The Effects of ICU Crisis Reorganization on Outcomes in Patients Not Infected With Coronavirus Disease 2019 During the Initial Surge of the Coronavirus Disease 2019 Pandemic

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OBJECTIVES: To determine if ICU reorganization due to the coronavirus disease 2019 pandemic affected outcomes in critically ill patients who were not infected with coronavirus disease 2019.

DESIGN: This was a Before-After study, with coronavirus disease 2019-induced ICU reorganization as the intervention. A retrospective chart review of adult patients admitted to a reorganized ICU during the coronavirus disease 2019 surge (from March 23, 2020, to May 06, 2020: intervention group) was compared with patients admitted to the ICU prior to coronavirus disease 2019 surge (from January 10, 2020, to February 23, 2020: before group).

SETTING: High-intensity cardiac, medical, and surgical ICUs of a community hospital in metropolitan Missouri.

PATIENTS: All patients admitted to the ICU during the before and intervention period were included. Patients younger than 18 years old and those admitted after an elective procedure or surgery were excluded. Patients with coronavirus disease 2019 were excluded.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: We identified a total of 524 eligible patients: 342 patients in the before group and 182 in the intervention group. The 28-day mortality was 25.1% (86/342) and 28.6% (52/182), respectively ($p = 0.40$). The ICU length of stay, ventilator length of stay, and ventilator-free days were similar in both groups. Rates of patient adverse events including falls, inadvertent endotracheal tube removal, reintubation within 48 hours of extubation, and hospital acquired pressure ulcers occurred more frequently in the study group (20 events, 11%) versus control group (12 events, 3.5%) ($p = 0.001$).

CONCLUSIONS: Twenty-eight-day mortality, in patients who required ICU care and were not infected with coronavirus disease 2019, was not significantly affected by ICU reorganization during a pandemic.

KEY WORDS: disaster; facility design; intrahospital transport; mortality; pandemic; patient safety

As the coronavirus disease 2019 (COVID-19) pandemic made its way to the United States, Mercy Hospital South began preparations for a potential surge in patients requiring intensive care in early March 2020.

Preparation strategies following disaster/pandemic guidelines from the Society of Critical Care Medicine (SCCM) were initiated. Strategies included creation of a tiered staffing model and identification of temporary ICU locations to allow for expansion from 38 ICU beds to potentially 120 ICU beds.

In mid-March 2020, our large, metropolitan community hospital admitted our first known patient infected with the novel coronavirus. Within a week, we had used all available ICU negative airflow rooms and we began to need to cohort patients into a neutral airflow ICU. To allow for the growing numbers of critically ill patients with COVID-19, our hospital began a series of acute care bed reorganizations to become temporary ICUs. This included relocating patients to different units to handle the surge of patients as well as to remodel the preexisting ICUs into completely negative airflow units. This required multiple intrahospital transfers (IHTs) as continued growth occurred expanding from three ICUs housing up to 38 patients to five ICUs (the three traditional ICUs, an intermediate care/step-down unit, and a progressive care unit) housing up to 83 ICU patients. Intensivists were assigned patients over multiple ICUs and non-ICU nurses and respiratory care providers were given patient care assignments in the ICUs under the guidance of ICU nursing and respiratory staff.

Primmaz et al (1) determined earlier this year that with appropriate preparation, rapid adaptive ICU reorganization for patients with severe COVID-19 maintained good quality of care and a resulting low mortality rate. The purpose of this study is to determine if ICU reorganization due to COVID-19 pandemic affected outcomes of critically ill patients who were "not" infected with COVID-19. Primarily, we sought to determine if there was a difference in 28-day mortality in critically ill patients without COVID-19 admitted before the pandemic (before group) versus those admitted after the reorganization (intervention group) of our ICUs.

Epidemiologists are predicting a second surge of COVID-19 in the late fall and winter of 2020–2021, which may require another round of ICU reorganization. This study is designed to guide our own and other community hospitals in the safety of the reorganization process. To our knowledge, this is the first study looking at this outcome in patients not diagnosed with COVID-19 during a pandemic-induced restructuring.

