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ORIGINAL RESEARCH

General Medicine

Selection bias in estimating the relationship between prolonged ED boarding and mortality in emergency critical care patients

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Abstract

Objectives: Studies have found that prolonged boarding time for intensive care unit (ICU) patients in the emergency department (ED) is associated with higher in-hospital mortality. However, these studies introduced selection bias by excluding patients with ICU admission orders who were downgraded and never arrived in the ICU. Consequently, they may overestimate mortality in prolonged ED boarders.

Methods: This was a retrospective cohort study at a single center covering the period from August 14, 2015 to August 13, 2019. Adult ED patients with medical ICU admission orders and at least 6 hours of subsequent critical care in either the ED or the ICU were included. Patients were classified as having either prolonged (>6 hours) or non-prolonged (≤6 hours) ED boarding. Downgraded patients were identified, and mortality was compared, both including and excluding downgraded patients.

Results: Of 1862 patients, 612 (32.9%) had prolonged boarding; at 6 hours after ICU admission order entry, they were still in the ED. The remaining 1250 (67.1%) had non-prolonged boarding; at 6 hours after the ICU admission order entry, they were already in the ICU. In-hospital mortality in the non-prolonged boarding group was 18.9%. In the prolonged boarding group, 296 (48.4%) patients were downgraded in the ED and never arrived in the ICU. Including these ED downgrades, the mortality in the prolonged boarding group was 13.4% (risk difference -5.5%, 95% confidence interval [CI] -8.9% to -2.0%, $P = 0.0031$). When we excluded downgrades, the mortality in the prolonged boarding group increased to 17.4% (risk difference -1.5%, 95% CI -6.2% to 3.2%, $P = 0.5720$). The lower mortality in the prolonged group was attributable to lower severity of illness (mean emergency critical care SOFA [eccSOFA] difference: -0.8, 95% CI -1.1 to -0.4, $P < 0.0001$).

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Conclusions: Excluding critical care patients who were downgraded in the ED leads to selection bias and overestimation of mortality among prolonged ED boarders.

KEYWORDS
critical care, ED boarding, mortality, selection bias

1 | INTRODUCTION

1.1 | Background

In the care of critically ill patients, the emergency department should provide initial resuscitation and evaluation, not ongoing longitudinal care. The American College of Emergency Physicians clinical policy on emergency department (ED) boarding of admitted intensive care unit (ICU) and non-ICU patients states that boarding "represents a failure of inpatient bed management and contributes to lower quality of care, decreased patient safety, reduced timeliness of care, and reduced patient satisfaction."[1]

1.2 | Importance

Despite this, prolonged ED boarding of admitted ICU patients is commonplace, especially in academic medical centers.[2–4] Several studies have found that ICU patients who board in the ED for prolonged periods have higher in-hospital mortality than those who board for shorter periods.[4–8] In our hospital, however, ICU patients with prolonged ED boarding times have significantly lower illness severity and consequently have lower rather than higher in-hospital mortality.[9] Additionally, a substantial proportion of admitted ICU patients who board in our ED for >6 hours are downgraded to non-ICU care and never reach the ICU, but these pre-ICU downgrades were excluded from previous studies.[5–7] This creates a selection bias in the prolonged boarding group by including only the patients who were too severely ill to be downgraded in the ED even after a prolonged period.

This type of selection bias is due to conditioning on a common effect.[10] Here, the common effect is arrival in the ICU. Prolonged boarding decreases the likelihood of arrival in the ICU; higher severity of illness increases the likelihood. Limiting the study population to those who arrive in the ICU creates a non-causal relationship between prolonged boarding and severity of illness, which in turn leads to higher apparent mortality. Only the more severely ill of the prolonged ED boarders ultimately arrive in the ICU; the less severely ill get downgraded to a non-ICU bed. Restricting the sample to those who arrive in the ICU biases up the estimated mortality associated with prolonged boarding.

1.3 | Goals of this investigation

We set out to measure the association between prolonged ED boarding and in-hospital mortality among all patients initially intended for ICU-level care with the hypothesis that mortality is lower among prolonged boarders when pre-ICU downgrades are included rather than excluded.

2 | METHODS

2.1 | Design/setting

This was a retrospective cohort study using electronic health record data from a tertiary care, suburban, academic medical center with 66 adult ED beds and an annual volume of approximately 70,000 adult ED visits per year. The project was approved by the Stanford institutional review board (Protocol #IRB-27542).

