

CONCEPTS

General Medicine

Design and implementation of a temporary emergency department-intensive care unit patient care model during the COVID-19 pandemic surge

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Abstract

The ongoing pandemic of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has resulted in rapid surges of critically ill patients infected with coronavirus disease 2019 (COVID-19) pneumonia presenting to the emergency department (ED) and requiring ICU admission nationwide. Despite adaptations in critical care personnel staffing, bed availability and supply provision, many inpatient ICUs have become acutely crowded, leading to boarding of critically ill patients with COVID-19 and other diseases in the ED. To address this scenario at our urban, safety net, tertiary care institution in the spring of 2020, we designed and implemented a temporary “emergency department-intensive care unit” (ED-ICU) patient care service. Critical care-trained emergency physicians took call and came into the hospital overnight/on weekends to provide bedside treatment to admitted ICU patients boarding for prolonged periods in our ED. In this manuscript, we describe the creation and execution of the ED-ICU service and the characteristics and management of the patients who received care under this model.

KEYWORDS

coronavirus infections, critical care, emergency medicine, health services accessibility, organizational models

1 | INTRODUCTION

The ongoing pandemic of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has resulted in a rapid surge of critically ill patients infected with coronavirus disease 2019 (COVID-19) pneumonia presenting to the emergency department (ED) and requiring admission to the ICU at hospitals worldwide.¹ This sudden influx of numerous patients simultaneously requiring significant technical and human resources has threatened to overwhelm health care capacity in

certain areas.² In response, medical personnel have quickly designed and implemented a variety of strategies to provide safe and effective treatment to the volumes of severely ill patients with COVID-19 as well as those with non-pandemic critical illness.³⁻⁵

Despite efforts to acutely expand inpatient critical care capacity during the pandemic, many hospitals are faced with ICU bed shortages, which often result in critically ill patients boarding in the ED.⁶ This phenomenon is not unique to the COVID-19 pandemic; ICU crowding and ED boarding of critically ill patients has been recognized for decades

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and found to be associated with worse outcomes for patients unable to be transferred to an ICU bed in a timely manner.^{7,8} This dilemma, in conjunction with recently expanded formal critical care fellowship training for emergency physicians, has led to the development of patient care models where ICU patients admitted through the ED for whom an inpatient bed is not immediately available are cared for by select emergency physicians, often in specialized physical spaces, and frequently for prolonged time periods until an inpatient critical care bed becomes available.^{9,10} This so-called ED-ICU structure existed in a few United States (US) institutions prior to the pandemic, but the creation and implementation of such a program specifically to accommodate for the COVID-19 pandemic has not been described previously.

Here, we describe the design and implementation of a temporary ED-ICU treatment service that was used at our hospital during the surge of the COVID-19 pandemic in the city of Philadelphia, Pennsylvania from April to May 2020.

2 | PRE-PANDEMIC STRUCTURE

Prior to the COVID-19 pandemic, Einstein Medical Center Philadelphia maintained 548 inpatient beds, with 48 located within 3 ICUs (medical, cardiac, surgical). The ED staffed 27–39 high-acuity beds, depending on time of day, with an additional 24 low-acuity treatment areas available for non-critically ill patients. The approximate annual census for the ED was 100,000 visits and the combined ICUs was 3500.

The ED was staffed 24 hours a day by board-certified attending emergency physicians, advanced practice providers, and emergency medicine (EM) residents. The standard ED nurse:patient ratio was 1:3–1:5 and 1 respiratory therapist was dedicated to the ED 24 hours a day with immediate backup available. The medical and cardiac ICUs were staffed by board-certified attending providers (medical ICU, pulmonary critical care; cardiac ICU, cardiology) during the daytime and by critical care medicine fellows or medical residents 24 hours a day. The surgical ICU was staffed by board-certified acute care surgeons and surgical residents 24 hours a day. Standard ICU nurse:patient ratio was 1:2 and respiratory therapist:patient ratio was 1:8.

For ICU patients being admitted from the ED, responsibility for bedside care was transitioned from the emergency physicians to the ICU physicians soon after the time of inpatient bed request. If an ICU bed was not immediately available, the patient remained physically located in the ED. The ICU physician team would perform an initial in-person patient evaluation after the request for critical care admission, and after that time physician treatment would be provided solely by the ICU providers, who resided 4–5 building floors away. Based on institutional quality-improvement data prior to the COVID-19 pandemic, ICU patients boarded in the ED for an average of 2–4 hours before being transported to an inpatient critical care bed.