MATERIALS AND METHODS

Setting

Mercy Hospital South is a metropolitan community hospital with level II trauma capabilities. The hospital is part of the larger Mercy Hospital system encompassing more than 20 hospitals across four Midwestern states. The hospital is licensed for 800 beds but with conversion to private rooms, practically functions as an approximately 450-bed hospital. There is a cardiac/cardiothoracic ICU (CCU), a medical ICU (MICU), and a neuro-/surgical ICU, which house 10, 12, and 16 patients, respectively. Each of the three ICUs is covered by a Board Certified/Board Eligible critical care physician during the day and collectively by a single in-house critical care physician as well as a virtual intensivist at night. Nursing-to-patient ratios are almost always 1:2 with occasional 1:1 staffing for patients with very high acuity or uncommonly 1:3 staffing for lower acuity patients. An additional charge nurse is available with intermittent patient staffing duties. A dedicated pharmacist is present during the daytime hours, and two or three respiratory therapists are present for the ICUs depending on patient acuity. The hospital meets all staffing criteria per Leapfrog guidelines.

Study Design, Methodology, and Time

This was a single-center retrospective, Before-After study, with COVID-19-induced ICU reorganization as the intervention. The before period consisted of patients who were hospitalized in our traditional ICUs in the 45 days prior to the pandemic's forced reorganization of our hospital's ICUs. This included ICU patients admitted between January 10, 2020, and February 23, 2020, with a follow-up period through March 22, 2020, to capture the 28-day mortality. The intervention period included patients who were hospitalized in the 45 days following the opening of the first makeshift ICU. These were ICU patients without COVID-19 who were admitted between March 23, 2020, and May 6, 2020, with follow-up information through June 3, 2020.

Exclusion criteria included less than 18 old, patients admitted to the ICU after an elective procedure or surgery (e.g., coronary artery bypass grafting, cardiac valve repair or replacement, carotid endarterectomy, elective craniotomy, peripheral revascularization, or endoscopic procedure), noncritically patients housed

in the ICU due to lack of intermediate beds (i.e., "step-down overflow"), and all COVID-19-positive patients. Those patients who were initially labeled as persons under investigation and were later found not to have COVID-19 were "not" excluded.

Patients were identified by electronic medical record census data reports for units functioning as ICUs. Characteristics of the before and intervention group patients, including age, sex, race, predicted Acute Physiology and Chronic Health Evaluation (APACHE)-IV mortality, use of vasopressors, use of mechanical ventilation, ICU length of stay (ICU LOS), ventilator length of stay (VLOS), ventilator-free days (VFDs), and IHT numbers, while in the ICU were determined through electronic chart review. Data for patient adverse events (PAEs) were collected through both electronic medical record review and referrals to the institutional incident reporting system.

The primary outcome was the difference in 28-day mortality between the patients, admitted in the before and intervention group. Secondary outcomes included ICU LOS, VLOS, VFD, and rates of PAE (PAEs included falls, inadvertent endotracheal tube removal, reintubation within 48 hr of extubation, and hospital-acquired pressure ulcers). Mann-Whitney (nonparametric test) was used when testing for significance among continuous variables. For categorical data, the Fischer exact test was used. The p value of less than 0.05 was used to calculate significance. When available via the electronic medical record, information was used after discharge for 28-day mortality data. Patients with no recorded data postdischarge were excluded from final analysis.

Mercy Institutional Review Board, St. Louis, MO, reviewed the protocol and waived the need for approval (exemption status granted, for study number: 1631800-1; 20-202; on July 16, 2020).

RESULTS

A total of 524 patients were included in the study, 342 in the before group and 182 in the intervention group. **Table 1** demonstrates the baseline characteristics of patients admitted during the before and intervention period. The groups were similar in age (65 vs 66 yr; p = 0.36), ethnicity (92% Caucasian), and use of vasopressors (31.9% vs 36%; p = 0.37). The IHTs during ICU stay were similar in both groups (50.3% vs 56.6%; p = 0.19).

