PACU	post-anesthesia care unit
PPE	personal protective equipment
RT	respiratory therapist
SARS	severe acute respiratory syndrome
VHA	Veterans Health Administration

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