CHEST

Actions Taken by US Hospitals to Prepare for Increased Demand for Intensive Care During the First Wave of COVID-19

A National Survey

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BACKGROUND: The COVID-19 pandemic placed considerable strain on critical care resources. How US hospitals responded to this crisis is unknown.

RESEARCH QUESTION: What actions did US hospitals take to prepare for a potential surge in demand for critical care services in the context of the COVID-19 pandemic?

STUDY DESIGN AND METHODS: From September to November 2020, the chief nursing officers of a representative sample of US hospitals were surveyed regarding organizational actions taken to increase or maintain critical care capacity during the COVID-19 pandemic. Weighted proportions of hospitals for each potential action were calculated to create estimates across the entire population of US hospitals, accounting for both the sampling strategy and nonresponse. Also examined was whether the types of actions taken varied according to the cumulative regional incidence of COVID-19 cases.

RESULTS: Responses were received from 169 of 540 surveyed US hospitals (response rate, 31.3%). Almost all hospitals canceled or postponed elective surgeries (96.7%) and nonsurgical procedures (94.8%). Few hospitals created new medical units in areas not typically dedicated to health care (12.9%), and almost none adopted triage protocols (5.6%) or protocols to connect multiple patients to a single ventilator (4.8%). Actions to increase or preserve ICU staff, including use of ICU telemedicine, were highly variable, without any single dominant strategy. Hospitals experiencing a higher incidence of COVID-19 did not consistently take different actions compared with hospitals facing lower incidence.

INTERPRETATION: Responses of hospitals to the mass need for critical care services due to the COVID-19 pandemic were highly variable. Most hospitals canceled procedures to preserve ICU capacity and scaled up ICU capacity using existing clinical space and staffing. Future research linking hospital response to patient outcomes can inform planning for additional surges of this pandemic or other events in the future. CHEST 2021; 160(2):519-528

KEY WORDS: COVID-19; critical care; ICU organization; triage

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Take-home Points

Study Question: What actions did US hospitals take in response to the surge in critical care demand that resulted from the COVID-19 pandemic?

Results: Hospital response actions were highly variable and largely unrelated to the prevalence of COVID-19 infection in their region, although almost all hospitals canceled elective procedures and very few expanded ICU services into nonclinical spaces.

Interpretation: Actions taken in response to the COVID-19 pandemic were variable across the United States, and future research to understand the impact of specific actions is needed.

COVID-19, the illness caused by the SARS-CoV-2 virus, has rapidly spread around the world in a global pandemic that has strained, and in some regions overwhelmed, the capacity of existing critical care resources. The virus first emerged in November 2019, and as of December 2020, there have been > 15 million cases worldwide, with ongoing spread at a rate of > 200,000 cases per day.[1] COVID-19 is associated with high rates of respiratory failure and critical illness. In the early phase of the pandemic, more than one-half of patients with COVID-19 required hospitalization,[2] and 15% to 20% of hospitalized patients were admitted to ICUs predominantly for respiratory failure requiring mechanical ventilation and shock requiring vasopressor support.[3-5] Critically ill patients with COVID-19 have prolonged ICU courses, requiring an average of 2 weeks of mechanical ventilation.[6,7] Thus, the sheer volume of patients and their extended critical illness combined have created an unprecedented demand for intensive care.

Prior to the current pandemic, several groups developed recommendations for hospitals and ICUs to respond to mass critical care needs in the case of an epidemic, bioterrorism, or other mass casualty event.[8,9] These recommendations were broad and far-reaching and were generally organized around the 3 S's of preparedness: space, staff, and stuff.[10,11] They outlined that hospitals should have the ability to expand ICU capacity by extending to other hospital areas, with appropriate beds and monitors for expansion areas; be able to rapidly increase clinical and nonclinical staffing and models of using noncritical care staff to care for ICU patients; and have plans to ensure availability of necessary medical equipment and medications. Recommendations also emphasized the importance of established networks of regional coordination across hospital systems and establishing objective, ethical, and transparent triage systems under the most extreme circumstances.

