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ORIGINAL RESEARCH

General Medicine

Emergency department length of stay and outcomes of emergency department–based intensive care unit patients

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Abstract

Objective: Emergency department (ED) boarding of patients who are critically ill is associated with poor outcomes. ED-based intensive care units (ED-ICUs) may mitigate the risks of ED boarding. We sought to analyze the impact of ED length of stay (LOS) before transfer to an ED-ICU on patient outcomes.

Methods: We retrospectively analyzed adult ED patients managed in the ED-ICU at a US medical center. Bivariate and multivariable linear regressions tested ED LOS as a predictor of inpatient ICU and hospital LOS, and separate bivariate and multivariable logistic regressions tested ED LOS as a predictor of inpatient ICU admission, 48-hour mortality, and hospital mortality. Multivariable analyses' covariates were age, sex, Charlson Comorbidity Index (CCI), Emergency Severity Index, and eSimplified Acute Physiology Score (eSAPS3).

Results: We included 5859 ED visits with subsequent care in the ED-ICU. Median age, CCI, eSAPS3, ED LOS, and ED-ICU LOS were 62 years (interquartile range [IQR], 48–73 years), 5 (IQR, 2–8), 46 (IQR, 36–56), 3.6 hours (IQR, 2.5–5.3 hours), and 8.5 hours (IQR, 5.3–13.4 hours), respectively, and 46.3% were women. Bivariate analyses showed negative associations of ED LOS with hospital LOS ($\beta = -3.4$; 95% confidence interval [CI], −5.9 to −1.0), inpatient ICU admission (odds ratio [OR], 0.86, 95% CI, 0.84–0.88), 48-hour mortality (OR, 0.89; 95% CI, 0.82–0.98), and hospital mortality (OR, 0.89; 95% CI, 0.85–0.92), but no association with inpatient ICU LOS. Multivariable analyses showed a negative association of ED LOS with inpatient ICU admission (OR, 0.91; 95% CI, 0.88–0.93), but no associations with other outcomes.

Conclusions: We observed no significant associations between ED LOS before ED-ICU transfer and worsened outcomes, suggesting an ED-ICU may mitigate the risks of ED boarding of patients who are critically ill.

KEYWORDS
bed occupancy, critical care, emergency service, hospital, length of stay, organization and administration, resuscitation

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1 | INTRODUCTION

1.1 | Background

Emergency department (ED) boarding of patients who are critically ill has been defined as time spent in an ED (1) after the decision to admit to an intensive care unit (ICU) is made[1] or (2) after 6 hours in the ED (from ED arrival), whichever happens first.[2] Increasing ED patient volumes, hospital closures, and increasing inpatient ICU occupancy rates have resulted in increased ED boarding of patients who are critically ill throughout the United States.[2] Prolonged ED length of stay (LOS) before transfer to an inpatient ICU has been repeatedly associated with increased morbidity and mortality across multiple patient populations.[3–15] In the United States, 33% of inpatient ICU admissions from the ED have an ED LOS >6 hours,[16] which is a temporal inflection point associated with higher inpatient ICU and hospital mortality.[6]

1.2 | Importance

As a mitigation strategy, ED-based ICUs (also known as Resuscitative Care Units) have been created. These units focus on providing timely critical care interventions during the transition from resuscitation in the ED to the longitudinal phase of critical care in an inpatient ICU.[17] The addition of ED-ICUs with expedited bed availability likely allows for the delivery of ICU-level care when the need is first identified rather than when a bed is available, potentially decreasing the negative impact of ED boarding in the care of patients who are critically ill. Observational prepost data from one ED-ICU showed a 15.4% reduction in risk-adjusted 30-day mortality among all ED patients as well as improvements in 24-hour and hospital mortality, inpatient ICU admissions from the ED, short-stay inpatient ICU admissions, time to ICU-level care, and proportion of patients receiving ICU-level care within 6 hours of ED presentation.[18]

1.3 | Goals of this investigation

All studies examining ED LOS and outcomes for patients who are critically ill used data from traditional inpatient ICUs, and data specific to ED-ICUs are lacking. It is unknown whether the effect of ED LOS in a setting with an ED-ICU differs from what is described for traditional inpatient ICUs. To fill this knowledge gap, our objective was to analyze associations between ED LOS before transfer to an ED-ICU with resource use and patient-oriented outcomes.

