Early Clinical Deterioration Among Emergency Department Boarders: A Retrospective Analysis

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Study objective: To define the incidence and identify factors associated with early clinical deterioration among patients boarding in the emergency department (ED).

Methods: We conducted a retrospective study of adult ED patients admitted to internal medicine or medicine subspecialty services at a floor level of care who boarded between 4 and 48 hours within a 5-hospital academic health system from January 2018 to June 2024. Early deterioration was any escalation from floor to intermediate or intensive level of care within 48 hours of admission order. Logistic regression models were employed to estimate adjusted odds ratios (aOR). Covariates included boarding time, demographics, comorbidities, vital signs, laboratory values, ED and hospital census, overnight admission, and socioeconomic status.

Results: Among 173,168 consecutive encounters meeting enrollment criteria, 6,299 (3.6%) experienced deterioration; 2,823 (45%) occurred while still in the ED. Median boarding time was 12.5 hours (interquartile range [IQR]: 8.2 to 20.7 hours) for those with deterioration versus 10.2 hours (IQR: 6.9 to 18.3) for those without. Boarding duration was associated with deterioration both overall (aOR: 1.17, 95% confidence interval [CI] 1.10 to 1.24) and deterioration occurring in the ED (aOR 1.58, 95% CI 1.46 to 1.71) with a 0.8% and 2.4% increased relative risk for each excess hour of boarding, respectively. Other independent predictors included care at an academic safety-net hospital (aOR 2.41; 95% CI 2.17 to 2.67), overnight admission (aOR 1.29; 95% CI 1.21 to 1.38), and elevated lactate (aOR 1.93; 95% CI 1.72 to 2.17). The 28-day mortality rate was higher in patients experiencing deteriorations (13.0% vs 3.9%, OR 3.66, 95% CI 3.38 to 3.96).

Conclusions: Early clinical deterioration occurs with a meaningful frequency among ED boarders. Boarding duration was independently associated with increased odds of early clinical deterioration, an event known to increase morbidity and mortality. These data underscore the considerable patient safety risks inherent to boarding. [Ann Emerg Med. 2026;87:681-693.]

Please see page 682 for the Editor's Capsule Summary of this article.

Keywords: ED crowding, Boarding, Patient safety, Health policy, Clinical deterioration.

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INTRODUCTION

Background

Emergency department (ED) boarding of inpatients due to hospital crowding and limited inpatient bed availability remains a significant public health and patient safety crisis.[1] An increase in patient volumes and complexity, particularly since the COVID-19 pandemic, has accelerated the boarding crisis and attracted the attention of the public and policymakers alike.[2-5] Clinical deterioration, particularly to a degree that necessitates an escalation in level of care, has been suggested as a potential boarding-related harm.[6-8] However, there remains limited evidence on the prevalence of clinical deterioration among ED patients and its association with boarding.[9,10]

Importance

Clinical deterioration represents a potentially serious boarding-related patient safety event. Boarding patients are known to be at risk for delays in care, including longer time to administration of home medications, antibiotics, and order completion.[8,11] Furthermore, ED boarding is associated with numerous adverse patient outcomes including excess mortality, increased length of stay, and prolonged duration of mechanical ventilation, with these impacts disproportionately affecting vulnerable populations and the critically ill.[12-17]

Editor's Capsule Summary

What is already known on this topic

Boarding in the emergency department (ED) is a risk factor for poor patient outcome.

What question this study addressed

What was the incidence of clinical deterioration for patients boarding in the ED and how was deterioration associated with boarding time?

What this study adds to our knowledge

Among 170,168 encounters, median boarding time was 10.3 hours. Clinical deterioration within 48 hours occurred in 3.6% with almost half that occurring while the patient was in the ED.

How this is relevant to clinical practice

Patients may get sicker while they board.

Clinical deterioration events requiring an escalation in level of care have been associated with increased mortality in the inpatient setting; they have also been shown to be potentially preventable.[7,18-20] The frequency and nature of clinical deterioration among ED boarders, patients who remain in the ED after the decision to admit, have not been well described. To our knowledge, there is only one published study on the topic: a retrospective analysis of data from a single hospital with a relatively low burden of ED boarding between 2013 and 2015.[6] This gap in the literature highlights a need for more contemporary, multisite data to better understand deterioration patterns during prolonged ED stays and to identify opportunities for early intervention.

Goals of This Investigation

In this study, we sought to measure the incidence of clinical deterioration events that occur early in the clinical course of patients subjected to boarding in the ED, and to explore the association between these events and potentially modifiable operational metrics. Our primary hypotheses were that early clinical deterioration occurs commonly in ED boarders and that risk for deterioration is independently associated with a longer interval between admission order and ED departure (ie, boarding time). We also assessed the relationships between deterioration and other key clinical and operational variables and performed stratified analyses to determine whether identified associations were pertinent to deterioration events that occurred early in the hospital visit, regardless of location, or only to events that occurred prior to ED departure.

METHODS

Study Design and Setting

We conducted a retrospective observational study of ED patients within a 5-hospital academic health system located in the mid-Atlantic United States spanning 6.5 years (January 2018 to June 2024), utilizing data from the electronic health record. The 5 sites had a typical combined annual ED volume of approximately 250,000 patients. This system includes a large urban quaternary referral center (Hospital A); an urban safety-net teaching hospital (Hospital B); and 3 community hospitals in both urban and suburban settings (Hospitals C-E). Detailed operational characteristics for each hospital are presented in Table E1 (available at http://www.annemergmed.com).