Despite these recommendations, as the COVID-19 pandemic unfolded, it quickly became obvious that many hospitals and clinicians were ill-prepared to meet the demands of caring for the surges of patients with COVID-19. Clinicians had concerns about inadequate staffing; shortages of supplies, medications, and beds; and overcrowding.[12,13] Anecdotal reports from hospitals experiencing surges suggested a patchwork of responses and solutions.[14-21] However, robust data on how hospitals actually responded to the surge in demand for critical care services during this period are lacking. To better understand this issue, we performed a structured survey of a representative sample of US hospitals asking what steps they planned for or undertook during the first phase of the COVID-19 pandemic.

Materials and Methods

Study Design and Population

We performed a cross-sectional survey of US hospitals identified by using the 2018 American Hospital Association Annual Survey Database. We also used the Centers for Medicare & Medicaid Services Healthcare Cost Reporting Information System to obtain hospital characteristics not present in the American Hospital Association Annual Survey, as well as the Pittsburgh Atlas crosswalk to assign hospitals to geographic regions that reflect their acute care catchment areas.[22] To estimate the total population by region, projections from the 2010 United States Census (Geolytics) were used. The *New York Times* COVID-19 case database was used to determine the incidence of COVID-19 according to region and date.[23]

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The survey was limited to general, acute care hospitals with an ICU. Because it was not feasible to survey all eligible hospitals, we created a sample using a combination of random and purposeful sampling. First, all eligible hospitals were stratified based on size, teaching status, health system membership, and cumulative incidence of COVID-19 in the hospital's geographic region on the date the study was launched (June 29, 2020), randomly selecting up to 10 hospitals in each stratum. Next, we enriched this sample by purposefully selecting all hospitals in the four regions with the greatest cumulative COVID-19 incidence at the time of study launch. This sampling approach ensured adequate representation of a broad range of hospital types, while also ensuring adequate representation of hospitals that dealt with a substantial burden of patients with COVID-19. A detailed description of the sampling strategy is provided in e-Appendix 1.

Survey Development

We drafted the survey instrument based on previous ICU organizational surveys,[24-28] existing frameworks for pandemic preparedness,[10,11,29] and published case studies about hospital responses during the early phases of the pandemic.[18-21] We piloted the survey with six ICU nursing leaders at two institutions to obtain their feedback about the content, form, and structure. The final survey included 30 items within five domains: hospital characteristics related to ICU organization and management; actions intended to reduce demand for critical care; actions intended to increase the supply and/or efficiency of critical care; actions related to mechanical ventilation; and actions related to staffing. For each action, respondents could indicate that they either did it, considered doing it but did not actually do it, never considered doing it, or were unsure. The complete survey instrument is provided in e-Appendix 2.

Survey Administration

The survey was administered from September 14, 2020, through November 20, 2020. A mixed methods approach was used whereby respondents were invited by mail and telephone to complete the survey on-line using a commercial electronic survey tool (Qualtrics). All mail correspondence was addressed to the hospital's Chief Nursing Officer, with instructions to pass the survey on to another individual should they not be the best person to complete the survey. We chose to send the survey invitation to the Chief Nursing Officer because this position exists at all US hospitals, and people in this role are well positioned to be able to answer questions about hospital surge planning. To incentivize participation, the initial invitation letter included a $10 bill and offered a $50 gift card upon completion. Nonrespondents were sent two additional letters at 2-week intervals. We then attempted to contact nonresponders by telephone to encourage them to complete the survey. During the telephone call, a research assistant also offered to complete the questionnaire over the telephone if desired by the participant.

Analyses

To evaluate for the possibility of nonresponse bias, characteristics of responding hospitals and nonresponding hospitals were compared by using Fisher exact test. Characteristics of interest included the stratification variables described earlier, as well as ICU size and the size of the hospital's metropolitan statistical area. For this analysis, we considered a survey to be a response when it was $> 30\%$ complete.