3 | INITIAL PANDEMIC RESPONSE

The first patient with confirmed COVID-19 disease was admitted to our hospital on March 23, 2020. The pandemic rapidly expanded and by March 30, 2020 over 75% of patients in the medical ICU were infected/suspected of infection with COVID-19. To increase inpatient critical care bed capacity, our hospital made multiple adaptations: all elective surgeries were discontinued, ICU bed allocation was modified so that all patients, regardless of presenting condition (medical vs cardiac vs surgical) could be admitted to any available ICU bed, and 2 units previously used for post-anesthesia care (PACU) were converted to an additional 12 ICU treatment spaces using anesthesia machines as mechanical ventilators. Several changes in critical care staffing were also made: during the daytime, 1 additional pulmonary critical care attending and 1 additional critical care medicine fellow were deployed to the medical ICU, 1 anesthesiologist was staffed in the PACU-ICU, and another additional pulmonary critical care attending and critical care medicine fellow were available for consultation in the management of medically critically ill patients who now could be cared for outside of the medical ICU by non-pulmonary critical care/critical care medicine staff. At night, no additional attending physicians were present and 1 additional critical care medicine fellow was present. All inpatient ICU beds were covered 24 hours a day by either medical or surgical residents and either critical care nurses, certified registered nurse anesthetists, or both.

4 | DESIGN OF THE ED-ICU SERVICE

Despite the increased inpatient critical care capabilities, we anticipated that ICU crowding could still occur and result in prolonged boarding times for critically ill patients in the ED. In the above staffing model, the additional pulmonary critical care attending and critical care medicine fellow available for consultation cared for ICU patients boarding in the ED during the daytime (7 am–5 pm, Monday–Friday); however, such patients had limited bedside physician care outside of these hours.

To address this gap, we created a patient care service in which 1 of 4 emergency physicians was on-call Monday–Friday, 5 pm–7 am and 24 hours Saturday/Sunday to provide bedside treatment to ICU patients boarding in the ED. Two emergency physicians (BCD and EES) who are board-certified in surgical critical care provided the majority of coverage, with some of their concomitant ED clinical shifts re-distributed to other EM providers. Two other physicians (DM and RO) with expertise/experience in resuscitation and critical care also provided intermittent staffing.

On a daily basis, members of the ED-ICU team monitored the ED and ICU censuses, in conjunction with physician and nursing leadership from both departments, and were called into the hospital if there were 1 or more ICU patients boarding in the ED after 5 pm (or anytime on weekends) who were anticipated not to receive an inpatient critical care bed within the next 2–4 hours. The ED-ICU physicians

assumed care from the treating ED team, performed all direct patient care while the patient resided in the ED, and then transitioned care to the nighttime ICU critical care medicine fellow if the patient subsequently received an inpatient ICU bed or to the consultation pulmonary critical care attending/critical care medicine fellow at 7 am the following morning, Monday–Friday. Because ED nurse staffing was not acutely expanded during the pandemic, the ED-ICU physicians also assisted with the bedside nursing care (medication titration, lab draws, patient positioning, etc).

5 | IMPLEMENTATION OF THE ED-ICU SERVICE

By April 6, 2020, it was evident that excess demand for ICU care was routinely resulting in multiple ICU patients boarding in the ED for prolonged periods, at which time the ED-ICU service was initiated. During the next 6 weeks, ED-ICU physicians cared for 20 consecutive, adult (age = ≥ 18 years old) patients who presented to the Einstein Medical Center Philadelphia ED and required ICU admission, but boarded in the ED for 4 or more hours during the overnight or weekend periods. Patients were identified and tracked prospectively by the ED-ICU physicians at the time of consultation. All patients had a standardized critical care assessment and plan documented in the medical record by the treating ED-ICU provider. Follow-up was completed through July 10, 2020, in which the disposition of all patients was finalized.

Retrospective review of enrolled subjects' medical records was performed in accordance with standard guidelines (see [Supporting Information](#)).¹¹ We collected information on patient demographics, comorbid conditions, presenting illnesses, vital signs, and laboratory values in the ED. Conduct of diagnostic/therapeutic procedures or treatments performed by the ED or ED-ICU physicians was recorded and categorized according to an *a priori* designated system (see [Supporting Information](#)). We also collected times of ED arrival, ICU bed request, ED-ICU care initiation, inpatient ICU transfer, and ICU length of stay. Incidence of mortality and whether it occurred with the withdrawal of life-sustaining therapy was recorded.