The Bottom Line

In a retrospective analysis of >5800 emergency department (ED) visits with subsequent care in an ED-based intensive care unit (ED-ICU), no significant negative associations were found related to ED length of stay before ED-ICU transfer, suggesting that an ED-ICU might mitigate the adverse outcomes associated with ED boarding of patients who are critically ill.

2 | METHODS

2.1 | Study design and setting

We conducted a retrospective cohort study using data from a single large academic medical center in the United States with ≈70,000 adult ED visits per year. The Joyce and Don Massey Family Foundation Emergency Critical Care Center (EC3) is an ED-ICU that opened at the University of Michigan in 2015. Of the 70,000 annual adult ED visits, ≈2300 (3%) are managed in EC3. Patients managed in EC3 have been previously described, including 30% requiring mechanical ventilation and 13% requiring vasopressors.[18] As outlined in figure 1 in Gunnerson et al,[18] all adult patients presenting to the ED are first seen and evaluated by ED clinicians, and when the need for ongoing critical care is identified, patients can be transferred to a distinct group of EC3 clinicians in a 9-bed ED-ICU with a 2:1 nursing ratio, regardless of whether an inpatient ICU bed is available. EC3 clinicians include emergency physicians with or without critical care fellowship training, emergency medicine residents, critical care fellows, physician assistants, and ED nurses with additional critical care training experience.

2.2 | Selection of participants

All ED patients aged ≥18 years transferred directly from the ED to the ED-ICU between August 1, 2017, and July 1, 2020, were included. Patients transferred for end-of-life care were excluded.[19] The sample size was determined by the time interval of data collection: although EC3 opened in February 2015, we included patients from August 1, 2017, forward to allow a "wash out" period given the operational and clinical complexities of implementing an ED-ICU.

2.3 | Measurements

Eligible patients were identified retrospectively via an electronic health record (EHR) query. Patients transferred for end-of-life care were excluded based on the use of an EHR order set for end-of-life care. Age, sex, and Emergency Severity Index (ESI) were extracted automatically from the EHR via available demographic and ED visit data. The Quan modification of the Charlson Comorbidity Index (qCCI), a numerical representation of chronic comorbidity predictive of both short-term and long-term outcomes,[20] was obtained automatically from the EHR using diagnostic coding data. The electronic Simplified Acute Physiology Score 3 (eSAPS3),[21] an electronic ICU risk-adjustment score based on the Simplified Acute Physiology Score 3, which incorpo-

rates acute physiologic measurements and is a predictor of short-term outcomes,[22] was obtained automatically using data points available in the EHR.

2.4 | Outcomes

Resource use and patient outcome data were obtained from automated EHR queries and included ED LOS, ED-ICU LOS, ED-ICU disposition, hospital LOS, inpatient ICU LOS, 48-hour mortality, and hospital mortality. ED LOS was defined as the time from patient arrival in the ED until the transition of care from the main ED team to the ED-ICU team. ED-ICU LOS was defined as the time from transition of care from the main ED team to the ED-ICU team until the first event between (1) handoff by ED-ICU to the inpatient team, (2) patient leaving the department, or (3) final disposition order (only in cases of discharge or death). Possible ED-ICU dispositions included death, discharge from EC3, admittance from EC3 to non-ICU, and admittance from EC3 to inpatient ICU. Hospital LOS was defined as the time from the patient physically leaving the ED-ICU until final hospital disposition. Inpatient ICU LOS was defined as the total elapsed time in any inpatient ICU during the hospital stay. This definition of ICU LOS excludes the time in the ED-ICU.