Among respondents, we then calculated the proportion of hospitals that took each potential action. Both unweighted proportions and weighted proportions were calculated. To estimate weighted proportions, we accounted for the sampling strategy by creating inverse probability sampling weights based on the number of hospitals in the respondent's stratum.[30] We also accounted for nonresponse by creating a propensity score for survey response using a logistic regression model in which the independent variables were all hospital characteristics described earlier.[31] The final survey weights were the product of the sampling weights and the propensity score.

A bivariate analysis was also performed in which we examined whether hospitals' actions were associated with the cumulative incidence of COVID-19 cases in their region. To simplify this analysis, the survey responses were dichotomized as either yes, indicating that the hospital completed the action, or no, indicating any other response. The cumulative incidence of COVID-19 in each hospital's region was also dichotomized as either high (defined as at or above the median) or low (defined as below the median). For this analysis, we used the incidence on the date the respondent took the survey rather than the date the survey was launched. The statistical significance of differences across groups was assessed by using Rao-Scott corrected F tests.[32]

Statistical analyses were performed with Stata 16.1 (StataCorp). A P value $\leq .05$ was considered significant. All aspects of this research were reviewed and approved by the University of Pittsburgh Human Research Protections Office.

Results

Surveys were sent to Chief Nursing Officers of 540 US hospitals, including 330 hospitals from the stratified random sample and 210 additional hospitals from the high-prevalence regions, and responses were received from 169 (31%) (Fig 1). A total of 148 (87.6%) respondents were Chief Nursing Officers. Other respondent types included hospital leaders of quality, safety, and patient care (n = 7 [4.1%]), ICU leaders (n = 5 [3.0%]), Chief Operating Officers (n = 4 [2.4%]), other nursing administrators (n = 3 [2.3%]), and other hospital administrators (n = 2 [1.2%]). Table 1 summarizes characteristics of surveyed hospitals. Nonresponding hospitals had more ICU beds, were located in larger communities, were more likely to be part of a hospital system, and were more likely to be in regions of higher COVID-19 caseloads.

Table 2 summarizes the actions and preparations in response to COVID-19-related surge in demand for critical care services, reported as weighted estimates of all US hospitals. The unweighted survey results are presented in e-Table 1. To reduce overall demand for intensive care by non-COVID-19 patients, the vast majority of hospitals canceled or postponed both elective surgeries (96.7%) and nonsurgical procedures (94.8%).

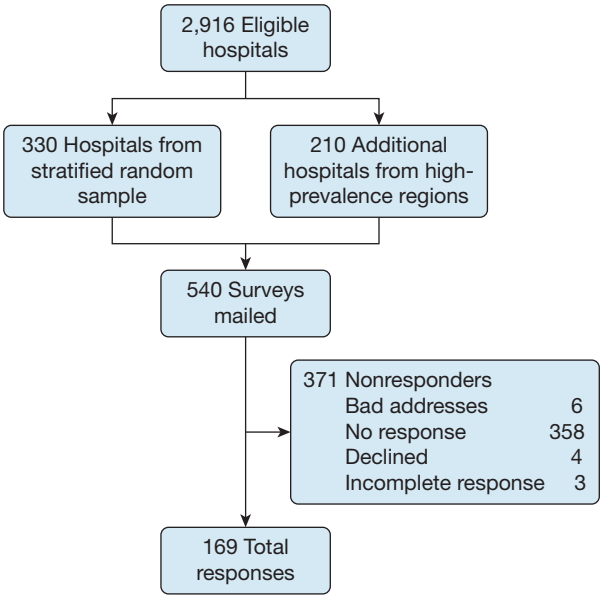

Figure 1 – *Flow diagram for hospital sampling strategy and survey responses.*

Many hospitals were also prepared to cancel medical treatments (53.3%) but did not do so. To increase efficiency/supply of ICUs, a majority of hospitals dedicated specific ICUs for patients with COVID-19 (63.3%). The majority of hospitals were also prepared to transform other clinical units (eg, step-down units, medical wards, even non-ward clinical spaces) into ICUs, but many did not actually do so, and only very few hospitals created new medical units altogether (12.9%).