Selection of Participants

We included all ED encounters by adult patients (≥18 years old) who were initially admitted (inpatient or hospitalized observation status) to floor level of care on a medicine or medicine subspeciality service (eg, cardiology, infectious diseases) and boarded in the ED between 4 and 48 hours. Boarding time was defined as the interval between admission order entry and patient departure from the ED. The lower limit of 4 hours was chosen based on a Joint Commission recommendation that ED dwell times exceeding this benchmark represent a patient safety risk and should be avoided.[21] This timepoint is frequently utilized to define patients as ED boarders.[9,22,23]

Encounters were determined to have an early clinical deterioration if their level of care was upgraded from floor to intermediate care or ICU within 48 hours of initial admission order. Escalation in level of care to intermediate care or ICU has been used as a surrogate for clinical decompensation in prior work and represents a clinically meaningful change in patient status that was acted on by the care team.[24-26] We included all level of care escalations within 48 hours, whether they occurred in the ED or after arrival to a medical ward, to avoid immortal time bias associated with prolonged ED stays.[27] Criteria for admission to a given care level (ward, intermediate care, ICU) were not standardized but in general, need for vasopressors or other actively titrated medications, mechanical ventilation, unstable vital signs, profound electrolyte or acid-base disturbances, hourly nursing interventions, or concern for declining clinical trajectory are known to be primary drivers of care-level escalation.[28] In the ED, emergency physicians were able to update the level of care to ICU with intensivist consultation and escalations to the intermediate care could occur with or

without consultation depending on site. Escalations in level of care taking place on the inpatient ward would occur typically after rapid response team activation or intensivist consultation. Level of care at the 1-hour mark was considered the initial level of care for purposes of analysis, as changes in level of care within the first hour likely reflect clerical error rather than a change in the patient's clinical status.

Measurement

Demographic and clinical data including age, gender, self-reported ethnicity, Charlson Comorbidity Index score, vital signs and laboratory results immediately prior to admission decision, chief complaint, boarding time, hospital and ED census data, time of admission, and mortality at 28 days from admission were bulk extracted from the electronic health record (Epic, Verona, WI). The Area Deprivation Index was calculated by a third party service (Alteryx, Irvine, CA) for each patient based on their address at the time of encounter and categorized into quintiles based on state Area Deprivation Index rankings, with higher quintiles indicating greater neighborhood disadvantage.[29] An encounter was deemed to be an overnight admission if the initial admission order was placed between 11:00 PM and 7:00 AM. Laboratory data were categorized as normal, abnormal, or missing. Abnormal threshold values were determined based on institutional practice and are included in Table E2 (available at http://www.annemergmed.com).

Analysis

Descriptive statistics were calculated for demographic, clinical, and environmental factors. Medians with interquartile ranges (IQR) for continuous factors and frequencies for discrete factors were calculated for encounters with and without early deterioration events. Chi-square tests were used to compare mortality frequencies between groups.

To identify risk factors associated with early deterioration, we utilized univariate and multivariable logistic regression to determine odds ratios (ORs) and adjusted odds ratios (aOR) with 95% confidence intervals (CIs) using heteroskedasticity-robust standard errors. Factors included boarding time, the numbers of total patients and boarders in the ED, hospital census at time of admission, age, race, ethnicity, gender, encounter year, previous health system admission one year prior to index encounter, overnight admission, chief complaint, last lab values available prior to admission decision (serum lactic acid, sodium, potassium, bicarbonate, glucose, hemoglobin, platelets, and white blood cells), Charlson comorbidity score, encounter hospital, Area Deprivation Index, and the last recorded vital signs (pulse, respirations, systolic blood pressure, and temperature) prior to time of admission. Multivariable logistic regression model covariates were chosen based on exploratory data analysis, prior literature, and clinical plausibility.[18,30,31] For logistic regression, boarding time was standardized to have mean of 0 and a SD of 1. Census covariates were also standardized at the encounter hospital given the wide range in ED and hospital volumes across sites in our system (ie, how many SDs above or below the mean was the hospital census for each encounter). Encounters with missing demographic information, vital signs, or census data were rare ($\sim$1%), appeared to be missing at random, and were not included in analyses. For site-specific models, given the low numbers of missing laboratory values at some sites, aORs for abnormal laboratory results only were calculated. A relative risk for escalation in care per hour of boarding time was calculated from the standardized boarding time aOR by using boarding time SD as a scalar. Although the incidence of escalations in level of care was rare and aOR would serve as a reasonable approximation for relative risk, to improve interpretability we calculated a relative risk using previously published methods and reported the results as percent change per hour.[32] A supplementary analysis including all boarding patients and categorizing encounters by boarding time into discrete brackets (0 to 4; 4 to 8; 8 to 12; 12 to 16; 16 to 24; 24 to 48 hours) was also performed. Additionally, we performed a subgroup analysis examining older patients aged $\geq$65 years.

Several additional sensitivity analyses were performed and are included in the supplement. (1) To account for potential autocorrelation across time and site, the multivariable model was clustered by hospital and year to assess for correlation across time and site; (2) to account for local practice patterns regarding upgraded level of care, we examined all and in-ED escalations to either the ICU or intermediate care alone separately; (3) to account for lab capacity strain, we performed our analyses using the first available labs, as opposed to the most recent labs at the time of admission order; (4) to assess our normal laboratory values, analyses using more liberal or strict laboratory thresholds were performed.

