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Western Journal of Emergency Medicine:

Integrating Emergency Care with Population Health

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Western Journal of *Emergency Medicine*:

Integrating Emergency Care with Population Health

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Official Journal of the California Chapter of the American College of Emergency Physicians, the America College of Osteopathic Emergency Physicians, and the California Chapter of the American Academy of Emergency Medicine

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JOURNAL FOCUS

Emergency medicine is a specialty which closely reflects societal challenges and consequences of public policy decisions. The emergency department specifically deals with social injustice, health and economic disparities, violence, substance abuse, and disaster preparedness and response. This journal focuses on how emergency care affects the health of the community and population, and conversely, how these societal challenges affect the composition of the patient population who seek care in the emergency department. The development of better systems to provide emergency care, including technology solutions, is critical to enhancing population health.

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Critical Time Intervals in Door-to-Balloon Time Linked to One-Year Mortality in ST-Elevation Myocardial Infarction

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Background: Timely activation of primary percutaneous coronary intervention (PCI) is crucial for patients with ST-segment elevation myocardial infarction (STEMI). Door-to-balloon (DTB) time, representing the duration from patient arrival to balloon inflation, is critical for prognosis. However, the specific time segment within the DTB that is most associated with long-term mortality remains unclear. In this study we aimed to identify the target time segment within the DTB that is most associated with one-year mortality in STEMI patients.

Methods: We conducted a retrospective cohort study at a tertiary teaching hospital. All patients diagnosed with STEMI and activated for primary PCI from the emergency department were identified between January 2013–December 2021. Patient demographics, medical history, triage information, electrocardiogram, troponin-I levels, and coronary angiography reports were obtained. We divided the DTB time into door-to-electrocardiogram (ECG), ECG-to-cardiac catheterization laboratory (cath lab) activation, activation-to-cath lab arrival, and cath lab arrival-to-balloon time. We used Kaplan-Meier survival analysis and multivariable Cox proportional hazards models to determine the independent effects of these time intervals on the risk of one-year mortality.

Results: A total of 732 STEMI patients were included. Kaplan-Meier analysis revealed that delayed door-to-ECG time (>10 min) and cath lab arrival-to-balloon time (>30 min) were associated with a higher risk of one-year mortality (log-rank test, $P < .001$ and $P = 0.01$, respectively). In the multivariable Cox models, door-to-ECG time was a significant predictor for one-year mortality, whether it was analyzed as a dichotomized (>10 min vs ≤10 min) or a continuous variable. The corresponding adjusted hazard ratios (aHR) were 2.81 (95% confidence interval [CI] 1.42–5.55) for the dichotomized analysis, and 1.03 (95% CI 1.00–1.06) per minute increase, respectively. Cath lab arrival-to-balloon time also showed an independent effect on one-year mortality when analyzed as a continuous variable, with an aHR of 1.02 (95% CI 1.00–1.04) per minute increase. However, ECG-to-cath lab activation and activation-to-cath lab arrival times did not show a significant association with the risk of one-year mortality.

Conclusion: Within the door-to-balloon interval, the time from door-to-ECG completion is particularly crucial for one-year survival after STEMI, while cath lab arrival-to-balloon inflation may also be relevant. [West J Emerg Med. 2025;26(2)180–190.]

INTRODUCTION

Primary percutaneous coronary intervention (PCI) stands as the cornerstone therapy for patients experiencing ST-segment elevation myocardial infarction (STEMI).[1–3] The prompt activation of primary PCI upon a STEMI patient's arrival at the emergency department (ED) is crucial for achieving coronary artery reperfusion.[1–3] The door-to-balloon (DTB) time, representing the interval from the patient's ED arrival to the inflation of a balloon within the occluded coronary artery, serves as a pivotal metric in this process.[1,3] Prolonged DTB times have consistently been associated with an elevated risk of short-term mortality and major adverse cardiac events.[4–6] Consequently, DTB time serves as a quality indicator for assessing the performance of a PCI-capable hospital.[1,7]