To increase or preserve ventilator capacity, most hospitals bought or borrowed additional mechanical ventilators (70.7%), and most of the remaining hospitals were at least prepared to do so (27.2%). Almost no hospitals actually developed protocols for rationing ventilators (5.6%) or connecting multiple patients to a single ventilator (4.8%), although a majority were prepared to do both (64.4% and 61.3%, respectively).

Many organizational modifications were made to increase or preserve ICU staff. In a majority of hospitals, ICU providers had increased working hours (61.3%) and newly created specialized procedure teams dedicated to patients with COVID-19 (59.5%). Most hospitals also either reassigned providers from other units and roles to ICUs (36.1%) or prepared to do so (49.2%). Table 3 summarizes provider reassignment patterns among hospitals that made this organizational change; unweighted estimates are given in e-Table 2. Relatedly, most hospitals employed or prepared to employ "team nursing" models, in which ICU nurses and medical/surgical nurses cared for patients as a team, to support the reassigned nursing staff (33.2% and 52.8%, respectively). Some hospitals also specifically expanded roles and responsibilities of advanced practice providers (24.8%), thereby expanding staff with prescribing, ordering, and procedural privileges. A majority of hospitals also either brought in new ICU providers (41.7%) or were prepared to do so if needed (34.0%). Finally, many hospitals expanded existing ICU telemedicine programs (39.1%), and a significant minority of hospitals introduced a new telemedicine program (25.6%) to extend critical care expertise to more hospital beds.

Hospitals in high-prevalence regions took four specific actions more often than those in low-prevalence regions (Fig 2): (1) they adopted policies to accept fewer interhospital transfer patients (32.3% vs 8.7%; $P < .001$); (2) they repurposed nonclinical spaces as ICUs (19.7% vs 6.2%; $P < .01$); (3) they adopted a protocol for connecting multiple patients onto a single ventilator (8.3% vs 1.4%; $P = .02$); and (4) they altered traditional provider-to-patient ratios (56.8% vs 11.5%; $P < 0.001$). Hospitals in low-prevalence regions more often canceled/postponed nonsurgical procedures compared with those in high-prevalence regions (98.0% vs 91.6%; $P = .02$).

Discussion

To the best of our knowledge, this study is the first nationally representative survey of organizational actions taken to respond to the surge in demand for critical care services in the United States due to the COVID-19 pandemic. Because of the sampling strategy used, we were able to generate national estimates of response actions and preparations. We found variability across hospitals in most actions, suggesting that hospitals' individual responses were likely tailored to their local perceived needs, priorities, and resources.

There were a few notable exceptions to this variability. First, virtually all hospitals reported canceling elective procedures, in line with national recommendations at the start of the pandemic.[33,34] Canceling elective procedures addressed several surge planning issues: preserving ICU bed capacity, preserving personal protective equipment, freeing up clinicians to staff ICU expansions, and potentially reducing risk of transmission among health care workers and patients, to

TABLE 1] Characteristics of Responding Hospitals and Nonresponding Hospitals

Characteristic	Responding Hospitals (n = 169)	Nonresponding Hospitals (n = 371)	*P* Value
Hospital size			.22
< 100 beds	42 (25.0)	74 (19.9)	
100-250 beds	67 (39.9)	138 (37.2)	
> 250 beds	60 (35.5)	159 (43.0)	
ICU size			.02
1-10 beds	41 (24.3)	81 (21.8)	
11-30 beds	67 (39.6)	110 (29.6)	
> 30 beds	61 (36.1)	180 (48.5)	
Teaching status[a]			.85
Teaching hospital	89 (52.7)	192 (51.8)	
Nonteaching hospital	80 (47.3)	179 (48.2)	
Community size[b]			.001
< 100,000	45 (26.6)	55 (14.8)	
100,000 to 1 million	47 (27.8)	92 (24.8)	
> 1 million	77 (45.6)	224 (60.4)	
Membership in a hospital system			.001
Member	89 (52.7)	251 (67.5)	
System nonmember	80 (47.3)	120 (32.5)	
COVID-19 regional case load[c]			.02
Low	38 (22.5)	58 (15.6)	
Medium	42 (24.9)	72 (19.4)	
High	89 (52.7)	241 (65.0)	