2.5 | Analysis

For descriptive statistics, results are presented as median (interquartile range [IQR]), mean (standard deviation [SD]), or n (percentage) where appropriate. Categorical variables are presented as frequency (percentage). Bivariate and multivariable linear regression analyses were used to test for ED LOS as a predictor of inpatient ICU LOS and hospital LOS. Separate bivariate and multivariable logistic regression analyses were used to test for ED LOS as a predictor of the odds of inpatient ICU admission, 48-hour mortality, and hospital mortality. Multivariable analyses were statistically controlled to minimize confounding bias, and covariates included age, sex, ESI, qCCI, and eSAPS3. All ED-ICU encounters during the period of data collection (besides end-of-life care) were included to avoid selection bias. An α level of 0.05 was used for all analyses, and all statistical significance tests were 2-tailed. Analyses were conducted with the SPSS software package (version 27.0; IBM).

2.6 | Ethics and reporting

The Institutional Review Board at the University of Michigan reviewed and approved this study (HUM00184307). We used data collected retrospectively during routine clinical care, and we treated all data in a manner compliant with the Security Rule and the Privacy Rule of the Health Insurance Portability and Accountability Act.[23] This study is reported in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.[24]

TABLE 1 Patient characteristics

Characteristic	
Patients, n	5859
Age, median (IQR), y	62 (48–73)
Women, n (%)	2709 (46.3)
Emergency Severity Index score, mean (SD)	2 (0.48)
Quan-Charlson Comorbidity Index score, median (IQR)	5 (2–8)
Electronic Simplified Acute Physiology Score 3, median (IQR)	46 (36–56)
ED LOS, median (IQR), h	3.6 (2.5–5.3)
ED LOS <6 hours, n (%)	4767 (81.4)
ED-ICU LOS, median (IQR), h	8.5 (5.3–13.4)
ED-ICU disposition, n (%)	
Admit non-ICU	3368 (57.5)
Admit ICU	1890 (32.2)
Discharge	537 (9.2)
Death	64 (1.1)
ICU LOS, median (IQR), d	3.1 (1.7–5.7)
Hospital LOS, median (IQR), d	5.0 (2.7–9.5)
48-h mortality, n (%)	129 (2.2)
Hospital mortality, n (%)	605 (10.3)

Abbreviations: d, days; ED, emergency department; ED-ICU, ED-based intensive care unit; h, hours; ICU, intensive care unit; LOS, length of stay; SD, standard deviation; y, years.

3 | RESULTS

3.1 | Characteristics of study patients

Between August 1, 2017, and July 1, 2020, a total of 6042 patients transferred directly from the ED to the ED-ICU were identified, and 183 patients who received end-of-life care in the ED-ICU were excluded. A total of 5859 patients were included for analysis. Rates of missing data were low: of 5258 patients admitted to the hospital, 63 (1%) had missing data for hospital LOS. All other variables had full data available for analysis.

The patients' baseline demographics and hospitalization outcomes are shown in Table 1. Patients had a median age of 62 years (IQR, 48–73 years), and 46.3% were women. Reported ethnicities include non-Hispanic 5,604 (95.6%), Hispanic 186 (3.2%), and unknown 69 (1.2%). The mean ESI was 2 (SD, 0.48). Median qCCI and eSAPS3 were 5 (IQR, 2–8) and 46 (IQR, 36–56), respectively. Median ED LOS and ED-ICU LOS were 3.6 hours (IQR, 2.5–5.3 hours) and 8.5 hours (IQR, 5.3–13.4 hours), respectively. ED LOS was <6 hours for 81.4% of the included patients. The full distribution of ED LOS in the study sample is shown in Figure 1. Dispositions from the ED-ICU were ICU admission (32.2%), admission to a non-ICU level of care (57.5%), discharge from the ED-ICU (9.2%), and death (1.1%). The median inpatient ICU and hospital LOS were 3.1 days (IQR, 1.7–5.7 days) and 5.0 days (IQR, 2.7–9.5 days), respectively. The overall 48-hour mortality and hospital mortality were 2.2% and 10.3%, respectively.