Within the DTB time, several time segments can be delineated, including door-to-electrocardiogram (ECG), ECG-to-catheterization laboratory (cath lab) activation, activation-to-cath lab arrival, cath lab arrival-to-needle insertion, and needle insertion-to-balloon inflation time. Delays in any of these time segments may lead to prolonged DTB time.[7–9]

Previous studies have explored the relationship between DTB and short-term mortality, such as in-hospital death or 30-day mortality.[5,6] However, the impact of DTB time on long-term mortality and which specific time segment within the DTB is mostly associated with long-term outcome remain unclear. To aid in the development of improvement strategies, our goal in this study was to determine the target period within the DTB that is most associated with one-year mortality in STEMI patients.

Population Health Research Capsule

What do we already know about this issue?
Timely percutaneous coronary intervention is essential for patients with ST-elevation myocardial infarction (STEMI); reducing door-to-balloon (DTB) time improves survival outcomes.

What was the research question?
Which interval within the DTB time is most associated with 1-year mortality in STEMI patients?

What was the major finding of the study?
The time from door-to-ECG completion within the DTB interval is particularly important for 1-year mortality in STEMI patients.

How does this improve population health?
Identifying key intervals within DTB time associated with long-term mortality in STEMI patients supports the development of targeted improvement strategies.

METHODS

Study Design, Setting, and Participants

We conducted a retrospective cohort study at Ditmanson Medical Foundation Chia-Yi Christian Hospital, a 1,000-bed tertiary teaching hospital in an urban city of Taiwan. The hospital's emergency department (ED) handles approximately 80,000 patient visits annually. Designated as an accredited, advanced emergency-responsibility hospital in Taiwan since 2013, it undergoes regular evaluations to ensure compliance with STEMI emergency management standards. Key objectives include providing 24/7 emergency cardiac catheterization services, ensuring that over 80% of STEMI patients receive an ECG examination within 10 minutes of ED arrival, initiating dual antiplatelet therapy for at least 80% of STEMI patients in the ED before primary PCI, and achieving DTB times of under 90 minutes for over 75% of STEMI patients. Consequently, a protocol for managing STEMI patients in the ED has been implemented (Supplementary Figure 1).

Upon arrival, immediate ECG is performed for patients with any cardiopulmonary-related symptoms in triage and promptly reviewed by an emergency physician. If STEMI is diagnosed, a loading dose of dual antiplatelet therapy and anticoagulants is administered, and the cardiologist is immediately consulted. The cardiologist activates primary PCI after assessment. Once the cath lab is prepared, the patient is transferred for primary PCI as expeditiously as possible.

All patients diagnosed with STEMI and activated for primary PCI from the ED are included in the hospital-based STEMI registry, where data was prospectively gathered for quality improvement. We identified patients hospitalized for STEMI between January 1, 2013–December 31, 2021, from the STEMI registry. Factors potentially influencing STEMI outcomes and DTB time, such as demographic data (age, sex, body mass index).[10,11] time of ED arrival,[12] weekend visit,[13] visit during the COVID-19 pandemic,[4,15] mode of transportation to the hospital,[16] triage level,[17] initial troponin-I levels,[18] comorbidities,[11] findings of ECG and coronary angiography,[10,11] and duration of hospitalization, were collected from the registry and electronic health records.

Various time points from ED arrival to balloon inflation were identified, including the time of completion of the first ECG, activation of the cath lab, arrival in the cath lab, and balloon inflation. We defined door-to-ECG time as the duration from ED arrival to completion of the first ECG,

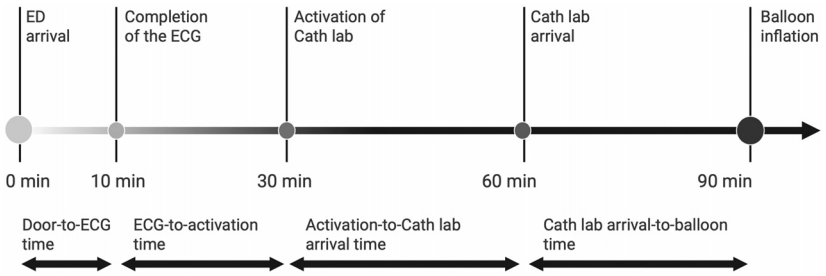

Figure 1. Time segments within the door-to-balloon time.
Cath lab, catheterization laboratory; *ECG*, electrocardiogram; *ED*, emergency department.