All values are frequency (percent). Percentages may not add to 100 due to rounding. *P* values comparing responding hospitals vs nonresponding hospitals are from Fisher's exact test.
[a]Teaching status determined by a resident full-time equivalents > 0 from the 2018 Centers for Medicare & Medicaid Cost Reports.
[b]Total population of the hospital's metropolitan statistical area obtained from the 2013 United States Census.
[c]Regional case load as determined from the *New York Times* COVID-19 database on June 29, 2020. Low = < 2,000; medium = 2,001 to 14,250; and high > 14,250.

name a few. However, canceling procedures also had potential downsides. Many procedures considered "elective" are important to patients, and delaying such procedures can cause emotional and physical harm.[35,36] Surgical procedures are also a financial lifeline for small hospitals and safety net hospitals that can ill-afford to forgo revenue during a pandemic.[37] More research is needed to better understand these tradeoffs. In the interim, the decision to cancel elective surgery should be made based on local considerations after weighing the needs of all relevant stakeholders.

Another action that was notably consistent across hospitals was that most hospitals transformed (or prepared to transform) existing clinical space (predominantly other hospital units) into ICUs but did not create new clinical space or use nonclinical space to add ICU capacity. Prior to this pandemic, the United States had more ICU beds per capita than almost any other country, sometimes by an order of magnitude.[38] Although this has been a cause for criticism as a potential source of inefficiency and high-cost/low-value care,[39] the COVID-19 crisis has tested this thesis, as some regions of the world have been forced to implement ICU triage protocols due to inadequacy of ICU resources.[40] Indeed, early in the pandemic, some projections led experts to call for emergency expansion of hospital and ICU beds.[41] By the time this survey was conducted, few US hospitals reached a point where they adopted a protocol for rationing ventilators or for connecting more than one patient to a single ventilator, reflecting that hospital leaders perceived that they could safely deliver care without resorting to explicit rationing of equipment. This suggests that with flexible use of clinical spaces, the US health care system was largely able to meet the demand for ICU beds, although our findings do not rule out the possibility of implicit rationing by clinicians at the bedside. Furthermore,

TABLE 2] Weighted National Estimates of Actions Taken to Prepare for and/or Respond to a Surge in Critically Ill Patients Related to COVID-19 Among US Hospitals

Action	Prepared and Did It	Prepared But Did Not Do It	Did Not Prepare or Unsure
Actions to reduce demand for intensive care			
Canceled/postponed elective surgery	96.7%	2.9%	1.0%
Canceled/postponed nonsurgical procedures	94.8%	3.6%	1.6%
Adopted a policy to transfer more patients to other acute care hospitals	36.0%	47.1%	17.0%
Canceled/postponed medical treatments	28.8%	53.3%	17.9%
Adopted a policy to accept fewer transfers from other acute care hospitals	20.4%	37.8%	41.7%
Actions to increase efficiency/supply of ICUs			
Dedicated specific ICUs as "COVID-19" ICUs	63.3%	21.0%	15.7%
Repurposed existing step-down units as ICUs	50.8%	37.6%	11.6%
Repurposed other clinical care space not typically dedicated to inpatient care as an ICU	32.7%	58.7%	8.6%
Repurposed existing medical/surgical units as ICUs	24.0%	49.6%	26.4%
Created new medical units in areas not typically dedicated to health care	12.9%	47.7%	39.4%
Actions to increase or preserve ventilator capacity			
Bought or borrowed additional mechanical ventilators	70.7%	27.2%	2.1%
Used noninvasive ventilators, CPAP machines, or anesthesia machines for mechanical ventilation	29.5%	63.8%	6.8%
Developed or adopted a protocol for rationing ventilators	5.6%	64.4%	29.9%
Developed or adopted a protocol for connecting more than one patient to a single ventilator	4.8%	61.3%	34.0%
Actions to increase or preserve ICU staff			
Created specialized teams to perform procedures on COVID-19 patients	59.5%	23.0%	17.5%
Asked ICU providers to work longer hours or extra shifts	61.3%	30.3%	8.4%
Brought in new ICU providers who do not typically work in the hospital to help out	41.7%	34.0%	24.3%
Altered traditional provider/patient ratios	33.3%	63.1%	3.6%
Used a "team nursing" model to care for patients in COVID-19 ICUs	33.2%	52.8%	14.0%
Put non-ICU providers to work in the ICUs	36.1%	49.2%	14.7%
Expanded APP roles and/or privileges	24.8%	36.1%	39.1%
Actions related to telemedicine			
Expanded an ICU telemedicine program to cover more beds in the hospital	39.1%	29.5%	31.4%
Introduced an ICU telemedicine program to cover beds within the hospital	25.6%	21.1%	53.3%