Analyses were performed in Stata (version 18SE, StataCorp, College Station, TX). Figures were generated with R (version 4.5.2, *R* Foundation for Statistical Computing, Vienna, Austria). This study was approved by the Johns Hopkins School of Medicine institutional review board (IRB #0443202).

RESULTS

Characteristics of Study Population and Sites

We identified 173,168 encounters that met criteria during the study period. Median boarding time was 10.3 hours (IQR: 6.9 to 18.3). Demographic and clinical data for the study cohort are presented in Table 1, with study site-level patient characteristics presented in Table E3 (available at http://www.annemergmed.com). Our study cohort was diverse in terms of sex, race, socioeconomic status, and reason for visit. The population was majority non-Hispanic (95%), older (median age 67 years, IQR 52 to 79), and had low to moderate clinical complexity as represented by the Charlson Comorbidity Index score and vital signs; a substantial proportion (29.5%) had been admitted to one of our system's hospitals within the preceding year (Table 1). The distribution of boarding times, early deterioration by boarding duration, and proportion of encounters with early deterioration by boarding duration for all encounters are shown in the Figure. There was an increasing proportion of encounters with early deterioration from 0 to 14 hours, with a persistently elevated rate of deterioration beyond that. Of note, boarding times observed at our academic safety-net hospitals were nearly double than those of our community hospitals (12.7 to 15.5 vs 7.2 to 8.6 hours), and a substantially higher proportion of patients at these sites belonged to the most disadvantaged Area Deprivation Index quintile (45.3% to 55.2% vs 1.9% to 6.2%) (Table E2).

Main Results

Clinical deterioration requiring an escalation in level of care within 48 hours occurred in 6,299 (3.6%) encounters. Of these, 2,823 (45%) occurred while the patient was still in the ED. Clinical deterioration requiring escalation to ICU-level care occurred in 3,100 (1.8%) encounters; the remainder were to intermediate care-level care. Death was much more likely (OR 3.66, 95% CI 3.38 to 3.96) for encounters where early clinical deterioration occurred than for those where it did not, with observed 28-day mortality rates of 13.0% and 3.9%, respectively. Similar findings were found when examining encounters with an early deterioration in the ED compared to those without (10.1% vs 4.1%, OR 2.56, 95% CI 2.28 to 2.93). Differential mortality risk varied based on the severity of deterioration; the 28-day mortality rate for patients who required escalation to ICU-level care was 17.5% (OR 5.20, 95% CI 4.72 to 5.73), whereas the rate for those who required escalation to intermediate care-level care was 8.6% (OR 2.31, 95% CI 2.03 to 2.63).

The median boarding time for encounters where early deterioration events occurred (before or after ED departure) was 12.5 hours (IQR: 8.2 to 20.7 hours), as compared to 10.2 hours (IQR: 6.9 to 18.3 hours) for encounters without an observed deterioration. Stratifying by location of deterioration, median boarding time was 15.9 hours (IQR: 11.4 to 24.1) for encounters where deterioration occurred in the ED and 9.5 hours (IQR: 6.6 to 16.3 hours) for those where deterioration occurred after ED departure.

Results of univariate analyses to identify patient demographic and clinical factors associated with early deterioration events in general, and those that occur in the ED specifically, are presented in Tables 2 and 3, respectively. Patients experiencing a deterioration had longer boarding times, were more likely to have abnormal labs, be treated at an academic teaching site, be male, and to be admitted overnight or during periods with higher than typical boarding. Results of multivariable logistic regression analyses for all early clinical deterioration events and only those that occur in the ED, are presented in Tables 2 and 3, respectively. Boarding time was independently associated with increased odds of clinical deterioration in any location within 48 hours (aOR 1.17, 95% CI 1.10 to 1.24); each hour of excess boarding was associated with a 0.8% increase in relative deterioration risk. Patients boarding between 12 and 16 hours were over twice as likely to have an early clinical deterioration than those boarding 0 to 4 hours (aOR 2.03, 95% CI 1.70 to 2.43; Table E4, available at http://www.annemergmed.com). When the analysis was restricted to events that occurred prior to ED departure, boarding time was even more strongly associated with increased odds of clinical deterioration (aOR 1.58, 95% CI 1.46 to 1.71); each excess hour of boarding was associated with a 2.4% increase in relative risk of clinical deterioration in the ED. Standardized number of boarding patients was also associated with increased odds of clinical deterioration, whether considering all early deterioration events (aOR 1.05, 95% CI 1.01 to 1.09) or only those that occurred prior to ED departure (aOR 1.11, 95% CI 1.05 to 1.18). Several clinical and operational variables also exhibited independent association with increased odds of early clinical deterioration, including abnormal vital signs, high-risk chief complaints (eg, chest pain, shortness of breath), laboratory abnormalities (eg, low hemoglobin, elevated lactate), patient socioeconomic status (Area Deprivation Index), and site of care (Tables 2 and 3). Subanalyses were performed at the individual study site level, with very similar trends observed (Table E5, available at http://www.annemergmed.com). Specifically, duration of boarding was

Table 1. Characteristics of study participants.