The intervention group patients were more likely to be male (53.2% vs 63.7%; p = 0.02) and more likely to require ventilators (37.4% vs 48.9%; p = 0.01). The APACHE-IV-predicted mortality was similar in both groups (19.1% vs 21.9%; p = 0.14).

Table 2 demonstrates the results of the primary and secondary outcomes. There was no difference in the primary outcome of 28-day mortality (25.1% vs 28.6%; p = 0.40) between the two groups. Secondary outcomes were similar in both groups: ICU LOS (4.31 vs 4.88 d; p = 0.84), VLOS (5.31 vs 6.08 d; p = 0.26), and VFD (14.2 vs 12.1 d; p = 0.40). PAEs (falls, inadvertent endotracheal tube removal, reintubation within 48 hr of extubation, and hospital-acquired pressure ulcers) were significantly higher in the intervention group (11% vs 3.5%; p = 0.001). **Figure 1** depicts the 28-day survival of the two groups.

To see if secular trends affected PAE, an interrupted time series (ITS) analysis was done. Linear regression for the post-ICU restructuring (intervention group) predicted a PAE every 3 days, compared with one PAE occurring every 4 days prior to restructuring (before group) (**Fig. 2**).

Code status of the expired patients on ICU admission was similar in the two groups. About 15 patients had do-not-resuscitate (DNR) status in before group, whereas 11 patients who expired had DNR status in intervention group (p = 0.8235). The observed mortality was higher than the predicted mortality in both groups; this difference, however, was not significant statistically (before group: p = 0.06; intervention group: p = 0.18).

DISCUSSION

Throughout the world, a prevailing theme of the COVID-19 pandemic has been to provide adequate hospital beds for acutely ill patients with severe acute respiratory syndrome-coronavirus-2 infections. Large quaternary centers have described their processes for expanding to meet the specific needs of the critically ill population. Deficits in ventilators, pharmaceutical agents, healthcare providers, and more have led to inventive and astute techniques to provide care for larger numbers of patients with the intent of not compromising patient care. Johns Hopkins Hospital described in detail how they turned half of their PICU into an adult MICU (2). Other facilities

TABLE 1.
Patient Demographics and Treatment Characteristics

Patient Demographics	Before Group, n = 342	Intervention Group, n = 182	Test	p
Age	65 ± 16.7	66.1 ± 17.7	Mann-Whitney	0.36
Males, n (%)	182 (53.2)	116 (63.7)	Fischer exact	0.02[a]
Female, n (%)	160 (46.8)	66 (36.3)		
Caucasian, n (%)	317 (92.7)	169 (92.9)	Fischer exact	1
Vasopressor use, n (%)	109 (31.9)	64 (36)	Fischer exact	0.37
Ventilator use, n (%)	128 (37.4)	89 (48.9)	Fischer Exact	0.01[a]
Predicted Acute Physiology and Chronic Health Evaluation IV Mortality	19.1% ± 20.7%	21.9% ± 21.0%	Mann-Whitney	0.14
Intrahospital transfer, n (%)	172 (50.3)	103 (56.6)	Fischer exact	0.19

[a]p value of less than 0.05.
Patients in the intervention group demonstrated statistically significant differences in ventilator usage and sex demographics as compared with the before group. The predicted Acute Physiology and Chronic Health Evaluation IV mortality was the same in both groups. Each variable had its mean value tested for significance using the Mann-Whitney or Fisher exact test for significance depending on whether it was a continuous or discrete variable, respectively.