ECG-to-activation time as the duration from ECG completion to activation of the cath lab, activation-to-cath lab-arrival time as the duration from cath lab activation to the patient's arrival in the cath lab, and cath lab-arrival-to-balloon time as the duration from the patient's arrival in the cath lab to balloon inflation (Figure 1).[1,3,7] Delays in different time intervals within the DTB were defined as follows: door-to-ECG time >10 min; ECG-to-activation time >20 min; activation-to-cath lab arrival time >30 min; cath lab arrival-to-balloon time >30 min; and DTB time >90 min.[1,5]

Outcome Measurement

The primary outcome assessed in this study was all-cause mortality within one year after admission for STEMI. All STEMI patients were followed up for at least one year from the date of admission to assess mortality. Mortality timing was accurately determined by cross-referencing study patients with the National Cause of Death Registry from the Taiwan National Health Insurance database, which documents the time and cause of death for all deceased individuals in Taiwan.[19] The last follow-up date was December 31, 2022. Since Taiwan National Health Insurance is a compulsory, single-payer healthcare system covering nearly 99.8% of the population, theoretically all enrolled patients who pass away are recorded in the National Cause of Death Registry.[19] Thus, unless a patient withdraws from the insurance systems, all included patients can be tracked either until the last follow-up date or their date of death. Patients with out-of-hospital cardiac arrest (OHCA) and those with missing data were excluded from the analysis.

This was a health record review study in which we followed the methodological criteria for health record review studies proposed by Woster et al.[20] After identifying STEMI patients from the hospital-based STEMI registry, we used a pre-designed form with defined variables to record patients' data. Four trained emergency residents and nurses reviewed the electronic health records and input data into the form. Regular meetings were held to ensure the correctness of data collection, and a supervisor randomly audited the accuracy of the data collected. The data abstractors were not aware of the study's hypothesis and were informed only that they were helping to establish a STEMI database for research purposes. The study protocol received approval from the Institutional Review Board of Ditmanson Medical Foundation Chia-Yi Christian Hospital (approval number: CYCH-IRB 2024010), with an exemption from informed consent owing to the retrospective nature of the study.

Statistical Analysis

We compared data from the included STEMI patients between two groups: those with and without one-year mortality. Continuous variables were expressed as mean ± standard deviation or median (interquartile range) and assessed between groups using the Student *t*-test or Mann-Whitney U test, respectively, based on data distribution. We present categorical variables as number (percentage) and assessed them using chi-square test. The mortality rate was expressed as events per 100 person-years. To identify the target time segment within the DTB most associated with one-year mortality, we employed Kaplan-Meier survival analysis. Survival curves were plotted for patients stratified into delay vs non-delay groups across different time intervals within the DTB, with differences assessed using log-rank tests. We used univariable Cox proportional hazards models to assess the association between each variable and one-year mortality. Time intervals within the DTB were treated as either dichotomized (delay or non-delay groups) or continuous variables. We further analyzed variables demonstrating a *P*-value of less than 0.1 in the univariable analysis in a multivariable Cox model employing forward variable selection (set at $P < 0.05$ for addition to the model) to determine their independent effect on the risk of one-year mortality. The Schoenfeld test was subsequently used to verify the assumption of proportional hazards.