Patient Characteristic	Median (IQR) or Count (%, N=173,168)
Age (y)	67.0 (52.0-79.0)
Gender	
Female	90,340 (52.2%)
Male	82,808 (47.8%)
Other*	20 (0.0%)
Ethnicity	
Non-Hispanic	164,595 (95.0%)
Hispanic	8,573 (5.0%)
Race	
Black	59,794 (34.5%)
Other	19,655 (11.4%)
White	93,719 (54.1%)
Area Deprivation Index quintile	
1 (least deprived)	47,696 (27.8%)
2	28,286 (16.5%)
3	23,697 (13.8%)
4	25,106 (14.6%)
5 (most deprived)	46,651 (27.2%)
Admission hospital	
A	50,781 (29.3%)
B	38,294 (22.1%)
C	38,111 (22.0%)
D	28,593 (16.5%)
E	17,389 (10.0%)
Charlson Morbidity Index weighted score	1.0 (0.0-3.0)
Boarding time (h)	10.3 (6.9-18.4)
Prior admission in last year	51,162 (29.5%)
Overnight admission	30,827 (17.8%)
Chief complaint	
Abdominal pain	20,156 (11.6%)
Chest pain	13,099 (7.6%)
Shortness of breath	23,760 (13.7%)
Other	116,153 (67.1%)
Pulse (min^{-1})	82.0 (71-95)
Systolic blood pressure (mmHg)	130 (115-147)
Respirations (min^{-1})	18.0 (16-20)
Temperature (°F)	98.2 (97.8-98.6)
Glucose (mg/dL)	115.0 (98-146)
Sodium (mEq/L)	138 (135-141)
Potassium (mEq/L)	4.1 (3.8-4.5)
Bicarbonate (mEq/L)	24 (22-27)
Lactate (mmol/L)	1.5 (1.1-2.0)
Hemoglobin (g/dL)	12.0 (10.2-13.6)
White blood cell count ($cells/mm^3$)	8.63 (6.36-11.86)
Platelets (K/μL)	231 (175-3)
Encounter year	
2018	27,180 (15.7%)
2019	29,561 (17.1%)
2020	24,673 (14.2%)
2021	23,251 (13.4%)
2022	22,089 (12.8%)
2023	31,356 (18.1%)
2024	15,058 (8.7%)

Continuous variables are reported as medians with IQRs, and discrete variables are presented as counts with percentages. Laboratory values represent the last measurements obtained prior to the admission decision.
*Patients who self-selected a gender identity other than male or female (eg, nonbinary) or chose not to specify a gender were categorized as other.

independently associated with risk of deterioration at all sites except our quaternary referral center (Hospital A), where there was a marginally significant trend toward boarding times being protective against deterioration. Additionally, at Hospital A there was an independent association between the number of ED boarders and risk of deterioration, which was not replicated at other sites.

Sensitivity Analyses

Sensitivity analyses using more liberal or strict definitions of abnormal laboratory values for the multivariable logistic regression produced qualitatively consistent results (Table E6, available at http://www.

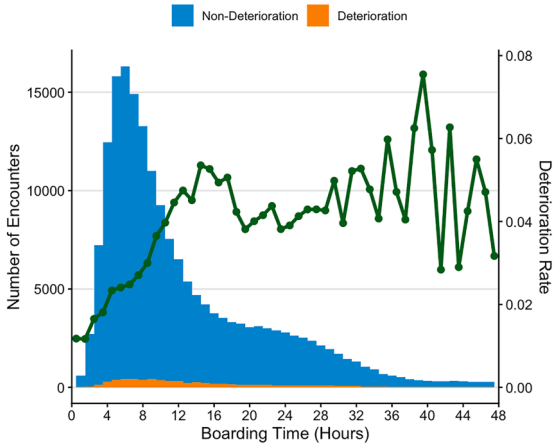

Figure. Distribution of boarding times. The histogram displays the frequency of encounters by total hours boarding, with the frequency of boarders experiencing an early clinical deterioration within 48 hours (orange) and those that did not (blue). The proportion of encounters experiencing by total hours boarding is displayed as the green line graph.

Table 2. Univariate and multivariable analysis of factors by presence of an early deterioration in the ED or inpatient setting.