TABLE 2.
Primary and Secondary Outcomes

Outcome	Before Group, n = 342	Intervention Group, n = 182	Test	p
28-d mortality[a], n (%)	86 (25.1)	52 (28.6)	Fischer exact	0.40
ICU length of stay (mean ± SD)	4.31 ± 4.63	4.88 ± 5.44	Mann-Whitney	0.84
Ventilator length of stay (mean ± SD)	5.31 ± 7.21	6.08 ± 7.77	Mann-Whitney	0.26
Ventilator-free days (mean ± SD)	14.2 ± 12.4	12.1 ± 12.2	Mann-Whitney	0.40
Patient adverse events, n (%)	12 (3.5)	20 (11)	Fischer exact	0.001[b]

[a]Primary outcomes.
[b]Statistically significant differences.
Patient adverse events (falls, inadvertent endotracheal tube removal, reintubation within 48 hr of extubation, and hospital-acquired pressure ulcers) occurred significantly more in the intervention group.
No other primary or secondary outcome presented a significant difference.
Ventilator-free days were defined as 28 d minus the number of days spent on a ventilator. If the patient spent more than 28 d on the ventilator or died prior to 28 d, then they were scored as 0.
Each outcome variable was tested for statistical significance in the difference of means by the Mann-Whitney or Fischer exact test depending on if it was a continuous or discrete measure, respectively.

have described transformation of step-down units, postanesthesia care units, and operating suites into temporary ICUs to meet the expanded needs of the COVID-19 population (1).

Our COVID planning team met bid beginning 3 weeks before the surge in patients to our local area and throughout our greatest time of crisis. We used the SCCM guidelines and American College of Chest
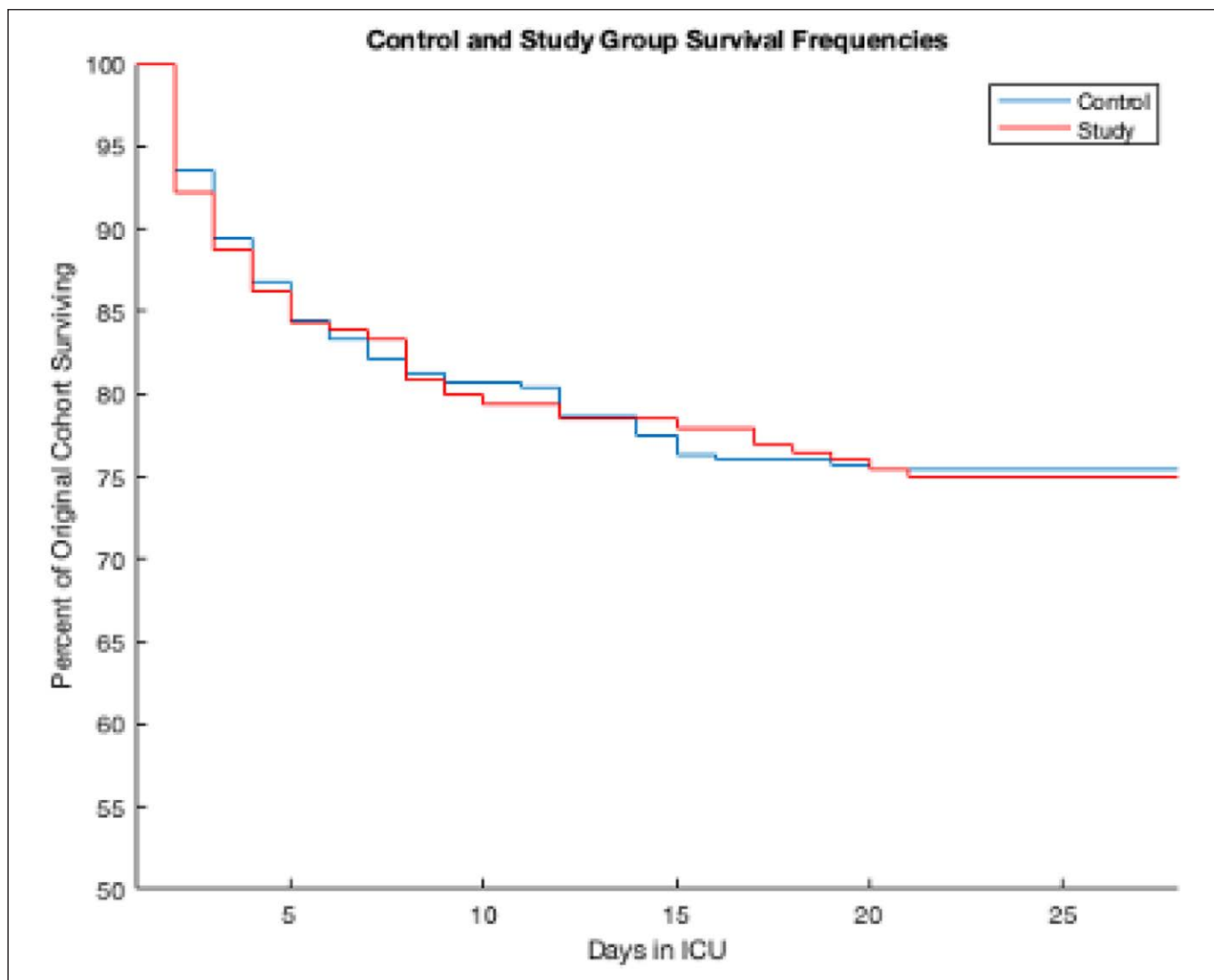
Figure 1. Twenty-eight day mortality.

