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Accelerated Critical Therapy Now in the Emergency Department Using an Early Intervention Team: The Impact of Early Critical Care Consultation for ICU Boarders

OBJECTIVES: Evaluate the impact of an emergency department (ED)-based critical care consultation service, hypothesizing early consultation results in shorter hospital length of stay (LOS).

DESIGN: Retrospective observational study from February 2018 to 2020.

SETTING: An urban academic quaternary referral center.

PATIENTS: Adult patients greater than or equal to 18 years admitted to the ICU from the ED. Exclusion criteria included age less than 18 years, do not resuscitate/do not intubate documented prior to arrival, advanced directives outlining limitations of care, and inability to calculate baseline modified Sequential Organ Failure Assessment (mSOFA) score.

INTERVENTIONS: ED-based critical care consultation by an early intervention team (EIT) initiated by the primary emergency medicine physician compared with usual practice.

MEASUREMENTS: The primary outcome was hospital LOS, and secondary outcomes were hospital mortality, ICU LOS, ventilator-free days, and change in the mSOFA.

MAIN RESULTS: A total 1,764 patients met inclusion criteria, of which 492 (27.9%) were evaluated by EIT. Final analysis, excluding those without baseline mSOFA score, limited to 1,699 patients, 476 in EIT consultation group, and 1,223 in usual care group. Baseline mSOFA scores (\pm SD) were higher in the EIT consultation group at 3.6 (\pm 2.4) versus 2.6 (\pm 2.0) in the usual care group. After propensity score matching, there was no difference in the primary outcome: EIT consultation group had a median (interquartile range [IQR]) LOS of 7.0 days (4.0–13.0 d) compared with the usual care group median (IQR) LOS of 7.0 days (4.0–13.0 d), $p = 0.64$. The median (IQR) boarding time was twice as long subjects in the EIT consultation group at 8.0 (5.0–15.0) compared with 4.0 (3.0–7.0) usual care, $p < 0.001$.

CONCLUSIONS: An ED-based critical care consultation model did not impact hospital LOS. This model was used in the ED and the EIT cared for critically ill patients with higher severity of illness and longer ED boarding times.

KEY WORDS: boarding; critical care outcomes; critical care; emergency service; evidence-based emergency medicine

Nationally, patient presentations to emergency departments have risen from 96 million in 1995 to 136 million in 2011, with 25% requiring admission to the ICU (1–4). The 2018 National Hospital Ambulatory Medical Care Survey reported that 16.2 million emergency department (ED) visits resulted in hospital admission, and 2.3 million of these were critical care admissions (5).

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From 1975 to 2015, the number of hospital beds in the United States decreased from 1.5 million to less than 1 million. This combination of factors has contributed to crowding and boarding of critically ill patients in the ED. The occurrence rate of boarding of critically ill patients in the ED is difficult to quantify, given lack of a consensus definition. A joint task force of the Society of Critical Care Medicine and the American College of Emergency Physicians (ACEP) has recommended that boarding be defined by the time spent in the ED after: 1) decision to admit to an ICU is made or 2) after 6 hours in the ED following arrival or whichever comes first (6).

Boarding of critically ill patients in the ED is associated with worse outcomes including increased hospital length of stay (LOS), mortality, duration of mechanical ventilation, and worsening organ dysfunction (6–10). Solutions to addressing delivery of critical care in the ED for ICU boarders can be divided into geography-based models and personnel focused models. Local factors influence selection of the best fitting model (11). Single-center studies have evaluated the impact on mortality and readmissions in geographic ED-based ICU models and hospital-based ICU consultation services (12, 13). The implementation and evaluation of ED-based critical care consultation services remain sparse. In 2017, our ED treated 101,432 patients. Recognizing evolving needs for delivery of critical care for ICU boarders, in February 2018, we initiated a personnel focused ED-based critical care consultation model. The aim of this study was to evaluate the impact of this model of accelerated critical care in the ED on the overall course of critically ill patients. The central hypothesis was that patients who receive an ED-based critical care consultation focused on accelerating the delivery of critical care in the ED will have a shorter hospital LOS compared with those who receive no ED-based critical care consultation.