2.2 | Patients

At our center, the triage process for medical ICU (MICU) patients begins when the emergency physician, after identifying the potential need for MICU care, contacts the MICU triage physician for evaluation and consideration of MICU admission. If the patient is deemed to require ICU level of care, the MICU triage physician then enters ICU admission orders. We included all adult patients with admission orders from the ED to the MICU during the study period (August 14, 2015 to August 13, 2019). During the entire study period, a dual trained critical care medicine/emergency medicine (CCM/EM) nurse was available to assist ED nurses with boarding ICU patients.[9] From August 14, 2017 to August 13, 2019, a dual trained CCM/EM physician was available from 2 pm to midnight on weekdays to assist with management.[11]

2.3 | Protocol

Patients who boarded >6 hours in the ED after the ICU admission order were classified as having prolonged boarding and those who boarded ≤6 hours were classified as having non-prolonged boarding. In order to avoid immortal time bias,[12] we excluded patients who died or were downgraded early and did not receive at least 6 hours of critical care either in the ICU or ED. Patients who died or were downgraded within 6 hours of the ICU admission order, by definition, could not be in the prolonged boarding group, only the non-prolonged group. If many of them died, this would falsely elevate the mortality in the non-prolonged group. If many were downgraded, this would falsely decrease the mortality in the non-prolonged group.

The Bottom Line

Increased boarding time for intensive care unit (ICU) patients waiting in the emergency department is associated with higher mortality. A key factor that has not been thoroughly studied in this area is selection bias and its impact on ICU mortality. This retrospective cohort study of 1862 ICU patients found that excluding patients downgraded while boarding caused a selection bias and subsequent impact on overestimation of mortality among ICU patients with prolonged boarding times.

2.4 | Measures

Among patients with prolonged boarding, we identified a subset (pre-ICU downgrades) who never reached the ICU because they were downgraded in the ED after 6 or more hours of boarding. To test our hypothesis, we first replicated the design of other studies by comparing in-hospital mortality of the prolonged boarding group to the non-prolonged group, excluding the pre-ICU downgrades. The analysis was then repeated, this time including the pre-ICU downgrades. The prolonged boarding group was further divided into 2 subgroups: 6–12 hours and >12 hours. In-hospital mortality was calculated in these 2 subgroups, first excluding and then including the pre-ICU downgrades.

2.5 | Analysis

We used the Sequential Organ Failure Assessment (SOFA) score as modified for use in the ED to measure severity of illness, emergency critical care SOFA (eccSOFA)[13] and compared in-hospital mortality in the prolonged and non-prolonged groups adjusting for severity of illness using logistic regression. Means and SDs for continuous variables and proportions for categorical variables are reported and exact *P* values and 95% confidence intervals (CIs) are calculated. Statistical calculations used Stata 16.1.

3 | RESULTS

The initial cohort consisted of 2160 patients with admission orders to the medical ICU entered in the ED. Within the first 6 hours after admission order entry, 49 patients died and 249 were downgraded to a lower level of care. This left 1862 patients who were still receiving critical care 6 hours after order entry, either in the ED or the ICU. The prolonged boarding group consisted of 612 (32.9%) patients who were still in the ED at 6 hours after the ICU admission order was entered. The non-prolonged boarding group consisted of 1250 (67.1%) patients who were already in the ICU at 6 hours. (Figure 1). Compared to the non-prolonged group, the prolonged group had a similar age distribution (mean age: prolonged 62.2, non-prolonged 62.5, $P = 0.74$), but more females (prolonged 51.3%, non-prolonged 45%, $P = 0.01$), and lower severity of illness as measured by the eccSOFA score (mean eccSOFA: prolonged 4.0, non-prolonged 4.8, $P = < 0.0001$) (Table 1).

In-hospital mortality of the non-prolonged boarding group was 18.9% (236/1250). Of the 612 patients in the prolonged boarding group, 296 (48.4%) were downgraded in the ED after 6 or more hours and never reached the ICU. Including these ED downgrades, the mortality in the prolonged boarding group was 13.4% (82/612), 5.5% lower than the mortality in non-prolonged boarding group (risk difference -5.5%, 95% CI -8.9% to -2.0%, $P = 0.0031$) (Table 2A). When adjusted for severity of illness as measured by eccSOFA, the mortalities in the non-prolonged and prolonged groups were 17.9% and 15.2%, respectively. The mortality difference decreased from 5.5% to 2.7% and the risk difference was no longer statistically significant (adjusted risk difference -2.7%, 95% CI -6.1% to 0.7%, $P = 0.132$) (Table 2A). When downgrades were excluded, the mortality in the prolonged boarding group increased to 17.4%, 1.5% lower than the mortality in non-prolonged boarding group, although this did not reach statistical significance (risk difference -1.5%, 95% CI -6.2% to 3.2%, $P = 0.5720$) (Table 2B). Within the prolonged boarders (the group of 612 admitted patients who were still in the ED after 6 hours), mortality among those who were downgraded and never arrived in the ICU was 9.1%, 8.3% lower than the 17.4% mortality for those who were not downgraded (risk difference -8.3%, 95% CI -13.6% to -3.0%, $P = 0.0026$). This explains the mortality difference between all prolonged boarders (13.4%) and those who were not downgraded (17.4%).