Variable	No Early Deterioration	Early Deterioration in ED or Inpatient Setting	Multivariable aOR
N	166,869 (96.4%)	6,299 (3.6%)	
Age, y	67 (52-79)	66 (54-78)	1.01 (1.01-1.01)
Gender			
Female	873 (52.3%)	3,040 (48.3%)	Reference
Male	79,551 (47.7%)	3,257 (51.7%)	1.18 (1.12-1.25)
Other	18 (0.0%)	2 (0.0%)	-
Hispanic ethnicity	8,243 (4.9%)	330 (5.2%)	1.05 (0.91-1.22)
Patient race			
Black	57,618 (34.5%)	2,176 (34.5%)	Reference
Other	18,963 (11.4%)	692 (11.0%)	1.13 (1.01-1.26)
White	90,288 (54.1%)	3,431 (54.5%)	1.08 (1.01-1.15)
Area Deprivation Index quintile			
1 (least deprived)	46,471 (28.1%)	1,225 (19.6%)	Reference
2	27,399 (16.6%)	887 (14.2%)	1.06 (0.96-1.17)
3	22,990 (13.9%)	797 (12.8%)	1.03 (0.93-1.14)
4	24,042 (14.6%)	1,064 (17.0%)	1.06 (0.96-1.18)
5 (most deprived)	44,383 (26.9%)	2,268 (36.3%)	1.12 (1.01-1.24)
Admission hospital			
A	48,552 (29.1%)	2,229 (35.4%)	1.98 (1.80-2.19)
B	36,106 (21.6%)	2,188 (34.7%)	2.41 (2.17-2.67)
C	37,285 (22.3%)	826 (13.1%)	Reference
D	27,831 (16.7%)	762 (12.1%)	1.25 (1.12-1.40)
E	17,095 (10.2%)	294 (4.7%)	0.72 (0.62-0.83)
Charlson Comorbidity Index weighted score	1 (0-3)	1 (0-3)	1.02 (1.01-1.03)
Admission in the last year	49,285 (29.5%)	1,877 (29.8%)	0.88 (0.83-0.94)
Overnight admit	29,390 (17.6%)	1,437 (22.8%)	1.29 (1.21-1.38)
Chief complaint			
Abdominal pain	19,568 (11.7%)	570 (9.0%)	0.95 (0.86-1.04)
Chest pain	12,517 (7.5%)	582 (9.2%)	1.47 (1.34-1.62)
Shortness of breath	22,460 (13.5%)	1,300 (20.6%)	1.59 (1.48-1.70)
Other	112,306 (67.3%)	3,487 (61.1%)	Reference
Boarding time*	10.2 (6.9 18.3)	12.5 (8.2-20.7)	1.17 (1.10-1.24)
Standardized number of patients in the ED†	0.07 (−0.64 to 0.73)	0.12 (−0.60 to 0.90)	0.99 (0.95-1.02)
Standardized number of patients boarding in the ED†	−0.02 (−0.67 to 0.74)	0.01 (−0.57 to 0.75)	1.05 (1.02-1.09)
Standardized number of patients in hospital†	0.04 (−0.59 to 0.66)	0.08 (−0.56 to 0.70)	1.02 (0.99-1.06)
Pulse (min^{-1})	82 (71-95)	89 (76-102)	1.02 (1.01-1.02)
Respirations (min^{-1})	18 (16-19)	18 (16-20)	1.03 (1.02-1.03)
Systolic blood pressure (mmHg)	130 (115-147)	126 (109-145)	0.99 (0.99-1.00)
Temperature (°F)	98.2 (97.8-98.6)	98.2 (97.7-98.7)	1.01 (0.99-1.04)
Glucose			
Abnormal	19,404 (11.8%)	973 (16.0%)	1.28 (1.19-1.38)
Normal	141,252 (86.2%)	4,785 (78.8%)	Reference
Missing	3,116 (1.9%)	313 (5.2%)	0.34 (0.08-1.52)
Sodium			
Abnormal	8,445 (5.2%)	458 (7.5%)	1.47 (1.33-1.64)
Normal	152,202 (92.9%)	5,298 (87.3%)	Reference

Table 2. Continued.

Variable	No Early Deterioration	Early Deterioration in ED or Inpatient Setting	Multivariable aOR
Missing	3,125 (1.9%)	315 (5.2%)	4.25 (1.04-17.40)
Potassium			
Abnormal	2,970 (1.8%)	166 (2.7%)	1.31 (1.11-1.56)
Normal	153,155 (93.5%)	5,389 (88.8%)	Reference
Missing	7,647 (4.7%)	516 (8.5%)	1.24 (1.10-1.41)
Bicarbonate			
Abnormal	7,760 (4.7%)	530 (8.7%)	1.64 (1.49-1.81)
Normal	152,636 (93.2%)	5,212 (85.9%)	Reference
Missing	3,376 (2.1%)	329 (5.4%)	1.23 (0.72-2.09)
Lactate			
Abnormal	3,525 (2.2%)	441 (7.3%)	1.93 (1.72-2.17)
Normal	57,041 (34.8%)	2,398 (39.5%)	Reference
Missing	103,206 (63.0%)	3,232 (53.2%)	0.86 (0.80-0.91)
Hemoglobin			
Abnormal	11,006 (6.7%)	518 (8.5%)	1.24 (1.12-1.36)
Normal	151,219 (92.3%)	5,431 (89.5%)	Reference
Missing	1,547 (0.9%)	122 (2.0%)	2.42 (0.55-10.64)
White blood cell count			
Abnormal	26,448 (16.1%)	1,328 (21.9%)	1.26 (1.17-1.34)
Normal	135,786 (82.9%)	4,623 (76.1%)	Reference
Missing	1,538 (0.9%)	120 (2.0%)	0.34 (0.07-1.61)
Platelets			
Abnormal	10,016 (6.1%)	523 (8.6%)	1.27 (1.15-1.41)
Normal	151,841 (92.7%)	5,405 (89.0%)	Reference
Missing	1,915 (1.2%)	143 (2.4%)	1.42 (0.92-2.18)
Encounter year			
2018	26,184 (15.7%)	996 (15.8%)	Reference
2019	286 (17.1%)	961 (15.3%)	0.91 (0.83-1.00)
2020	23,804 (14.3%)	869 (13.8%)	0.95 (0.86-1.06)
2021	22,324 (13.4%)	927 (14.7%)	1.04 (0.95-1.15)
2022	21,224 (12.7%)	865 (13.7%)	1.00 (0.91-1.11)
2023	30,153 (18.1%)	1,203 (19.1%)	1.06 (0.96-1.16)
2024‡	14,580 (8.7%)	478 (7.6%)	0.89 (0.79-1.01)