Of the 42 days in which ED-ICU physicians were on-call, they were called into the hospital on 9 (21%). These days were distributed roughly evenly throughout the 6-week period. The characteristics of the 20 patients cared for by the ED-ICU physicians during the study period are displayed in Table 1. The high proportion of non-Caucasian individuals, residents of skilled nursing facilities, and the significant burden of comorbid conditions reflect the patient population served by our hospital and the demographics of the 10 (50%) patients infected with COVID-19.

Table 2 displays the clinical conditions of the patients on initiation of bedside care by the ED-ICU staff, which occurred an average of 6 ± 3.1 hours after arrival. Table 3A summarizes the therapeutic management performed by the ED-ICU physicians for the entire study population (Table S3B in the [Supporting Information](#) displays the COVID-19 population only). ED-ICU physicians provided care for an average of 8 ± 4.5 hours. Fifteen (75%) patients received a critical care

TABLE 1 Patient characteristics on presentation (N = 20)

Age, years	61 \pm 15.7
Male sex, n (%)	11 (55)
Race/ethnicity, n (%)	
African American	11 (55)
Caucasian	4 (20)
Hispanic	4 (20)
Asian-American	1 (5)
Residence, n (%)	
Private home	9 (45)
Skilled nursing facility	11 (55)
Method of arrival, n (%)	
Ambulance	19 (95)
Self	1 (5)
BMI	28.5 (24–31.8)
Comorbid conditions, n (%)	
Prior stroke	2 (10)
Seizure disorder	4 (20)
Alcohol or drug abuse	3 (15)
Dementia or mental illness	7 (35)
Hypertension	13 (65)
Coronary artery disease	3 (15)
Congestive heart failure	5 (25)
Arrhythmia	6 (30)
Diabetes	6 (30)
COPD or asthma	4 (20)
Chronic mechanical ventilation	2 (10)
Chronic kidney disease	5 (25)
Cirrhosis	2 (10)
Active cancer or immunosuppression	3 (15)
Number of comorbidities per patient	3.3 \pm 1.8
Vital signs	
Glasgow coma scale	10 (7–15)
≤ 8 , n (%)	7 (35)
Temperature, °C	37.3 \pm 1.3
≥ 38 , n (%)	5 (25)
Heart rate, beats/min	107 \pm 40
Mean arterial pressure, mm Hg	82 \pm 29
≤ 65 , n (%)	3 (15)
Respiratory rate, breaths/min	27 \pm 12
≥ 30 , n (%)	9 (45)
Pulse oximetry, %	93 (91–97)
Fraction of inspired oxygen	0.44 \pm 0.16
S/F ratio	183 (156–266)
$< 220^a$	9 (64%)

(Continues)

TABLE 1 (Continued)

Acute diagnoses, ^c n (%)	
COVID-19 infection	10 (50)
Stroke, ischemic or hemorrhagic	2 (10)
Status epilepticus	2 (10)
Overdose	2 (10)
Hypertensive emergency	1 (5)
Hypotension	8 (40)
Acute coronary syndrome	1 (5)
Decompensated heart failure	1 (5)
Unstable arrhythmia	5 (25)
Cardiac arrest	2 (10)
Pulmonary embolism	0 (0)
Hypoxemic respiratory failure	12 (60)
Hypercarbic respiratory failure	3 (15)
Acute renal failure	13 (65)
Gastrointestinal bleeding	1 (5)
Diabetic ketoacidosis	2 (10)
Sepsis	7 (35)
Laboratory results among COVID-19 patients only (n = 10) ^b	
Absolute lymphocyte count, cells/mm ³	700 (530–1400)
D-dimer, ng/mL	3340 (2408–9663)
Ferritin, ng/mL	1249 (910–1856)
C-reactive protein, mg/L	259.9 ± 95.5
Procalcitonin, ng/mL	0.79 (0.64–4.39)
SOFA score	8 ± 3.5

Abbreviations: BMI, body mass index; S/F ratio, ratio of peripheral oxygen saturation to fraction of inspired oxygen; COPD, chronic obstructive pulmonary disease; COVID-19, coronavirus disease 2019; SOFA, sequential organ failure assessment; ED, emergency department.

^aAn S/F ratio ≤220 roughly corresponds to a P/F ratio <300 and a respiratory SOFA score = 2. Data available for 14/20 patients as S/F ratio is not accurate with SpO₂ >96%.

^bData available for the following number of patients: absolute lymphocyte count n = 10, D-dimer n = 8, ferritin n = 7, C-reactive protein n = 5, procalcitonin n = 7.