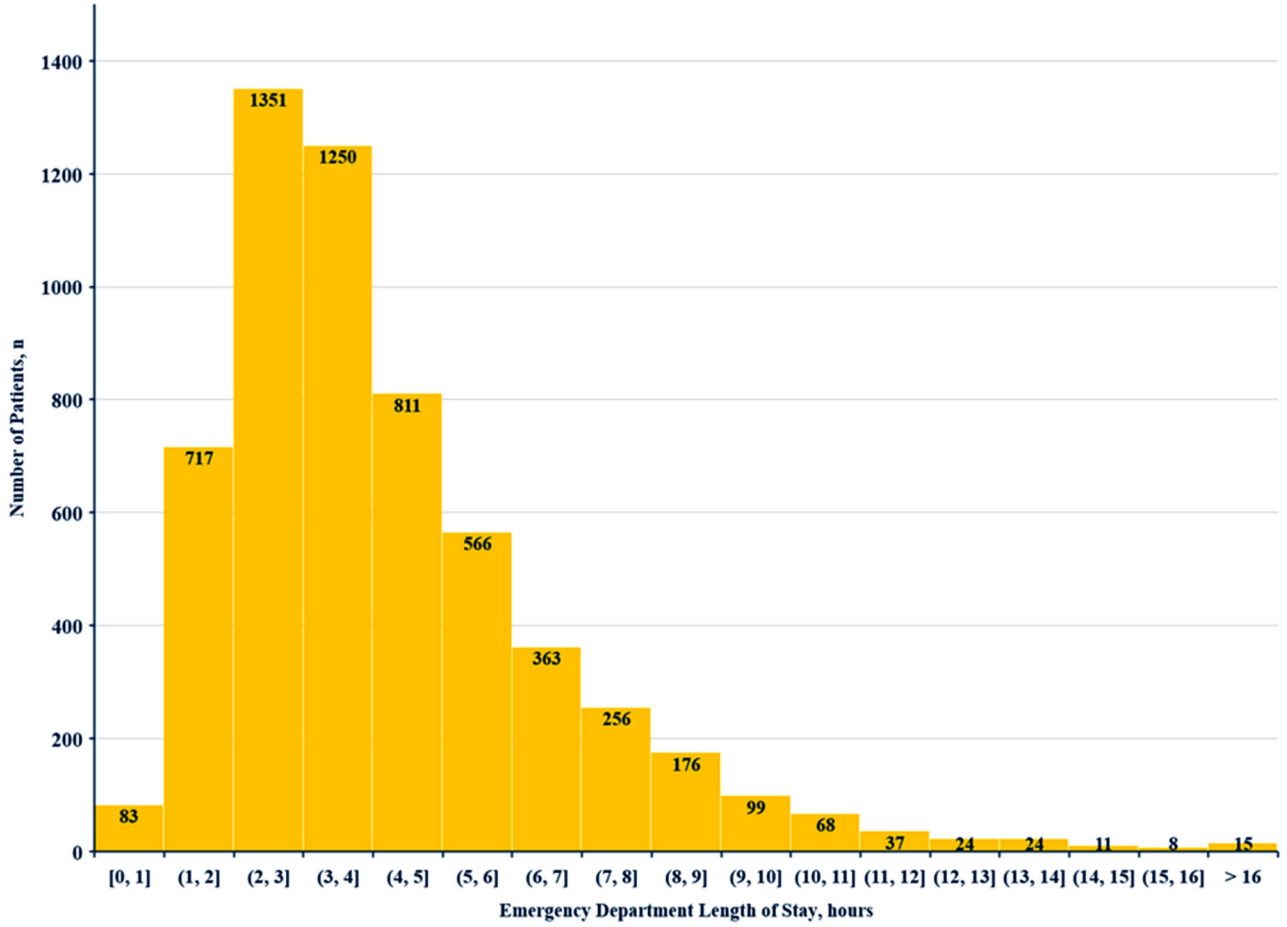

FIGURE 1 Distribution of emergency department length of stay prior to transfer to ED–ICU

TABLE 2 Main results: ED LOS before transfer to ED-ICU as a predictor for resource use and patient-oriented outcomes