MATERIALS AND METHODS

This was a single-center retrospective observational study conducted between February 2018 and February 2020. The study was approved by the Henry Ford Hospital (HFH) institutional review board (approval no. 11902-01).

Setting

HFH is an 877-bed academic quaternary referral center with 156 ICU beds. In 2017, with an annual

census of 101,432 patients, the average ED LOS was 298 minutes, and the average time from ICU bed request to bed assignment was 134 minutes. In 2019, although the total annual ED census was lower at 99,428, the average time for ICU boarders (from bed request to bed assignment) rose to 294 minutes.

The early intervention team (EIT) is an adapted personnel focused ED-based critical care consultation service in the highest acuity area of the ED. It is composed of board eligible/certified physicians in both emergency medicine and critical care medicine (EM-CCM) with clinical practices based on the ED and ICU (medical ICU, surgical ICU, and cardiothoracic ICU) (see **Supplemental Digital Content, Fig. 1**, <http://links.lww.com/CCX/A949>). The EIT physician is available from Monday to Friday, 2–10 PM, to provide consults for those boarding for the ICU and/or at the discretion of the primary emergency medicine (EM) clinicians. The consults are initiated by the primary EM attending physician. Suggested criteria for consultation include presence of greater than or equal to two ICU boarders or patients in the high-acuity area of the ED; patients on vasopressors, inotropes, and advanced modes of mechanical ventilation; and planned admission to the ICU or boarding for the ICU for any patient in the high-acuity area of the ED.

Participants

Patients were retrospectively identified in the electronic health record (EHR) if they presented to the ED Monday to Friday between the hours of 2 and 10 PM and were admitted to the ICU.

Inclusion criteria are as follows:

- 1) Adult patients greater than or equal to 18 years old
- 2) Patients who were admitted to the ICU

Exclusion criteria are as follows:

- 1) Patients less than 18 years old
- 2) Patients with a documented do not resuscitate/do not intubate prior to ED arrival
- 3) Patients with identified advanced directives outlining limitations of care
- 4) Patients in which a modified Sequential Organ Failure Assessment (mSOFA) score could not be calculated at baseline

Variables

The EIT consultation group was identified by the presence of a specific EHR note type (“Treatment plan”)

written by the EIT physician. Patients who presented to the ED and were admitted to the ICU during the same period without an EIT consultation (usual care group) were the comparator.

Boarding time was defined as the time from placement of the order requesting ICU admission to the time of transfer to the ICU. The critical care hours were defined as the total time from placement of order requesting ICU admission to the patient's arrival in the general practice unit (GPU), inclusive of the ICU course. This time, therefore, includes total ED boarding and ICU time.

The primary outcome of interest was the hospital LOS. Secondary outcome measures included inhospital mortality, critical care hours, ventilator-free days, and change in mSOFA.

Data Sources

All data were retrospectively identified using the EHR and local population health databases. To quantify and weigh severity of illness, an mSOFA score was calculated at baseline. The mSOFA calculation derived from the work of Grissom et al (14) in which saturation of oxygen/fraction of oxygen (S/F) ratio was substituted for partial pressure of oxygen/fraction of oxygen ratio and the liver component of the score was identified through clinical examination (see Supplemental Digital Content, **Table 1**, <http://links.lww.com/CCX/A949>). For the purposes of this study, we assumed that, in the absence of scleral icterus, an emergency clinician would not test bilirubin levels, and thus, a score of 0 was imputed for the liver component of the initial mSOFA score when the bilirubin result was unavailable. The bilirubin result was included when available to calculate the liver subcomponent. The first recorded values for each component were used to calculate the initial score. Scores were calculated at 24 and 48 hours using values recorded within ± 6 hours of the 24- and 48-hour mark from time of completion of triage.

Hospital LOS was determined using date of hospital discharge. Hospital mortality was calculated using a data variable labeled "Alive at discharge" identified in the EHR. This was a binary variable of "Yes" or "No," where "No" reflected a status of died in hospital.