Weighted estimates used inverse probability weighting to account for the sampling strategy and propensity score methods to account for nonresponse. APP = advanced practice providers.

whether those beds are adequately staffed is another important consideration that remains unanswered.

Regarding staffing, hospitals also showed remarkable flexibility. The fact that there was no single dominant strategy for ICU staffing highlights the preceding organizational variability and that hospitals tailored their approaches accordingly. Of note, hospitals in high-prevalence regions were more likely to alter traditional staffing ratios, presumably to assign more patients for a single provider. This pattern may reflect the strong belief

TABLE 3] Weighted National Estimates of Patterns of Nontraditional ICU Providers in the Roles of ICU Providers

Type	%
Medical/surgical nurses used in the role of ICU nurses	29.9
ED, PACU, or operating room nurses in the role of ICU nurses	15.7
Physicians without critical care certification in the role of intensivists	9.7
PICU clinicians in the role of adult ICU clinicians	2.2
Other	13.8

Weighted estimates used inverse probability weighting to account for the sampling strategy and propensity score methods to account for nonresponse. PACU = postanesthesia care unit.

in certain staffing ratios and the potential negative impact of strain, with respect to both patient outcomes and clinician wellness. California and Massachusetts have mandated nurse-to-patient ratios (eg, two patients per nurse in the ICU).[42,43] Although California's governor waived these ratios during the pandemic, the governor of Massachusetts did not. Also remarkable is the relatively high proportion of hospitals using innovative staffing approaches such as team nursing, where teams of nurses work collectively to care for a larger number of patients[44,45] (eg, four registered nurses and one aide for 10 patients compared with one ICU nurse for two patients), thereby extending the critical care expertise of individual nurses to a larger number of patients.

Our study has a few important limitations. First, although we sent the surveys to a nationally representative hospital sample to generate population estimates, the response rate was low, posing a risk of response bias. We used typical incentives to promote participation; however, busy hospital leaders likely had more limited availability to participate in a voluntary survey. Nonresponders included a higher percentage of larger hospitals in larger communities. We used statistical techniques to account for nonresponse in weighted estimates. Second, because of the nature of the virus transmission, the first "surges" happened in different regions at different times; our survey was administered at one point in time, however, such that hospitals were at variable stages of their pandemic planning and response. In some cases, hospitals may have prepared to take a specific action but not yet taken it, but may proceed to take it following the survey or in the future. This too may have led to inaccuracy in capturing the complete picture of the US response to the pandemic. However, this limitation reflects the reality of conducting organizational research during a fast-moving pandemic. In addition, we specifically aimed to capture data regarding the initial response to the pandemic and accounted for local prevalence in our analyses. Finally, our study was not designed to identify implicit rationing that may have occurred at the bedside.

Interpretation

The current survey of a representative sample of US hospitals summarizes the variability in hospital responses to the mass need for critical care services due to the COVID-19 pandemic. Most hospitals canceled procedures to preserve ICU capacity and scaled up ICU capacity by using existing clinical space, resources, and staffing. Almost no hospitals needed to adopt triage protocols or protocols for ventilator sharing. Future research linking hospital response to patient outcomes can inform planning for additional surges of this pandemic or other events in the future.