Early deterioration is an upgrade in level of care within the first 48 hours, either in the ED or inpatient setting. For univariate continuous factors, a median and IQR are presented for patients with and without early deteriorations in level of care. For univariate discrete factors, total number and frequency (%) are presented. The outputs of the multivariable model are presented as adjusted odds ratios. For continuous variables this represents the odds of a clinical deterioration per one unit (eg, per year for age).
*For boarding time, the odds ratio is presented in terms of the standardized boarding time.
†For census data, the number of patients at time of admission was standardized for each encounter hospital.
‡Through June 2024. Due to very low numbers the "Other" gender category was not included as independent predictor in the multivariable model.

annemergmed.com). Additionally, similar results were seen when examining the association between covariates and ICU-only or intermediate care-only clinical deteriorations (Table E7, available at http://www.annemergmed.com) as well as when using initial lab results rather than latest labs, when restricting to older adults, and when clustered by hospital and year (Tables E8 to E11, available at http://www.annemergmed.com).

LIMITATIONS

This work does have limitations that should be considered. First, our study was performed within a single health system which may limit its generalizability. However, our study sites did include academic and community EDs with a variety of boarding practices. Second, each hospital within our system has unique criteria for admission to ICU or intermediate care level of

Table 3. Univariate and multivariable analysis of factors by presence of an early deterioration in the ED only.

Variable	No Deterioration in the ED	Early Deterioration in the ED	Multivariable aOR
N	170,345 (98.4%)	2,823 (1.6%)	
Age, y	67 (52-79)	64 (51-76)	1.01 (1.01-1.01)
Gender			
Female	88,993 (52.2%)	1,347 (47.7%)	Reference
Male	81,334 (47.7%)	1,474 (52.2%)	1.17 (1.08-1.27)
Other	18 (0.0%)	2 (0.1%)	-
Hispanic ethnicity	8,417 (4.9%)	156 (5.5%)	1.22 (0.98-1.52)
Patient race			
Black	92,239 (54.1%)	1,480 (52.4%)	1.19 (1.08-1.31)
Other	58,729 (34.5%)	1,065 (37.7%)	1.14 (0.95-1.36)
White	19,377 (11.4%)	278 (9.8%)	Reference
Area Deprivation Index quintile			
1 (least deprived)	47,357 (28.1%)	339 (12.1%)	Reference
2	27,955 (16.6%)	331 (11.8%)	1.09 (0.92-1.28)
3	23,369 (13.9%)	328 (11.7%)	1.07 (0.90-1.27)
4	246 (14.6%)	506 (18.1%)	1.11 (0.94-1.31)
5 (most deprived)	45,359 (26.9%)	1,292 (46.2%)	1.38 (1.18-1.62)
Hospital			
A	49,476 (29.0%)	1,305 (46.2%)	4.23 (3.56-5.02)
B	37,169 (21.8%)	1,125 (39.9%)	4.20 (3.51-5.02)
C	37,911 (22.3%)	2 (7.1%)	Reference
D	28,432 (16.7%)	161 (5.7%)	1.19 (0.95-1.48)
E	17,357 (10.2%)	32 (1.1%)	0.36 (0.24-0.53)
Charlson Comorbidity Index weighted score	1 (0-3)	1 (0-4)	1.01 (0.99-1.02)
Admission in the last year	50,273 (29.5%)	889 (31.5%)	0.91 (0.83-0.99)
Overnight admit	30,138 (17.7%)	689 (24.4%)	1.33 (1.21-1.46)
Chief complaint			
Abdominal pain	19,954 (11.7%)	202 (7.2%)	0.74 (0.63-0.86)
Chest pain	12,831 (7.5%)	268 (9.5%)	1.46 (1.27-1.67)
Shortness of breath	23,181 (13.6%)	579 (20.5%)	1.60 (1.44-1.77)
Other	114,379 (67.1%)	1,774 (62.8%)	Reference
Boarding time (h)*	10.2 (6.9-18.2)	15.9 (11.4-24.1)	1.58 (1.46-1.71)
Standardized number of patients in the ED†	0.066 (−0.641 to 0.729)	0.215 (−0.530 to 0.893)	0.97 (0.91-1.02)
Standardized number of patients boarding in the ED†	−0.020 (−0.673 to 0.738)	0.183 (−0.530 to 0.895)	1.11 (1.05-1.18)
Standardized number of patients in hospital†	0.038 (−0.591 to 0.657)	0.161 (−0.450 to 0.768)	1.04 (0.98-1.09)
Pulse (min^{-1})	82 (71-95)	92 (77-107)	1.02 (1.02-1.02)
Respirations (min^{-1})	18 (16-20)	18 (16-21)	1.02 (1.01-1.03)
Systolic blood pressure (mmHg)	130 (115-147)	124 (107-145)	0.99 (0.99-1.00)
Temperature (°F)	98 (97-98)	98 (97 98)	1.02 (0.98-1.05)
Glucose			
Abnormal	19,955 (11.9%)	422 (15.7%)	1.20 (1.07-1.34)
Normal	143,973 (86.1%)	2,064 (76.6%)	Reference
Missing	3,220 (1.9%)	209 (7.8%)	0.37 (0.06-2.43)
Sodium			
Abnormal	8,691 (5.2%)	212 (7.9%)	1.76 (1.51-2.06)
Normal	155,227 (92.9%)	2,273 (84.3%)	Reference
Missing	3,230 (1.9%)	210 (7.8%)	4.23 (0.74-24.27)

Table 3. Continued.