Physicians Consensus Statement for pandemic and disaster preparedness (3–5). Initially, we placed COVID-positive patients in designated negative airflow ICU rooms. We quickly surpassed our four negative airflow rooms and changed to cohorting COVID patients in our CCU. Routine and elective cases were canceled creating more ICU bed availability. During the study period, the CCU and MICU were each temporarily closed to convert both ICUs into an entirely negative airflow space. As this restructuring progressed, critically ill ICU patients who did not have the diagnosis of COVID-19 were moved from one ICU to another and finally to a 32-bed cardiac progressive unit that became a makeshift ICU.

The current study was designed to see if this reorganization and restructuring affected outcome in

patients who did not have the diagnosis of COVID-19. A 45-day period was chosen, since the COVID-19 surge started to subside at our institute around this time, and the ICUs started moving back to their previous locations. As well, we reverted to our regular ICU nursing and physician staffing models. We excluded all patients who required ICU admission after an elective procedure or surgery, since, during the pandemic, all of these were suspended. With the above inclusion and exclusion criteria, the two groups had similar APACHE-IV-predicted mortality. APACHE-IV-predicted mortality was used for acuity, as it was our hospital system's standard practice at the time.

The primary outcome of 28-day mortality was similar in two groups. Mortality in ICU can be affected by DNR status and the pandemic may have resulted in
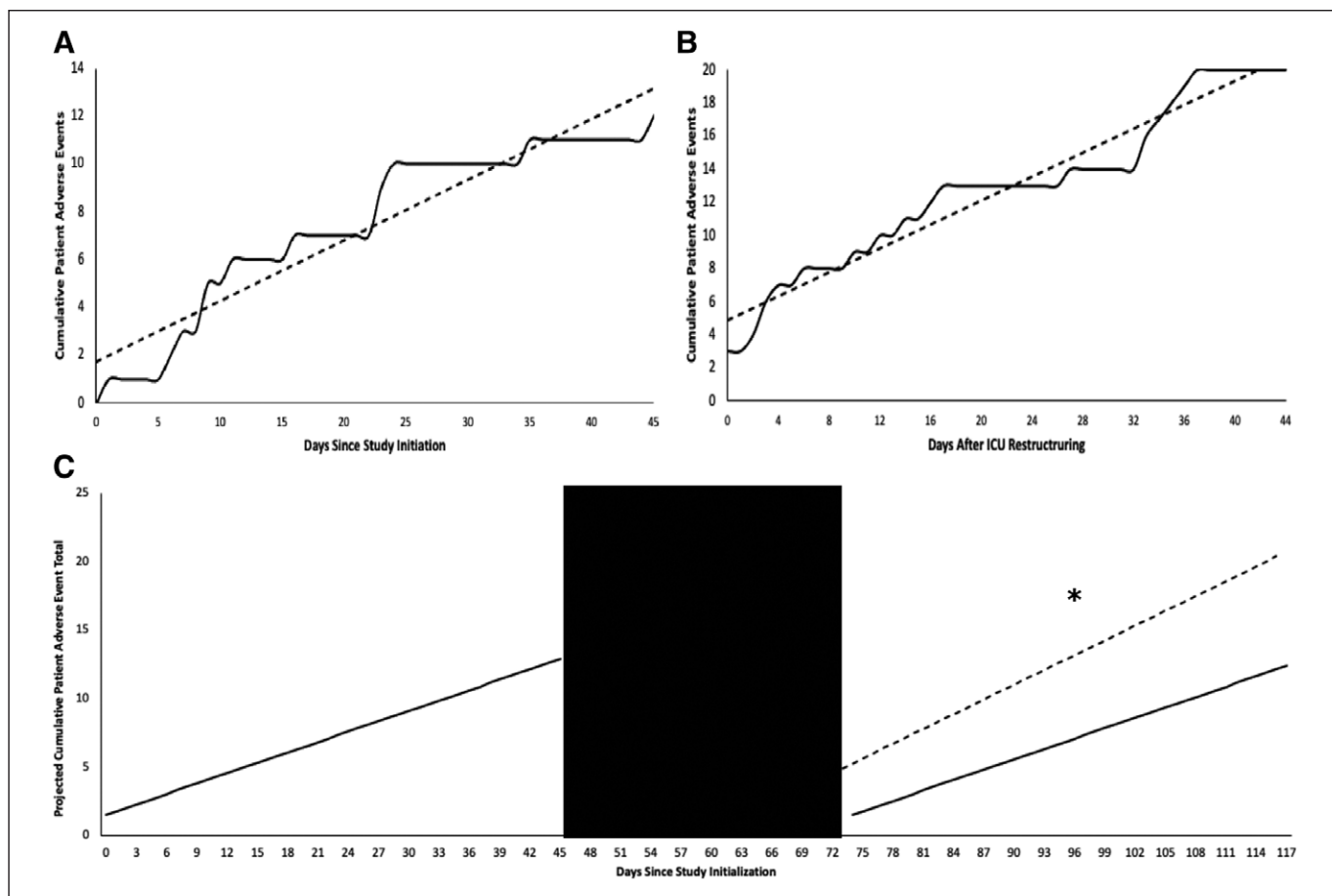