Statistical Methods

All continuous variables are summarized by values of mean and SD or median and interquartile range

(IQR), whereas binary variables are described using percentage. Chi-square test was used to compare categorical variables and analysis of variance or Kruskal-Wallis test for continuous variables. To build the propensity matching model, mSOFA score, age, body mass index, gender, and race were included. Univariate and multivariate regression models were used to compare outcomes of interest. The linear mixed model was performed to examine the 24- and 48-hour modified SOFA scores between the two groups.

For subanalyses, subjects were further stratified into four groups by quartiles of the baseline mSOFA score. The Fisher exact test was used to compare the baseline mSOFA score between the quartiles. The Cochran-Armitage Trend Test (one-side) $p < 0.001$ was applied to compare those who received EIT consultation versus usual care in terms of mortality, LOS, critical care hours, vent days, and ED boarding time. LOS is naturally a skewed distribution in most cohorts of patients, so the Gamma model was used to evaluate whether baseline modified SOFA score was associated with LOS in both univariate and multivariate analyses. For vent days, we used zero inflated gamma model to account for $\sim 70\%$ of patients who did not have mechanical ventilation in the ED.

RESULTS

A total of 1,764 patients met inclusion criteria and were admitted to the ICU during the study period, of which 492 (27.9%) received an EIT consultation. Patients in whom a baseline mSOFA score could not be calculated were excluded. This leaves a final cohort of 1,699 patients, of which 476 (28.0%) received an EIT consultation and 1,223 (72.0%) received usual care with no EIT consultation (**Fig. 1**). Missing data were attributed to a lack of reporting of oxygen saturation levels or oxygen device in the EHR, limiting the ability to calculate the S/F ratio required for the mSOFA score.

The mean (\pm SD) age of the "EIT consultation" group was 59.3 (\pm 14.1) and 59.6 (\pm 17.2) for the "Usual care" group. The mean (\pm SD) baseline mSOFA was higher in the "EIT consultation" group compared with "Usual care" at 3.6 (\pm 2.4) versus 2.6 (\pm 2.0), $p = < 0.001$. Patients were predominately middle-aged, and the majority were identified as Black race. Most patients in the "EIT consultation" group were discharged with a principal diagnosis related to respiratory conditions (see Supplemental Digital Content, **Table 2**, <http://links.lww.com/CCX/A949>). The propensity

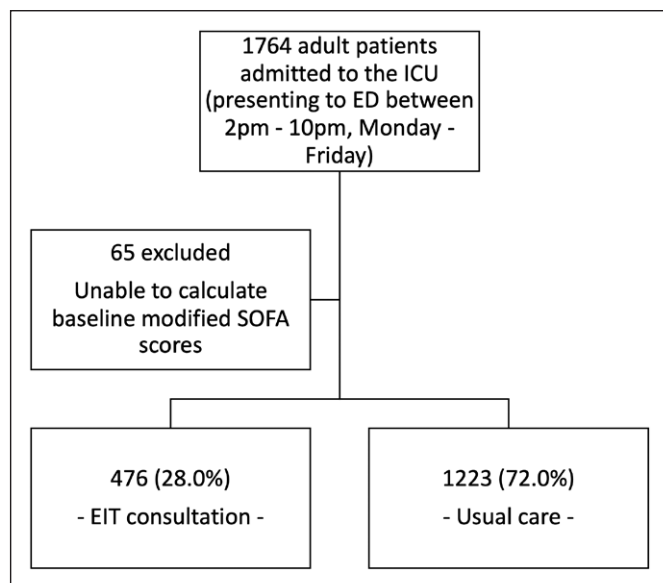


Figure 1. Flow of study subjects. ED = emergency department, EIT = early intervention team, SOFA = Sequential Organ Failure Assessment.

score matched model distributed 469 patients to each group (see **Table 1**).

There was no difference in the primary outcome of hospital LOS. After propensity matching, the “EIT consultation” group had a similar median (IQR) hospital LOS at 7.0 days (4.0–13.0 d) compared with the “Usual care” group, which had a median (IQR) LOS of 7.0 days (4.0–13.0 d), $p = 0.64$. For secondary outcomes of interest, after propensity matching, eight patients (1.7%), $p = 0.99$, died in hospital in both groups. The median (IQR) ED “boarding time” was 8 hours (5–15 hr) in the “EIT consultation” group compared with 4.0 hours (3–7 hr), $p < 0.001$. The median (IQR) critical care time, inclusive of ICU LOS and ED boarding time, was not statistically different in the two groups (EIT consultation group: 63.0 hr [38–111 hr] and usual care group: 60 hr [36–99 hr]; $p = 0.68$) (see **Table 2**).