Sensitivity Analysis

We conducted additional sensitivity analyses to examine the association between various time intervals within the DTB and short-term mortality outcomes, such as in-hospital and 30-day mortality, as well as one-year mortality. These analyses used multivariable logistic regression with a forward stepwise Wald test. The variables included in these analyses

were the same as those in the multivariable Cox analysis. The time intervals within the DTB were incorporated into the models separately and were treated as either dichotomized or continuous variables. Furthermore, considering the extended recruitment period of this study (nine years), we conducted another sensitivity analysis to control for potential confounding factors across different time periods. In addition to adjusting for associated variables, we performed a multivariable Cox model including the year of patient recruitment as a covariate. Finally, a sensitivity analysis using a multivariable Cox model was conducted to evaluate the relationship between DTB time intervals and cardiovascular-related one-year mortality. We performed statistical analyses using Stata 17.0 (StataCorp, College Station, TX), with statistical significance set at two-tailed <0.05.

RESULTS

During the study period, 738 patients with STEMI were identified. After excluding those with OHCA or missing data, 732 patients were finally included. Among them, 59 patients died within one year after STEMI (Figure 2), with 37 deaths attributed to cardiovascular-related causes. The overall mortality rate was 9.05 per 100 person-years (95% confidence interval [CI], 7.02–11.69).

Table 1 presents the characteristics of patients with and without mortality within one year after STEMI. Patients who died within one year after STEMI were older (73.2 ± 13.7 vs 61.0 ± 12.6 years, $P < .001$) and had a higher proportion of females (35.59% vs 14.56%, $P < .001$). They were more likely to be transported to the hospital by ambulance (40.68% vs 24.37%, $P = 0.006$) and had higher triage acuity (triage level 1: 32.2% vs. 8.92%, $P < .001$) and initial troponin-I levels (1.72 [0.12–8.52] vs 0.13 [0.02–2.40) nanograms per milliliter, $P < .001$]. They were also more likely to have diabetes mellitus (54.24% vs 38.04%, $P = 0.02$), hypertension (76.27% vs 63.30%, $P = 0.05$), cerebrovascular accident (20.34% vs. 6.39%, $P < .001$), and chronic kidney disease (20.34% vs 6.69%, $P < .001$), while being less likely to have hyperlipidemia (27.12% vs 63.30%, $P < .001$). Additionally, they had longer hospitalization durations (6 [3–14] vs 5 [4–6] days, $P = 0.02$) and longer door-to-ECG (7 [5–11] vs 4 [3–6] min, $P < .001$], cath lab arrival-to-balloon (25 [17–40] vs 22 [16–28] min, $P = 0.02$), and DTB times (74 [56–88] vs 64 [52–75] min, $P < .001$]. Moreover, a higher proportion of patients had DTB time longer than 90 min (22.03% vs 8.82%, $P < .001$).

Figure 3 shows the Kaplan-Meier curves for mortality after admission for STEMI. We analyzed the mortality probability between two groups based on the DTB time (Figure 3A). The cumulative mortality rate was significantly higher in the delayed DTB group (DTB > 90 min) compared to the non-delayed group (DTB ≤ 90 min) during the one-year follow-up period (long-rank test, $P < .001$). Next, we separately analyzed for the different time segments within the DTB. Patients with delayed door-to-ECG (Figure 3B) and cath lab arrival-to-balloon times (Figure 3E) had a higher mortality risk than their non-delayed counterparts ($P < .001$ and P = 0.007, respectively). However, no significant difference was observed between patients with and without delays in ECG-to-cath lab activation (Figure 3C) and activation-to-cath lab arrival (Figure 3D).

In the univariable Cox analyses (Table 2), an increase in age, female sex, ambulance-transported patients, higher