	Unadjusted[a]	*P* value	Risk adjusted[b]	*P* value
ICU admission, OR (95% CI)	0.86 (0.84 to 0.88)	<0.001	0.91 (0.88 to 0.93)	<0.001
Hospital LOS, h, β (95% CI)	−3.4 (−5.9 to −1.0)	0.006	−0.69 (−3.2 to 1.8)	0.59
Inpatient ICU LOS, h, β (95% CI)	−1.3 (−4.1 to 1.5)	0.35	−0.002 (−2.9 to 2.9)	0.99
48-h mortality, OR (95% CI)	0.89 (0.82 to 0.98)	0.01	1.02 (0.93 to 1.11)	0.64
Hospital mortality, OR (95% CI)	0.89 (0.85 to 0.92)	0.001	0.97 (0.93 to 1.02)	0.23

Note: For all logistic regression models, ORs are interpreted as the effect of a 1-hour increase in ED LOS before transfer to ED-ICU on the odds of each outcome.

Abbreviations: CI, confidence interval; ED, emergency department; h, hours.; ICU, intensive care unit; LOS, length of stay; OR, odds ratio.

[a]Bivariate linear regressions were used to test ED LOS as a predictor of hospital and ICU LOS. Separate bivariate logistic regressions were used to test ED LOS as a predictor of the odds of ICU admission, 48-hour mortality, and hospital mortality.

[b]Multivariable linear regressions were used to test ED LOS as a predictor of hospital and ICU LOS. Separate multivariable logistic regressions were used to test ED LOS as a predictor of the odds of ICU admission, 48-hour mortality, and hospital mortality. Risk adjustment was performed with covariates in the multivariate models of age, sex, Charlson Comorbidity Index, Emergency Severity Index, and electronic Simplified Acute Physiology Score 3.

3.2 | Main results

3.2.1 | Association of ED LOS with ICU admission

We used logistic regression analysis and tested whether ED LOS before transfer to the ED-ICU was a predictor for admission to an inpatient ICU (Table 2). Unadjusted results showed a statistically significant negative association of ED LOS with inpatient ICU admission (odds ratio [OR], 0.86; 95% 95% confidence interval [CI], 0.84–0.88; $P < 0.001$). This demonstrates that on average, every 1-hour increase in ED LOS was associated with a 14% decrease in the odds of inpatient ICU admission. When adjusted for age, sex, ESI, qCCI, and eSAPS3, the

results showed a negative association (OR, 0.91; 95% CI, 0.88–0.93; $P < 0.001$), indicating that, on average, every 1-hour increase in ED LOS was associated with a 9% decrease in the odds of inpatient ICU admission.

3.2.2 | Association of ED LOS with hospital and ICU LOS

We used linear regression analysis and tested whether ED LOS before transfer to the ED-ICU was a predictor for hospital LOS (Table 2). Unadjusted results showed a statistically significant negative association of ED LOS with hospital LOS ($\beta = -3.4$; 95% CI, −5.9 to −1.0; $P = 0.006$). This demonstrates that on average, every 1-hour increase in ED LOS was associated with a decrease of 3.4 hours in hospital LOS. However, when adjusted for age, sex, ESI, qCCI, and eSAPS3, the results showed no statistically significant association between ED LOS and hospital LOS ($\beta = -0.69$; 95% CI, −3.2 to 1.8; $P = 0.59$). In the same manner, we tested whether ED LOS before transfer to the ED-ICU was a predictor for inpatient ICU LOS. Both unadjusted ($\beta = -1.3$; 95% CI, −4.1 to 1.5; $P = 0.35$) and risk-adjusted ($\beta = -0.002$; 95% CI, −2.9 to 2.9; $P = 0.99$) results showed no statistically significant association between ED LOS and inpatient ICU LOS.

3.2.3 | Association of ED LOS with mortality

We tested whether ED LOS before transfer to the ED-ICU was a predictor for 48-hour mortality or hospital mortality (Table 2). Results from unadjusted logistic regression analyses showed a negative association of ED LOS with 48-hour mortality (OR, 0.89; 95% CI, 0.82–0.98; $P = 0.01$) and hospital mortality (OR, 0.89; 95% CI, 0.85–0.92; $P < 0.001$). This demonstrates that, on average, every 1-hour increase in ED LOS was associated with an 11% decrease in the odds of 48-hour mortality or hospital mortality. However, when adjusted for age, sex, ESI, qCCI, and eSAPS3, the results showed no statistically significant association between ED LOS and 48-hour mortality (OR, 1.02; 95% CI, 0.93–1.11; $P = 0.64$) or hospital mortality (OR, 0.97; 95% CI, 0.93–1.02; $P = 0.23$).