The prolonged boarding group was further subdivided into those who boarded 6 to 12 hours and those who boarded >12 hours. Excluding pre-ICU downgrades, the mortality of patients with >12 hours of boarding time was 20.0% (19/95), that is, 1.1% higher than the mortality of the non-prolonged group (risk difference 1.1%, 95% CI -7.2% to 9.5%, $P = 0.786$). Including the 149 patients downgraded in the ED after >12 hours, the mortality in this subgroup was 13.5% (33/244), that is, 5.4% less than the mortality of the non-prolonged group (risk difference -5.4%, 95% CI -10.6% to 0.0%, $P = 0.046$) (Table 3).

4 | LIMITATIONS

We did this study to highlight the problem of selection bias in determining the effect of prolonged ED boarding. It was a single-center study of only MICU patients. The sample size was small, particularly in the prolonged boarding group. Given institutional variations in ICU bed allocation, severity of illness among ICU boarders in the ED, and physician and nursing resources available to care for these patients, our results may not be generalizable to other institutions.

5 | DISCUSSION

We undertook this study because we noticed that almost half of our admitted ICU patients with prolonged boarding were downgraded in

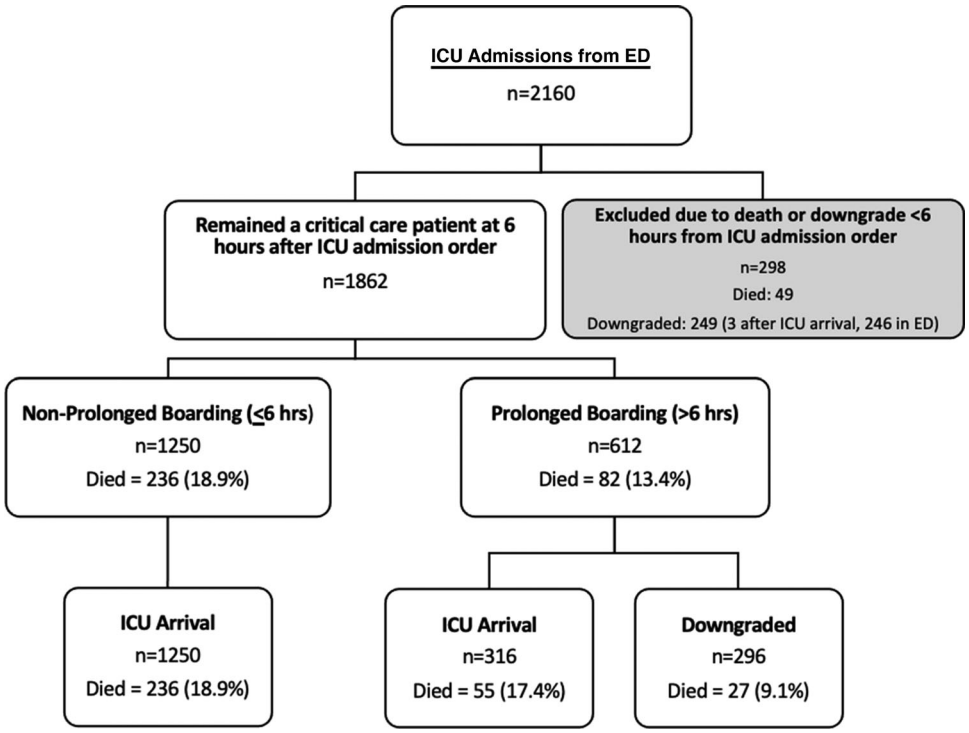

FIGURE 1 Study flow and final study population

TABLE 1 Patient demographics 1657 patients at 12 hours post ICU admission order

		Prolonged		Non-prolonged		
N		244		1413		*P*-value
Female sex	N (%)	119	(48.8%)	638	(45.2%)	0.2947
Age	Mean (SD)	63.1	(19.4)	62.9	(18.4)	0.9008
eccSOFA	Mean (SD)	4.2	(3.1)	4.8	(3.4)	0.0157

eccSOFA difference: -0.6, 95% confidence interval -1.0 to -0.1.

the ED. These patients would be excluded from a study restricted to patients who reach the ICU, which means that those studies overestimate mortality in patients with prolonged boarding. The largest study on this topic[7] excluded patients who were downgraded while in the ED and reported an in-hospital mortality of 12.9% for patients with boarding time <6 hours versus 17.4% for patients with ED boarding time ≥6 hours. The study authors attribute this 4.5% higher mortality to lack of highly specialized and skilled environment of the ICU.