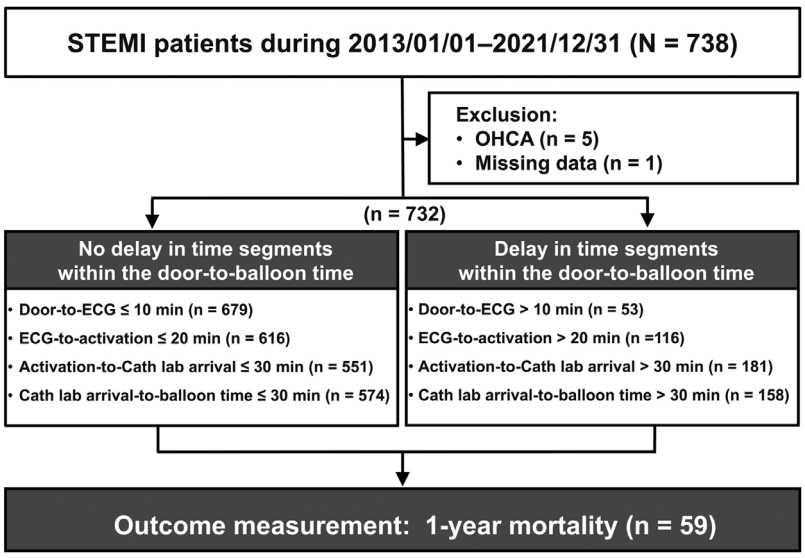

Figure 2. Flowchart of the patients included in the study.
ECG, electrocardiogram; *OHCA*, out-of-hospital cardiac arrest; *STEMI*, ST-segment elevation myocardial infarction.

Table 1. Characteristics of patients with and without one-year mortality after admission for STEMI*.

Characteristics	1-year survival (N = 673)	1-year mortality (N = 59)	*P-value*
Age (year)	61.0 ± 12.6	73.2 ± 13.7	<.001
BMI	25.1 (23.0–27.8)	24.1 (21.1–27.5)	0.08
Female sex	98 (14.56)	21 (35.59)	<.001
Patient arrival time			
Day shift	294 (43.69)	33 (55.93)	0.19
Evening shift	251 (37.30)	17 (28.81)	
Night shift	128 (19.02)	9 (15.25)	
Weekend visit	197 (29.27)	18 (30.51)	0.84
During COVID-19 pandemic (2020–2021)	143 (21.25)	8 (13.56)	0.16
Ambulance-transported patient	164 (24.37)	24 (40.68)	0.006
Triage level			
1	60 (8.92)	19 (32.20)	<.001
2	553 (82.17)	38 (64.41)	
3	60 (8.92)	2 (3.39)	
Laboratory test			
Troponin-I (ng/mL)	0.13 (0.02–2.40)	1.72 (0.12–8.52)	<.001
Medical history			
Diabetes mellitus	256 (38.04)	32 (54.24)	0.02
Hypertension	426 (63.30)	45 (76.27)	0.05
Hyperlipidemia	426 (63.30)	16 (27.12)	<.001
Cerebrovascular accident	43 (6.39)	12 (20.34)	<.001
Chronic kidney disease	45 (6.69)	12 (20.34)	<.001
Coronary artery disease	92 (13.67)	9 (15.25)	0.74
COPD	18 (2.68)	4 (6.78)	0.08
PAOD	8 (1.19)	1 (1.70)	0.53
Smoking	410 (60.92)	29 (49.15)	0.08
ECG report			
Anterior STEMI	305 (45.32)	31 (52.54)	0.29
Inferior STEMI	340 (50.67)	25 (42.37)	0.22
Lateral STEMI	23 (3.43)	2 (3.39)	1.00
Posterior STEMI	12 (1.79)	0 (0.00)	0.61
Numbers of vessel disease	2 (1–3)	2 (2–3)	0.06
Findings of coronary angiography			
1 vessel disease	206 (30.66)	14 (23.73)	0.23
2 vessels disease	244 (36.31)	18 (30.51)	
3 vessels disease	220 (32.74)	27 (45.76)	
Duration of hospitalization (day)	5 (4–6)	6 (3–14)	0.02
Time interval			
Door-to-ECG (min)	4 (3–6)	7 (5–11)	<.001
ECG-to-activation (min)	10 (6–15)	11 (8–19)	0.13
Activation-to-cath lab arrival (min)	23 (16–30)	22 (16–30)	0.94
Cath lab arrival-to-balloon (min)	22 (16–28)	25 (17–40)	0.02

(*Continued on next page*)

Table 1. Continued.