Finally, we examined the 24- and 48-hour mSOFA scores between the “EIT consultation” and “Usual care” groups for the propensity matched samples (see Supplemental Digital Content, **Fig. 2**, <http://links.lww.com/CCX/A949>). There was no statistically significant change of mSOFA score at 24 and 48 hours compared with baseline in both the EIT consultation and usual care groups, and no difference was seen between case types for such change trends.

To further compare outcomes based on severity of mSOFA, we categorized all propensity score-matched patients into four groups by creating quartiles of

baseline mSOFA score. Five hundred and ninety-one patients were classified in the lowest quartile, 288 patients in the second quartile, 439 patients were in the third quartile, and the remaining 381 patients fell in the highest quartile of mSOFA scores. Supplemental Digital Content, **Table 3**, <http://links.lww.com/CCX/A949>, highlights the demographics stratified by baseline mSOFA quartiles. There was a statistically significant difference for age ($p = 0.004$) and percentage of “EIT consultation” cases per quartile ($p < 0.001$). The probability of an “EIT consultation” increased as baseline mSOFA score quartile increased when applying a Cochran-Armitage trend test (one-side) (**Fig. 2**).

Primary and secondary outcomes of interest were further compared across the quartiles of baseline mSOFA score (see **Table 3**). There was a statistical difference among baseline mSOFA score quartiles for mortality. In addition, a Cochran-Armitage Trend test one-sided $p < 0.001$ indicated that mortality increased as baseline mSOFA score quartiles increased. Additionally, hospital LOS, ED boarding time, and critical care time were longer in the higher quartiles. The median number of ventilator days was not statistically different across the four mSOFA score quartiles.

In both univariate and multivariate regression models, a higher baseline mSOFA score was associated with a longer LOS. Consistent with the Kruskal-Wallis test, a higher baseline mSOFA score was associated with a longer time on mechanical ventilation (see Supplemental Digital Content, **Table 4**, <http://links.lww.com/CCX/A949>).

There are several limitations to this study. First, the study design is limited by its retrospective observational nature. We defined boarding as the time when an order requesting ICU admission was placed in the EHR, which is not reflective of the initiation of critical care interventions. An EIT consultation was identified by the presence of a “Treatment plan” note in the EHR, though the interventions were not quantified and may vary. Documentation of a consultation does not account for verbal communications that may have impacted care for non-EIT patients. If an EM-CCM physician was working as the primary EM physician in category 1, EIT may not have been consulted while longitudinal critical care may have still been delivered to the patients. The nature of a consultation model contributes to a selection bias with selective utilization of the EIT for a more ill patient population and for those with longer boarding times. The

TABLE 1.
Baseline Characteristics and Patient Demographics

Variable	EIT Consultation, <i>n</i> = 476	Usual Care, <i>n</i> = 1,223	<i>p</i>
Age (mean ± sd)	59.3 ± 14.1	59.1 ± 17.2	0.77
BMI (mean ± sd)	31.1 ± 44.3	29.8 ± 10.6	0.47
Baseline mSOFA (mean ± sd)	3.6 ± 2.4	2.6 ± 2.0	< 0.001
Female gender (<i>n</i> [%])	228 (47.9)	523 (42.8)	0.056
Race (<i>n</i> [%])			
White	92 (19.3)	368 (30.1)	< 0.001
Black	338 (71.0)	737 (60.3)	
Other	46 (9.7)	118 (9.6)	
Charlson comorbidity index (mean ± sd)	6.5 ± 3.0	6.6 ± 3.4	0.46
Propensity Matched Model			
Variable	EIT Consultation, <i>n</i> = 469	Usual Care, <i>n</i> = 469	<i>p</i>
Age (mean ± sd)	59.2 ± 15.2	58.1 ± 17.1	0.26
BMI (mean ± sd)	29.1 ± 9.1	29.5 ± 10.6	0.79
Baseline mSOFA (mean ± sd)	3.5 ± 2.3	3.5 ± 2.2	0.99
Female gender (<i>n</i> [%])	224 (47.8)	218 (46.5)	0.69
Race (<i>n</i> [%])			
White	92 (19.6)	92 (19.6)	0.98
Black	332 (70.8)	330 (70.4)	
Other	45 (9.6)	47 (10.0)	
Charlson comorbidity index (mean ± sd)	6.5 ± 3.0	6.8 ± 3.4	0.15