Variable	No Deterioration in the ED	Early Deterioration in the ED	Multivariable aOR
Potassium			
Abnormal	3,038 (1.8%)	98 (3.6%)	1.80 (1.43-2.26)
Normal	156,252 (93.5%)	2,292 (85.0%)	Reference
Missing	7,858 (4.7%)	305 (11.3%)	1.38 (1.16-1.63)
Bicarbonate			
Abnormal	7,999 (4.8%)	291 (10.8%)	1.99 (1.73-2.28)
Normal	155,663 (93.1%)	2,185 (81.1%)	Reference
Missing	3,486 (2.1%)	219 (8.1%)	1.39 (0.70-2.73)
Lactate			
Abnormal	3,686 (2.2%)	280 (10.4%)	2.21 (1.89-2.58)
Normal	58,271 (34.9%)	1,168 (43.3%)	Reference
Missing	105,191 (62.9%)	1,247 (46.3%)	0.77 (0.71-0.85)
Hemoglobin			
Abnormal	11,254 (6.7%)	270 (10.0%)	1.41 (1.23-1.62)
Normal	154,293 (92.3%)	2,357 (87.5%)	Reference
Missing	1,601 (1.0%)	68 (2.5%)	1.98 (0.25-15.86)
White blood cell count			
Abnormal	27,168 (16.3%)	608 (22.6%)	1.28 (1.16-1.42)
Normal	138,389 (82.8%)	2,020 (75.0%)	Reference
Missing	1,591 (1.0%)	67 (2.5%)	0.32 (0.04-2.78)
Platelets			
Abnormal	10,298 (6.2%)	241 (8.9%)	1.25 (1.09-1.45)
Normal	154,873 (92.7%)	2,373 (88.1%)	Reference
Missing	1,977 (1.2%)	81 (3.0%)	1.64 (0.94-2.85)
Year			
2018	26,825 (15.7%)	355 (12.6%)	Reference
2019	29,211 (17.1%)	350 (12.4%)	0.92 (0.79-1.08)
2020	24,334 (14.3%)	339 (12.0%)	1.04 (0.88-1.23)
2021	22,827 (13.4%)	424 (15.0%)	1.26 (1.09-1.47)
2022	21,650 (12.7%)	439 (15.6%)	1.29 (1.11-1.50)
2023	30,705 (18.0%)	651 (23.1%)	1.52 (1.31-1.75)
2024‡	14,793 (8.7%)	265 (9.4%)	1.31 (1.10-1.57)

Early deterioration is an upgrade in level of care within the first 48 hours only in the ED setting. For univariate continuous factors, a median and IQR are presented for patients with and without early deteriorations in level of care. For univariate discrete factors, total number and frequency (%) are presented. The outputs of the multivariable model are presented as adjusted odds ratios. For continuous variables this represents the odds of a clinical deterioration per one unit (eg, per year for age).
*For boarding time, the odds ratio is presented in terms of the standardized boarding time.
†For census data, the number of patients at time of admission was standardized for each encounter hospital.
‡Through June 2024. Due to very low numbers the "Other" gender category was not included as independent predictor in the multivariable model.

care, and these vary between floor and service. Such within- and across-site practice variability is common in health care, but does potentially restrict both the internal and external validity of this work.[28] Third, although we intentionally selected escalation of care as a specific and measurable marker of clinical deterioration, it does not capture all clinical deterioration events. Deterioration events that necessitated additional resuscitation without a level of care change may be clinically important but were not included in our analyses. As a retrospective, observational study we cannot assess causality nor the direction of the association. It is possible that patients had transport out of the ED delayed given concerns for deterioration. Although we did include numerous

covariates in our multivariable analyses to reduce confounding, it is impossible to account for all potential confounders under a retrospective observational research design. Additionally, increased hospital capacity strain has also been shown to decrease the rate of initial triage to ICU and increase subsequent mortality.[33] Although capacity strain and congestion appears to be important for initial level of care and hospital course, we could only approximate through hospital census data from our data set. Moreover, the impact of relative staffing levels in times of high ED congestion (particularly nursing and allied health staff) likely does have a substantial impact on the clinical course of boarding patients, with a report demonstrating that improved nurse staffing leads to higher rates of survival for in-hospital cardiac arrest.[34] Although relative volumes to staffing would be a very useful metric to incorporate into our model, this information is not currently available to us.

DISCUSSION

In this study, we analyzed over 6 years of data related to clinical deterioration among ED boarders within a large health system that included both community and academic sites. Within this system, we found that early clinical deterioration occurs with meaningful frequency (3.6%) among patients who are subjected to ED boarding, with 45% of these events taking place during the boarding period. Boarding time duration was independently associated with early clinical deterioration regardless of location, with every excess hour of boarding increasing the relative risk of early deterioration by 0.8%. For deteriorations occurring in the ED, the impact was much higher, with a 2.4% relative risk increase for each additional hour of excess boarding. Moreover, the 28-day mortality rate was higher for boarders who experienced early deterioration than those who did not, arguing that these represent clinically meaningful events.