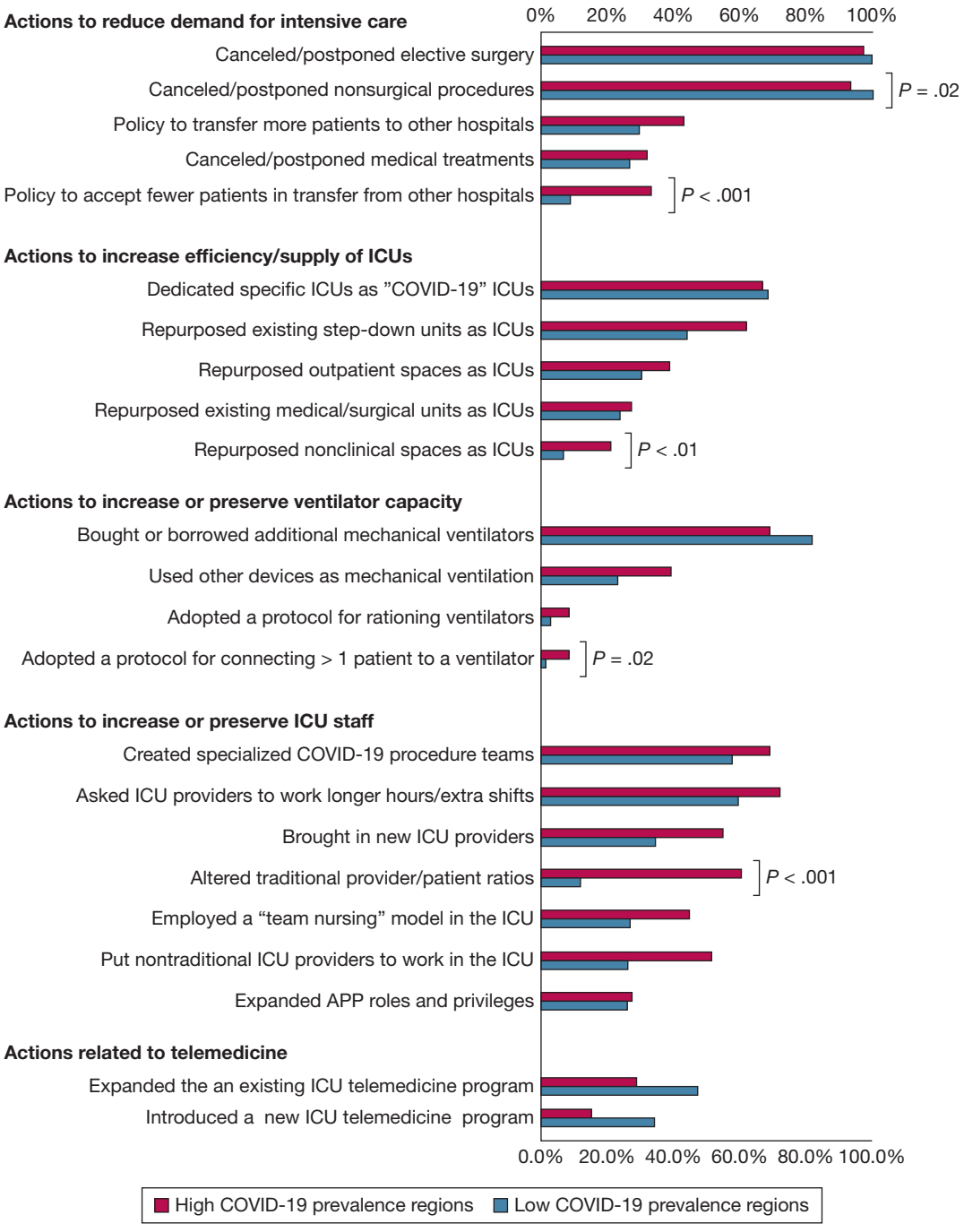

Figure 2 – *Actions taken comparing hospitals in high and low COVID-19 prevalence regions. APP = advanced practice providers.*

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

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