Figure 2. Interrupted time series analysis of patient adverse events prior to and after coronavirus disease-induced ICU restructuring. **A**, Linear regression model (*dotted line*) for the total patient adverse events (PAE) over the 45 days prior to ICU restructuring predicted 13 total events ($R = 0.90$) by the end of the period compared with the 12 actually recorded. **B**, Another linear regression model (*dotted line*)-predicted 20 total PAEs ($R^2 = 0.95$) for the 45 days immediately following the ICU restructuring that exactly matched the 20 recorded PAEs. **C**, The superimposition of the two models demonstrated a clear divergence for predicted PAEs for the period immediately following ICU restructuring. The linear regression for the post-ICU restructuring predicted a PAE every 3 d compared with the pre-ICU restricting model that predicted a PAE every 4 d.

less DNR status patients being admitted to the ICU to conserve scarce resources. To evaluate this, code status of patients who expired were compared (code status at admission to ICU). Both groups had a similar number of DNR patients.

To see if secular trend affected PAE, ITS analysis of PAE was done. ITS demonstrated that the rate of PAE occurrences prior to ICU restructuring and the rate of PAE occurrences after ICU restructuring differed significantly ($p = 0.01$). **Figure 2C** projected the pre-ICU-restructuring PAE rate onto the post-ICU-restructuring period. This demonstrated that the pre-ICU-restructuring model cannot account for the observed number of PAEs recorded after ICU-restructuring occurred. Therefore, the difference in observed PAEs after ICU-restructuring occurred can

be attributed to the change in the rate of occurrence rather than any secular trends.

ICU design, increased physician and nursing workload, and IHTs have all been associated with adverse patient outcomes. We describe below how each of these was affected during our hospital's initial COVID-19 surge.