BMI = body mass index, EIT = early intervention team, mSOFA = modified Sequential Organ Failure Assessment.
Boldface font signifies significant values where $p < 0.05$.

study did not account for total number of boarders on any given day or number of ICU bed requests originating outside of the ED and influencing ICU triaging. Severity of illness scores based on physiologic and clinical variables are validated in the ICU setting and, however, not in the ED environment. Thus, stratifying by a score such as mSOFA may not capture the impact of early interventions in the ED phase of illness. Patients who received

an EIT consultation in our study had longer boarding times than the usual care group; however, we did not analyze whether interventions between the groups were similar, which may have blunted the impact on patient-centered outcomes. Further, hospital LOS is influenced by social factors beyond the initial clinical presentation. For example, placement in a nonacute care facility can be impacted by delays related to administrative requests

TABLE 2.
Propensity Score Matched Clinical Outcomes of Interest

Variable	Early Intervention Team Consultation, <i>n</i> = 469	Usual Care, <i>n</i> = 469	<i>p</i>
Hospital length of stay (d), median (IQR)	7.0 (4.0–13.0)	7.0 (4.0–13.0)	0.64
Emergency department boarding time (hr), median (IQR)	8.0 (5.0–15.0)	4.0 (3.0–7.0)	< 0.001
Critical care time (hr), median (IQR)	63.0 (38.0–111.0)	60.0 (36.0–99.0)	0.68
Inhospital mortality, <i>n</i> (%)	8 (1.7)	8 (1.7)	0.99

IQR = interquartile range.
Boldface font signifies significant values where $p < 0.05$.