^cIndividual patients may have >1 diagnosis.

procedure and 14 (70%) patients had treatment plans significantly adjusted by the ED-ICU physician. Patients spent an average of 15 ± 8.5 hours awaiting an inpatient ICU bed, with 18 (90%) boarding for ≥6 hours. During this period, 2 (10%) patients were downgraded to non-ICU level of care and 1 (5%) patient expired.

The 17 patients admitted to an inpatient critical care bed spent a median of 5 (1–11) days in the ICU. Hospital mortality was 60% with 11/12 patients undergoing withdrawal of life-sustaining therapy. The ED-ICU service and the adapted inpatient critical care bed allocation and staffing continued until May 17, 2020 at which point incident patient volumes and prevalent bed capacity returned to near pre-pandemic levels. Subsequently, the pre-existing ED and ICU care structures were resumed.

TABLE 2 Patient characteristics on ED-ICU admission (N = 20)

Time from presentation to ICU bed request, hours	2.3 (1.6–3.6)
Time from presentation to ED-ICU care, hours	6.0 ± 3.1
Vital signs	
Glasgow coma scale ^a	9 (7–13)
≤8, n (%)	9 (45)
Temperature, °C	36.7 ± 1.0
≤36, n (%)	4 (20)
Heart rate, beats/min	98 ± 29
Mean arterial pressure, mm Hg	82 ± 19
≤65, n (%)	4 (20)
Respiratory rate, breaths/min	23 (20–28)
≥30, n (%)	4 (20)
Pulse oximetry, %	99 (94–99)
Fraction of inspired oxygen	0.68 ± 0.3
100%	8 (40%)
Arterial blood gas results ^b	
Ph	7.31 ± 0.16
≤7.2, n (%)	4 (20)
Partial pressure of carbon dioxide, mm Hg	39 (31–48)
Partial pressure of oxygen, mm Hg	105 (80–124)
Base deficit, mEq/L	4.6 ± 8.9
≥10, n (%)	4 (20)
Lactate, mmol/L	2.0 (1.3–2.6)
P/F ratio	153 (104–198)
≤100, n (%)	4 (22)
101–200, n (%)	10 (56)
201–300, n (%)	1 (6)
Completed or ongoing treatments, n (%)	
Non-invasive ventilation	3 (15)
Mechanical ventilation	11 (55)
Intravenous fluid bolus	13 (65)
Vasopressors	5 (25)
Antimicrobial agents	12 (60)
Central venous access	3 (15)
Invasive arterial pressure monitoring	2 (10)

Abbreviations: ICU, intensive care unit; S/F ratio, ratio of peripheral oxygen saturation to fraction of inspired oxygen; P/F ratio, ratio of partial pressure of arterial oxygen to fraction of inspired oxygen.

^aPatients intubated and sedated had their most recent GCS carried forward.

^bData available for 18/20 patients.

6 | LIMITATIONS

Our results come from a small, descriptive case series of patients collected over a short period at a single institution. A validated scale categorizing and quantifying bedside diagnostic and therapeutic interventions performed by physicians during the early resuscitation of

TABLE 3A ED-ICU management—all patients (N = 20)

Procedures, n (%)	
Endotracheal intubation	2 (10)
Airway exchange	2 (10)
Central venous access	6 (30)
Invasive arterial pressure monitoring	7 (35)
Focused transthoracic echocardiography	12 (60)
Cardioversion, electrical or chemical	2 (10)
Any procedure(s)	15 (75)
Patient management, n (%)	
Analgesia/sedation, neurological	13 (65)
Advanced cardiac life support	1 (5)
Vasopressors	8 (40)
Cardiac rhythm	2 (10)
Volume status	12 (60)
Titration of non-invasive ventilation	4 (20)
Titration of mechanical ventilation	12 (60)
Advanced ventilatory maneuvers	5 (25)
Hematological	6 (30)
Endocrine	2 (10)
Infectious disease	4 (20)
Palliation	4 (20)
Any management change(s)	14 (70)

critically ill patients, unfortunately, does not exist.^{7,9,12} We attempted to describe the frequency and type of care provided by the ED-ICU service in as structured and generalizable a method as possible. Further, we are unable to compare patients treated by the ED-ICU service to other patients admitted from the ED to the ICU during the COVID-19 pandemic who were not treated by the ED-ICU team, nor do we have data on ICU patients who experienced prolonged ED boarding times prior to the pandemic.