Characteristics	1-year survival (N = 673)	1-year mortality (N = 59)	*P-value*
Door-to-balloon (min)	64 (52–75)	74 (56–88)	<.001
Door-to-balloon > 90 min	58 (8.62)	13 (22.03)	<.001

Data are presented as n (%), mean ± SD, or median (interquartile range).
BMI, body mass index; *COPD*, chronic obstructive pulmonary disease; *ECG*, electrocardiography; *ng/mL*, nanograms per milliliter; *PAOD*, peripheral arterial occlusion disease; **STEMI*, ST-segment elevation myocardial infarction.

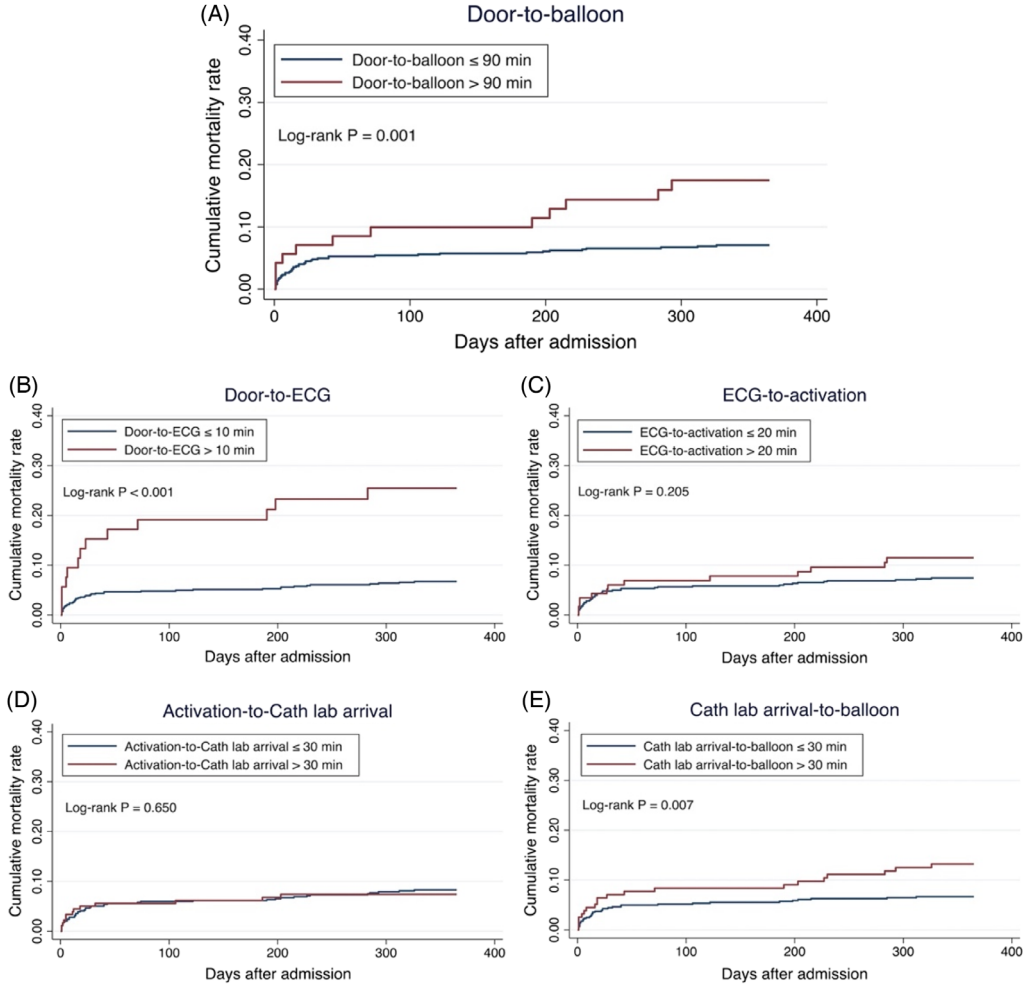

Figure 3. Kaplan-Meier curves illustrating cumulative mortality rates within a one-year follow-up period after STEMI* admission for delay and non-delay groups in door-to-balloon (A), door-to-ECG (B), ECG-to-activation (C), activation-to-cath lab arrival (D), and cath lab arrival-to-balloon (E) times.
**STEMI*, ST-elevation myocardial infarction.