ICU Design

Since 1992, the importance of ICU design has been recognized (6). ICU design includes components of patient room construction, central areas/overall layout, and overall support services. These central areas support bedside care and assist in themes of healing, privacy, informatics, communication, infection control, and foster cohesive ICU environments,

and ideally central stations should have unobstructed views of ICU patients (7). Recommendations in the initial design of an ICU include prescriptive guidelines by The Facilities Guidelines Institute for minimal requirements and prescriptive guidelines for optimal conditions. These prescriptive guidelines should "balance innovation and functionality," whereas they work to reduce medical errors, improve patient outcomes, reduce LOS, increase social support/provide a healing environment, and reduce costs. Recommendations for ideal ICU designs include reduced travel distances for staff and ability for caregivers to observe patients readily (7, 8). All of the above considerations went into selecting our makeshift ICU. The unit was a double-rectangular/double-corridor design with private enclosed suites (**Fig. 3**). Both the layout and suite type carried the disadvantages of reduced visibility and longer walking/reduced efficiency (6). Previous studies have demonstrated that low-visible rooms and longer walking distances are associated with increased mortality in high acuity patients (9, 10).

Increased Physician and Nursing Workload

Along with this physical restructuring, personnel reorganization (physician, nursing, and respiratory therapy) also occurred. During the study period, the regular intensivist staffing model was disturbed, and the intensivist taking care of non-COVID-19 patients routinely had a census of more than 15. An intensivist-to-patient ratio of more than 15 has been associated with increased ICU LOS (11). The SCCM in their guidelines acknowledges this, but currently do not make a specific recommendation about staffing. SCCM has suggested staffing should be adequate to account for a surge and to get timely daily rounds done (12). Sometimes, due to excess census, intensivists taking care of COVID-19 patients had to additionally help in taking care of non-COVID-19 patients admitted in a different ICU. In addition, pulmonary critical care physicians who normally had a hybrid inpatient and outpatient model of pulmonary practice were recruited to staff ICUs during the surge.

Nurse-staffing-to-patient ratio has been associated with worse patient outcomes (13). Multiple changes occurred to our standard nursing practice during the study period. First, there was recruitment of non-ICU nurses to work under the supervision of an ICU nurse. ICU float pool nurses from our hospital system's regional float pool and agency nurses were used at a higher rate than during the intervention period in our ICUs. In addition, the non-COVID charge nurse covered up to 35 patients compared to less than 20 during standard
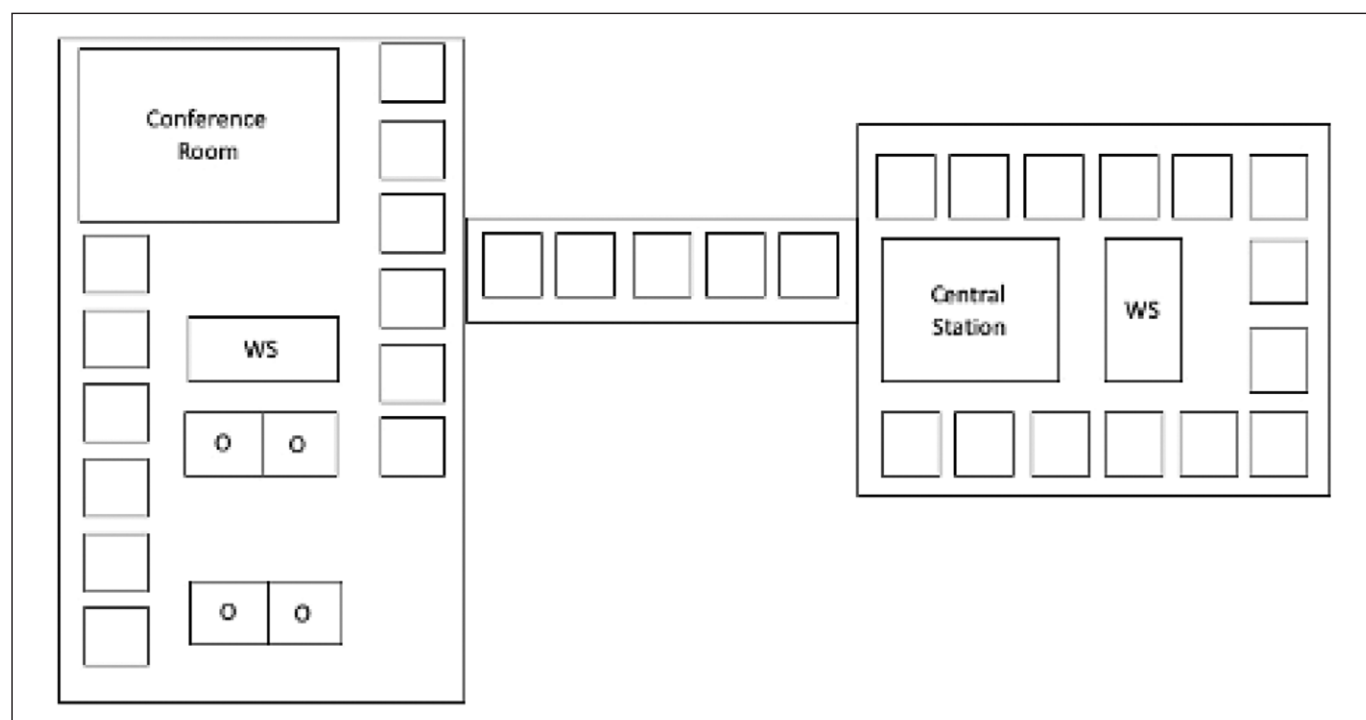