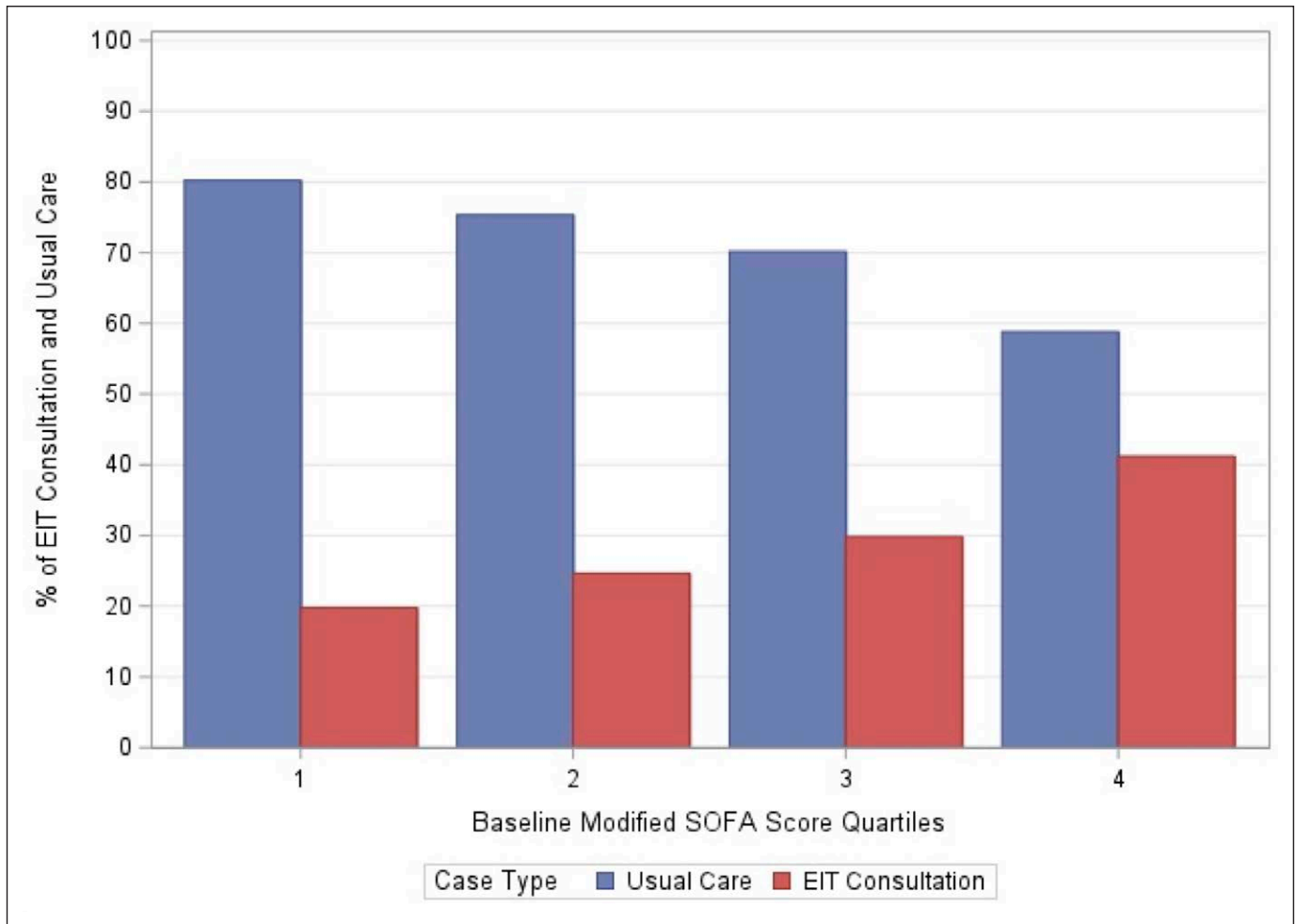


Figure 2. Percentage of cases per baseline modified Sequential Organ Failure Assessment (SOFA) quartile. EIT = early intervention team.

and exchange of information between facilities. Finally, this model of delivery of critical care is a physician consultation service and relies on existing infrastructure of nursing, respiratory therapists, and pharmacists to

implement recommendations and orders. The treatment effect may be blunted by limited healthcare resources unable to fully implement accelerated critical interventions recommended by consulting physicians.

TABLE 3.
Clinical Outcomes per Quartile of Baseline Modified Sequential Organ Failure Assessment

Outcome of Interest	Baseline Modified Sequential Organ Failure Assessment Score Quartiles				p ^a
	1 (n = 591)	2 (n = 288)	3 (n = 439)	4 (n = 381)	
Inhospital mortality, n (%)	3 (0.5)	5 (1.7)	3 (0.7)	16 (4.2)	< 0.001
Length of stay, median (IQR), d	5.0 (3.0–9.0)	6.0 (4.0–11.0)	8.0 (5.0–13.0)	8.0 (5.0–15.0)	< 0.001
Emergency department boarding time, median (IQR), hr	4.0 (2.0–7.0)	4.0 (2.0–7.0)	5.0 (3.0–9.0)	5.0 (3.0–9.0)	0.01
Critical care time, median (IQR), hr	42.0 (23.0–67.0)	49.0 (34.0–91.5)	63.0 (37.0–109.0)	77.0 (44.0–137.0)	< 0.001
Ventilator days, median (IQR), d	3.0 (2.0–9.0), n = 41	3.0 (1.0–6.0), n = 34	4.0 (2.0–10.0), n = 97	4.0 (2.0–11.0), n = 120	0.17

IQR = interquartile range.

^aFisher exact test.

Boldface font signifies significant values where p < 0.05.

DISCUSSION

An ED-based critical care consultation service designed to accelerate delivery of critical care in the ED did not impact hospital LOS. The proportion of patients receiving an EIT consultation had higher mSOFA scores and longer ED boarding times. The inhospital mortality among those that had an EIT consultation versus those who received usual care was overall low and not different between the groups.