This study represents a significant contribution to the limited body of evidence on clinical deterioration among ED boarders. In the only preceding full-length study on this topic, Lord et al[9] reported no relationship between boarding duration and early deterioration. However, their analysis was performed prior to the COVID-19 pandemic and in a clinical setting where ED boarding was much more limited; only 12.7% of patients in their study waited longer than 4 hours for a bed, compared with 92.8% in ours.[9] Conversely, Sangal et al[10] did find an association between ED boarding time and deterioration risk; in an abstract they reported a 0.3% increase in probability of deterioration for every excess hour of boarding (less than half of the 0.8% increase in our population). Their study was performed in a population with a mean boarding time of only 4.3 hours, which may not fully capture the deleterious effects of prolonged boarding. Our study is unique in that it examines the phenomenon of clinical deterioration within the context of near-universal ED boarding—a state that has become all too common in US health care.

Literature on other specific risk factors for early deterioration is similarly sparse, particularly in the ED boarding population. Previous work has shown an association between laboratory, comorbidities, overnight admission, and sex with early escalation to the ICU, but unlike our work, did not examine boarding patients specifically.[24] Our work provides further evidence that patients boarding overnight represent an at-risk population, building on a previous French study of elderly admitted patients who remained in the ED overnight.[35] Lastly, although there have been several reports from the inpatient setting showing that escalations in level of care have increased mortality, our report extends this association in the ED boarding population.[25,26] The current literature on clinical deterioration among ED boarders is limited and heterogeneous, and standardized definitions and measures will be required to better understand the phenomenon.

We identified several patient-level markers of acuity risk factors associated with early clinical deterioration. Several abnormal lab results were associated for increased risk of deterioration. Concordant with prior literature, elevated lactic acid results are a particularly important marker of risk, approximately doubling of the odds of early deterioration in our cohort.[36-38] Additionally, chief complaints mapping to chest pain or dyspnea appear to place patients at increased risk for early deterioration. These findings suggest that readily available clinical and laboratory data may be useful to predict clinical deterioration and proactively identify patients who may benefit from targeted interventions such as triggered reassessments or expedited transfer of care. Although early warning systems do exist, focus on the ED boarding population has been limited; development of tools optimized to guide care decisions in this population is an active area of investigation for our group.[39]

Although clinical deterioration risk is impacted by patient-level factors, prolonged exposure to congested ED environments is equally important. Our analyses revealed that duration of boarding was independently associated with early clinical deterioration even after accounting for patient acuity and complexity. Additionally, patients at our 2 large safety-net hospitals had increased odds of

clinical deterioration, especially during the ED boarding period. These hospitals are chronically congested and serve highly complex patient populations compared with our community hospitals, potentially straining ED resources. Interestingly, the total number of patients in the hospital or the ED was not associated with early deterioration, arguing that volume alone is not sufficient to increase the risk for escalations in level of care. By contrast, an observed independent association between the number of ED boarders and risk for deterioration suggests that "gridlocked" EDs in congested hospitals are risky environments where patient safety may be compromised.

Boarding has substantial impacts on safety and quality; however, it is incompletely incorporated into current safety frameworks.[40,41] Although the Joint Commission effectively requires instances of boarding to be tracked, in our experience hospitals rarely share operational data on boarding-associated safety incidents publicly.[42] Many hospitals do treat early unexpected escalations in level of care as a trigger event, prompting review of these cases through a root cause analyses, morbidity and mortality conference, or other formal safety review process, but often fail to account for boarding as a causal factor.[43-45] Our findings argue that both ED and inpatient safety event reviews should account for boarding duration as a potential contributing factor. Additionally, the Agency for Healthcare Research and Quality's recent summit on boarding recognized the safety threat posed by prolonged boarding, and urged the development of quality measures to help improve care for boarding patients.[46] Based on our findings, early clinical deterioration requiring an escalation in level of care would represent just such a clinically meaningful measure. Our results may also aid health system leaders and policymakers, providing additional evidence that boarding duration is an important and modifiable risk factor for patient harm.

In conclusion, in this large, multisite analysis, we found that early clinical deterioration occurs in a meaningful proportion of ED inpatient boarders, with nearly half of these events happening while patients remain in the ED. Longer boarding times were independently associated with increased risk of deterioration, particularly for patients remaining in the ED. These findings highlight ED boarding not only as an operational challenge but also as a modifiable, systems-level risk factor for patient harm. Our results underscore the need for real-time deterioration risk monitoring among boarders and support the development of targeted safety measures, including early warning tools and protocols to mitigate risk during prolonged ED stays.

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Data sharing statement: The clinical data used in this study are from the Johns Hopkins Health System (JHHS). These individual-level patient data are protected for privacy. Qualified researchers affiliated with Johns Hopkins University (JHU) may apply for access through the Johns Hopkins Institutional Review Board (IRB) (https://www.hopkinsmedicine.org/institutional_review_board/). Those not affiliated with JHU seeking to collaborate may contact the corresponding author. Access to these data for research collaboration with JHU must ultimately comply with IRB and data sharing protocols (https://ictrweb.johnshopkins.edu/ictr/dmig/Best_Practice/c8058e22-0a7e-4888-aecc-16e06aabc052.pdf). All analyses were performed using State 18SE. Analytic code is available in a public repository (https://github.com/CDEM-JHU/EDBoardingDeterioration).

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