We tested whether including all patients with ICU admission orders, even those who were downgraded in the ED and never transferred to the ICU, would decrease the estimated in-hospital mortality for patients with prolonged boarding. We first replicated previous studies and excluded ED critical care patients who were downgraded and never reached the ICU. We expected mortality to be higher in the prolonged boarding group than in the non-prolonged group when pre-ICU downgrades were excluded.[7] Interestingly, at our institution, even with the exclusion of the pre-ICU downgrades, there was slightly lower mortality in the prolonged boarding group compared to that of the non-prolonged group (17.4% vs 18.9%). This may be because of the ICU triage process in our institution. Patients who are sicker or have higher nursing needs are given higher priority for ICU transfer. The patients with prolonged boarding have lower illness severity and therefore lower mortality. We also have a dedicated critical care nurse and (during peak weekday hours) a dual-boarded CCM/EM physician in the ED who can continue to care for boarding ICU patients.

When downgraded patients were included in the analysis, mortality in the prolonged group was even lower, and the risk difference as compared to patients in the non-prolonged group was statistically significant. Adjustment for severity of illness attenuated this effect but did not eliminate it, most likely because our illness severity measure does not fully capture mortality risk.

When the prolonged boarding group was further subdivided into 6–12 hours and >12 hours, the >12-hour group had a higher mortality than the non-prolonged group when the pre-ICU downgrades were

TABLE 2 In-hospital mortality by boarding type (≤6 hours vs >6 hours)

Boarding type	Boarding time	Total	In-hospital death	Mortality
A: 296 downgraded patients included*				
Non-prolonged	≤6 h	1250	236	18.9%
Prolonged	>6 h	612	82	13.4%
			Difference:	−5.5%
B: 296 downgraded patients excluded				
Non-prolonged	≤6 h	1250	236	18.9%
Prolonged	>6 h	316	55	17.4%
			Difference:	−1.5%
				$P = 0.572$

*Adjusting for eccSOFA, mortalities are 17.9% and 15.2%, $P = 0.132$.

TABLE 3 In-hospital mortality by boarding type (≤6 hours, 6-12 hours, >12 hours)

Boarding time	Downgrades		Total	In-hospital deaths	Mortality
≤6 h	0		1250	236	18.9%
6-12 h	147		368	49	13.3%
		Downgrades excluded	221	36	16.3%
>12 h	149		244	33	13.5%
		Downgrades excluded	95	19	20.0%
			Difference from ≤6 h: 1.1%		
				$P = 0.786$	

excluded, but lower mortality when the downgrades were included. It is true that patients who arrived in the ICU after boarding 12+ hours in the ED had higher mortality than patients who arrived in the ICU after boarding <6 hours, but this does not mean that prolonged ED boarding per se causes higher mortality. Rather, it shows that patients who cannot be downgraded after prolonged ED boarding are a particularly high-risk group.

Nearly half of patients who boarded in the ED for >6 hours could be downgraded, likely because they were less severely ill to begin with. They may also have been selected for boarding because they had conditions, such as diabetic ketoacidosis, that can be stabilized within a shorter period. These patients had much lower mortality than other ICU patients. It may appear that this subgroup of patients was not harmed by staying in the ED for the entire duration of their critical care time. However, their mortality may have been still lower if they had been promptly transferred to the ICU.

We still believe that prompt transfer of an admitted patient to the ICU is better for that patient, for other ED patients, and for the ED in general. But restricting the study sample to patients who arrive in the ICU means selecting the most severely ill of the prolonged boarders and fails to account for those who improve during their boarding period.

When studying an association between ED boarding of the critically ill and in-hospital mortality, excluding pre-ICU downgrades leads to selection bias and potential overestimation of mortality among ICU patients who experience prolonged boarding in the ED. To quantify the true effect of prolonged boarding on outcomes, studies should include all patients initially admitted to the ICU from the ED.

AUTHOR CONTRIBUTIONS

All authors contributed to the design and implementation of the research. AJG, BS, KG, MK contributed to data collection. MK contributed to data analysis. KG and MK wrote the manuscript in consultation with other authors. All authors discussed the results and commented on the manuscript.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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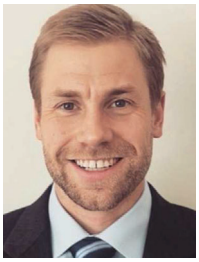

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