troponin-I levels, a medical history of diabetes, hypertension, cerebrovascular accident, or chronic kidney disease, and each additional day of hospitalization were associated with a higher risk of one-year mortality. Additionally, patients with a lower triage level and hyperlipidemia had a lower risk of one-year mortality. Moreover, door-to-ECG and cath lab arrival-to-balloon times were significantly associated with a higher risk of onw-year mortality after STEMI.

Table 3 presents the results of multivariable Cox analyses. In model 1, we analyzed the time intervals as dichotomized variables (delay vs non-delay groups). After adjusting for associated factors, a delayed door-to-ECG time (>10 min) remained an independent predictor of one-year mortality, with an adjusted hazard ratio (HR) of 2.81 (95% CI 1.42–5.55). In model 2, the time intervals were analyzed as continuous variables. We found that each minute increase in

Table 2. Univariable Cox models for predicting one-year mortality after STEMI* admission.

Characteristics	Univariable unadjusted HR (95% CI)	*P-value*
Age (year)	1.08 (1.05–1.10)	<.001
BMI	0.94 (0.88–1.01)	0.11
Female sex	2.95 (1.73–5.03)	<.001
Patient arrival time		
Day shift	Reference	
Evening shift	0.63 (0.35–1.13)	0.12
Night shift	0.63 (0.30–1.31)	0.21
Weekend visit	1.06 (0.61–1.84)	0.85
During COVID-19 pandemic (2020–2021)	0.63 (0.30–1.33)	0.23
Ambulance-transported patient	2.06 (1.23–3.47)	0.006
Triage level		
1	Reference	
2	0.24 (0.14–0.41)	<.001
3	0.11 (0.03–0.48)	0.003
Laboratory test		
Troponin-I (ng/mL)	1.01 (1.01–1.02)	<.001
Medical history		
Diabetes mellitus	1.85 (1.11–3.08)	0.02
Hypertension	1.84 (1.01–3.35)	0.05
Hyperlipidemia	0.23 (0.13–0.40)	<.001
Cerebrovascular accident	3.35 (1.78–6.31)	<.001
Chronic kidney disease	3.13 (1.66–5.91)	<.001
Coronary artery disease	1.17 (0.58–2.38)	0.66
COPD	2.42 (0.88–6.69)	0.09
PAOD	1.35 (0.19–9.76)	0.77
Smoking	0.63 (0.38–1.05)	0.07
ECG report		
Anterior STEMI	1.36 (0.81–2.26)	0.24
Inferior STEMI	0.71 (0.43–1.20)	0.20
Lateral STEMI	0.98 (0.24–4.00)	0.97
Posterior STEMI	4.53E-15 (0–∞)	1.00
Numbers of vessel disease	1.37 (0.99–1.90)	0.06
Duration of hospitalization (day)	1.03 (1.02–1.05)	<.001
Time interval		
Door-to-ECG >10 min	4.82 (2.68–8.66)	<.001
ECG-to-activation > 20 min	1.48 (0.80–2.75)	0.21
Activation-to-cath lab arrival > 30 min	0.87 (0.47–1.61)	0.65
Cath lab arrival-to-balloon time >30 min	2.05 (1.20–3.49)	0.008
Time interval		
Door-to-ECG time (min)	1.02 (1.00–1.04)	0.03
ECG-to-activation time (min)	1.00 (0.99–1.01)	0.91
Activation-to-cath lab arrival time (min)	1.01 (0.99–1.03)	0.50
Cath lab arrival-to-balloon time (min)	1.03 (1.02–1.05)	<.001