The average annual critical care hours billed by an EM physician increased by greater than 200% from 2000 to 2009, with many patients in the ED for greater than 6 hours awaiting ICU admission (15). Healthcare systems are responding by implementing models of delivery of critical care in the ED. The late 1990's redesign of the HFH category 1 area to function as an ED-based ICU was a response to the need of the time. Nguyen et al (16) described the changes in physiologic scoring and delivery of focused critical care in ICU bound patients from this area. Among the 81 patients enrolled in that study, the inhospital mortality was 30.9%, the ED LOS was 5.9 ± 2.7 hours, and hospital LOS was 12.2 ± 16.6 days. There was a higher Acute Physiology and Chronic Health Evaluation II score in nonsurvivors versus survivors; however, no significant difference was seen in Simplified Acute Physiology Score II or multiple organ dysfunction score scores (16). More recently, the University of Michigan constructed a geography-focused ED-based ICU (12). This model demonstrated a reduction in risk-adjusted 30-day mortality and risk-adjusted rate of ED admissions to the ICU (12).

Evolving needs with rising volumes and boarders resulted in implementation of the ED-based consultation model at HFH. The beginning of the COVID-19 pandemic in March 2020 coincided with the start of the third year of EIT. In the third year, 240 EIT cases would have met study inclusion criteria, and 634 were usual care. EIT hours expanded to begin at 7 AM in response to the first and second surges of COVID-19 patients. This is an example of how an ED-based personnel focused model, such as the EIT, has the flexibility to expand to meet pandemic or otherwise related surges.

Early critical care interventions may not only prevent onset of disease but mitigate severity (16–18). The longer the ED boarding time, the worse the outcome (8, 19, 20). The ICU triage decisions for available beds must accommodate patients both from the ED and from external sources (e.g., GPU and/or outside hospital systems). This contributes to variation in the

number and type of boarders in the ED on any given day. Thus, EIT may have been selectively consulted on boarding patients who were deemed more unwell by the ED team or had greater bedside clinical needs, contributing to the higher severity of illness and longer boarding times. The use of EIT consultants for stabilization and ongoing management of the highest acuity patients also allows for the primary EM team to care for newly arriving undifferentiated ill patients.

As models of delivery of critical care are evaluated, some important questions remain unaddressed: what is the time zero for critical care? Is there a severity of illness score identifiable within the initial ED presentation that allows stratification to interventions? How do different models compare in terms of patient-centered outcomes? The critical care team model of the ICU environment includes critical care trained nurses, respiratory therapists, nursing assistants, etc. The impact of an ED-based critical care consult team may be greater when the team is inclusive of these roles. Understanding the value in replicating the ICU team environment outside its borders is important. The EIT's role may extend beyond direct patient care, assisting with streamlining of processes such as ICU triaging and bed allocation. The EIT that responds to consults is reactive. However, with accepted automated thresholds and expanded roles such as triaging, EIT has the potential to play a proactive role.

CONCLUSION

This single-center retrospective observational study describes the outcomes of an ED-based critical care consultation model. The model is being used and has a role in the care of the more severely ill of ICU boarders with longer boarding times. Delivery of critical care in the ED is a key factor in the management of critically ill boarders. Although future studies are of benefit in the areas of identifying an optimal time zero, quantifying severity of illness, and understanding the impact of initiating early critical care interventions on patient-centered outcomes, the model of Accelerated Critical Therapy Now EIT in the ED has a role in impacting the care of critically ill boarders.

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Drs. Jayaprakash, Pflaum-Carlson, Gardner-Gray, Hurst, Coba, and Rivers conceived the study. Dr. Jayaprakash designed the trial and obtained grant support. Drs. Jayaprakash, Pflaum-Carlson, Gardner-Gray, Hurst, Kinni, Coba, and Rivers participated in data collection. Ms. Tang performed all statistical analysis, developed tables and graphs, and drafted statistical methods and results. Drs. Jayaprakash, Pflaum-Carlson, Gardner-Gray, Hurst, and Kinni drafted the article as a whole, and all authors contributed to the revisions. All authors have reviewed and approved the final version of the article.

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The remaining authors have disclosed that they do not have any potential conflicts of interest.

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