4 | LIMITATIONS

The retrospective nature of this study limits interpretation to association only rather than direct causation. Although our multivariable linear/logistic regression analyses accounted for demographics (age, sex), chronic comorbidity (Charlson Comorbidity Index), and disease severity (ESI and Simplified Acute Physiology Score), it is possible that additional unaccounted factors (such as ED census, inpatient ICU census, ED-ICU census, physician:patient ratios, chronic comorbidity not accounted for via the Charlson Comorbidity Index, or acuity/disease severity not accounted for by the ESI or eSAPS3) confounded the observed results. Patients are transferred from the ED to the ED-ICU at the discretion of the treating clinician without specific criteria;[18] thus, the observed ED LOS before ED-ICU transfer may have been impacted by individual clinician practice patterns, which could confound the observed results. This study was conducted at a single United States academic medical center with a unique ED-ICU care delivery model, and generalizability to other centers is unknown.

5 | DISCUSSION

To evaluate the association of ED LOS with outcomes of patients who are critically ill in a setting with an ED-ICU, we retrospectively analyzed data from patients treated in the ED-ICU of a large academic center in the United States. After controlling for covariates, we observed no statistically significant associations between ED LOS before transfer to the ED-ICU and hospital LOS, inpatient ICU LOS, 48-hour mortality, or hospital mortality. We did observe a statistically significant negative association of ED LOS with the rate of ICU admission, demonstrating that a longer ED LOS was associated with lower odds of inpatient ICU admission.

The present study is the first to our knowledge to evaluate the impact of ED LOS on outcomes of patients who are critically ill in a setting with an ED-ICU. Although many prior studies have demonstrated worse outcomes with prolonged ED LOS of patients who are critically ill before ICU admission,[3–15] our observed findings demonstrate no statistically significant associations between ED LOS before ED-ICU transfer and worsened patient-oriented outcomes after covariates were statistically controlled. This discrepancy highlights the difference between time in the ED attributed to ED-related care versus boarding of patients who are critically ill because of the absence of ICU bed availability. In the United States, 33% of ICU admissions have ED LOS >6 hours,[16] whereas 19.6% of the patients in this study had an ED LOS >6 hours before transfer to the ED-ICU. Departmental bed occupancy data from the study period shows that ≥2 ED-ICU beds were available for 94% of the study period. Therefore, it is likely that prolonged ED LOS (>6 hours) before ED-ICU transfer was not related to ED boarding or ED-ICU bed unavailability, but more likely reflects the need for further interventions or human factors.[25]

These findings of prompt availability of ICU-level care with avoidance of prolonged ED boarding of patients who are critically ill are a benefit of the ED-ICU care delivery model. Multiple recent studies have demonstrated benefits of ED-ICUs, including observed reduction in mortality, reduction in rates of ICU admission or hospitalization, and reductions in hospital LOS.[18,19,26–30] Centers with high rates of ED boarding of patients who are critically ill and those considering implementing an ED-ICU can consider these findings in the context of their individual practice environments to best mitigate detrimental effects of ED boarding of patients who are critically ill on the local scale. With increasing numbers of ED-ICUs and more centers considering implementing similar units, continued assessment of outcomes (including prospective research) to guide further development is essential.

After adjustment, we observed no statistically significant associations between increased ED LOS before ED-ICU transfer and

worsened patient outcomes. As prior studies have found worse outcomes for prolonged ED LOS before inpatient ICU admission, these findings suggest an ED-ICU may help mitigate the risks of prolonged ED boarding of patients who are critically ill by delivering ICU-level care when the need is first identified rather than when a bed is available.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Nathan L. Haas and Henrique A. Puls contributed to the design, acquisition, analysis, interpretation, drafting, and revising. James A. Cranford contributed to the analysis and revising. Richard P. Medlin contributed to the acquisition and revising. Benjamin S. Bassin contributed to the design, acquisition, analysis, and revising.

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