The incidence and consequences of ICU crowding, ED boarding, and inpatient critical care surge capacity, both before and during the COVID-19 pandemic, are strongly affected by local hospital (bed capacity, staffing capabilities, clinician expertise, finances, etc) and population characteristics (demographics, access to outpatient health care services, comorbidity burden, etc).¹⁰ Therefore, our model of providing care to the surge of critically ill patients we experienced may not be directly applicable to other health care systems under dissimilar circumstances. Nevertheless, many of the issues we experienced and attempted to solve are germane to other institutions, and our results provide evidence on which to guide future pandemic responses.

7 | DISCUSSION

We designed and operationalized a temporary patient care service to accommodate for the acutely increased demand for bedside critical

care within our ED during the COVID-19 pandemic in Philadelphia, Pennsylvania during the spring of 2020. Through adaptations in bed utilization, staffing, and interdisciplinary cooperation, our department and hospital was able to provide aggressive early resuscitation to an increased number of critically ill patients with COVID-19 and other severe illnesses.

The problem of ICU crowding and boarding of critically ill patients in the ED has existed for years before the COVID-19 pandemic.^{8,10} As a result, emergency physicians often perform significant amounts of critical care diagnostics and therapies on patients waiting for an inpatient ICU bed. For example, several studies have shown that between 15% and 30% of critical care procedures are completed by emergency physicians for patients being admitted to the ICU.^{7,13} Nevertheless, these patients may actually require even more advanced treatment. On retrospective, expert case-review, McQuillan et al¹² found that 54% of patients admitted to the ICU from the ED were judged to have received some element of “sub-optimal” care prior to ICU admission. Using our ED-ICU care model, a significant number of critically ill patients presenting during a pandemic surge received potentially beneficial diagnostic and therapeutic interventions, as a result of emergency physicians formally trained in critical care providing bedside treatment. These patients boarded in our ED for prolonged periods; under our pre-COVID care structure they would have likely received less aggressive care and have been at risk for adverse outcomes.

The COVID-19 pandemic has only compounded the already-existing stress on critical care capabilities of many health systems. Hospitals worldwide have used a variety of methods to expand their treatment capacity for critically ill patients, such as repurposing non-critical care wards or entire hospitals into ICUs, redeploying critical-care or non-ICU trained staff members, or regionally cohorting COVID-19 patients within certain locations at a local or national level.¹⁻⁵ Our work is the first to describe a specific adaptation for providing expanded bedside critical care in the ED during the pandemic. The presence of emergency physicians specifically trained in critical care and the flexibility of our department and hospital to adjust physician staffing were critical in the achievement of our particular strategy. Jayaprakash et al¹⁰ recently reviewed existing models for providing critical care to boarding ED patients; several US institutions use personnel-based strategies using specialized emergency physicians to provide critical care consultation in a manner similar to our ED-ICU model. Other geography-based strategies involving dedicated resuscitation spaces within the ED also exist, such as that described by Gunnerson et al¹⁴ at the University of Michigan. Although our results may not be extrapolated to permanent care models, they show the possibility of a temporary ED-ICU care structure to provide support for acute, unplanned surges in critical care demand like those occurring during an infectious pandemic.

As a disease, COVID-19 presents a particularly difficult challenge to hospital critical care capacity. Not only do a large number of patients, many elderly with significant comorbidities, require invasive ventilation and other organ support immediately on hospital presentation, but a significant proportion of patients initially admitted to general wards with mild illness suffer respiratory decompensation and may unexpectedly require critical care admission.¹⁵ In many hospitals, such

as ours, these inpatients are given priority for available ICU beds over critically ill ED patients because of the extremely limited capability of staff to provide bedside critical care on a general hospital ward. Consequently, real-time prediction of ICU capacity and ED boarding is difficult to perform accurately. We identified this phenomenon early in the pandemic at our institution, with a particular prevalence of inpatient decompensation occurring in the evening. This resulted in the majority of ED boarding occurring overnight, and we developed our ED-ICU staffing model to parallel this need. COVID-19 patients requiring mechanical ventilation can also have unusual respiratory physiology, as described recently.¹⁶ Having critical care trained emergency physicians present at the bedside to respond to and adjust mechanical ventilator settings in boarding ED patients was particularly beneficial given the increased workload on respiratory therapists and other trained personnel during the pandemic.

In conclusion, we present a novel potential solution to the acutely increased demand for critical care resources experienced by hospitals during the COVID-19 pandemic. This structure required the presence of a few, specially trained emergency physicians and focused collaboration between the ED and ICU departments but was able to provide high quality care to vulnerable, sick patients who would have otherwise possibly overwhelmed the hospital's critical care capacity. We encourage clinicians who find themselves in similar circumstances in the near future to incorporate our experiences into their actions to respond to the COVID-19 health care crisis.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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