Figure 3. Structure of reorganized "makeshift" ICU during pandemic surge, which cared for patients without coronavirus disease 2019. WS = Work Station.

practice times. These personnel changes resulted in daily multidisciplinary rounds occurring at variable times and sometimes being canceled.

IHTs have been shown to affect ICU LOS in ventilated patients (14, 15) and PAEs including change in heart rate, hypotension, hypertension, arrhythmias, cardiac arrest, and respiratory decompensation (16–19). Prior studies have recommended protocols for IHT for policies for as well as use of transport teams (20). Inexperienced nurses and those without Bachelor of Science in Nursings have been noted to have higher risks of PAE with intrahospital transport (20). About two-thirds of nurses say their ICUs have transport policies to provide guidance, but nurses have described them as unsafe and stressful tasks (19). We did not account for how this mental burden or other IHT risk factors might have affected our patient outcomes. For workload during the study period, one charge nurse recalled, "The manpower required to transfer patients was crazy! There was a day when I transferred seventeen patients between units… Just to think about the amount of coordinating and time it takes to do that now is crazy! It's not just the time to actually roll them, it's making sure they have tele[metry] safe handoff, cleaning of the rooms, etc."

Despite having all the above factors that adversely affect patient outcome, our study did not show any difference in the primary outcome of 28-day mortality. The secondary outcomes of ICU LOS, VLOS, and VFD were also similar. The PAEs did occur at a significantly higher rate in the study group. This could be due to any of the above factors discussed. Given the significantly higher PAE, daily multidisciplinary rounds during crisis time assume more importance and should not be ignored or canceled. The importance of these rounds should be emphasized to the nursing and physician staff who will be staffing the ICU during crisis time.

A major limitation of our study is its retrospective Before-After design, with its associated flaws. Second, the COVID 19 pandemic resulted in a decline in admissions to hospitals across United States for almost all conditions (21). Despite the two groups in our study having the same APACHE-IV mortality, we were likely dealing with a different patient population in the intervention period (more male admission and mechanical ventilation use occurred during the intervention period). Our small sample size prevented us from risk matching the two groups. Third, we tried to capture transfer between different units by looking at the nursing and intensivist notes, but it is likely we missed transfers when patients were moved from one ICU to another due to lack of documentation. Although the number of transfers between the groups in our study was not statistically different, we did not specifically look at only those patients that required higher numbers of transfers.

CONCLUSIONS

Twenty-eight-day mortality, in patients who required ICU care and were not infected with COVID-19, was not significantly affected by ICU reorganization during a pandemic.

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