BMI, body mass index; *COPD*, chronic obstructive pulmonary disease; *CI*, confidence interval; *ECG*, electrocardiography; *HR*, hazard ratio; *PAOD*, peripheral arterial occlusion disease; **STEMI*, ST-segment elevation myocardial infarction.

door-to-ECG time (adjusted HR, 1.03; 95% CI 1.00–1.06) and cath lab arrival-to-balloon time (adjusted HR, 1.02; 95% CI 1.00–1.04) were independently associated with one-year mortality. Furthermore, age, triage level, initial troponin-I levels, and a history of diabetes mellitus and hyperlipidemia were independent predictors of one-year mortality (Table 3). The Schoenfeld test yielded *P*-values of 0.65 and 0.43 for models 1 and 2, respectively, indicating no violation of the proportional hazards assumption for the included covariates.

Supplementary Table 1 presents the sensitivity analysis conducted using logistic regression for the outcomes of in-hospital, 30-day and one-year mortality. After adjusting for associated factors, door-to-ECG time was consistently identified as an independent predictor for in-hospital, 30-day, and one-year mortality, regardless of whether it was analyzed as dichotomized or continuous variables. Moreover, cath lab-arrival-to balloon time was identified as an independent predictor for the one-year mortality outcome when it was analyzed as a continuous variable. Supplementary Table 2 displays another sensitivity analysis that included the year of patient recruitment as a covariate to address potential confounding factors across different time periods. The results were similar to the main analysis. Supplementary Table 3 shows the results of a sensitivity analysis focused on one-year cardiovascular-related mortality, which were consistent with the main findings.

DISCUSSION

In this study, we explored specific time segments within the DTB interval associated with one-year mortality in patients with STEMI. Our findings revealed that the duration from door to ECG completion is particularly associated with one-year mortality, while cath lab arrival-to-balloon inflation may also be relevant. However, the intervals from ECG completion to cath lab activation and from

Table 3. Multivariable Cox models for predicting one-year mortality after STEMI* admission.

Characteristics**	Model 1 adjusted HR (95% CI)	*P-value*	Model 2 adjusted HR (95% CI)	*P-value*
Age (year)	1.06 (1.03–1.08)	<.001	1.06 (1.03–1.08)	<.001
Triage level				
1	Reference		Reference	
2	0.35 (0.19–0.62)	<.001	0.33 (0.18–0.59)	<.001
3	0.14 (0.03–0.62)	0.01	0.12 (0.02–0.66)	0.02
Troponin-I (ng/mL)	1.01 (1.00–1.01)	0.05	1.01 (1.00–1.01)	0.02
Diabetes mellitus	1.77 (1.01–3.10)	0.05	1.90 (1.08–3.32)	0.03
Hyperlipidemia	0.31 (0.17–0.58)	<.001	0.31 (0.16–0.57)	<.001
Time interval				
Door-to-ECG >10 min	2.81 (1.42–5.55)	0.003		
Cath lab arrival-to-balloon >30 min	-			
Time interval				
Door-to-ECG time (min)			1.03 (1.00–1.06)	0.04
Cath lab arrival-to-balloon time (min)			1.02 (1.00–1.04)	0.02

**The variables included in the multivariable Cox model with forward selection analysis were age, sex, ambulance-transported patient, triage level, troponin I, diabetes mellitus, hypertension, hyperlipidemia, cerebrovascular accident, chronic kidney disease, numbers of vessel disease, duration of hospitalization, door-to-ECG time, and cath lab arrival-to-balloon time. The characteristics presented in the table represent the variables that were ultimately selected for inclusion in the Cox models.
ECG, electrocardiography; *HR*, hazard ratio; *ng/mL*, nanograms per milliliter; **STEMI*, ST-segment elevation myocardial infarction.

activation-to-cath lab arrival were not significantly associated with one-year mortality. Additionally, age, triage acuity level, initial troponin-I levels, and a history of diabetes mellitus and hyperlipidemia were identified as independent predictors for one-year mortality in STEMI patients.

We observed that a delay in door-to-ECG time (>10 min) was associated with a 2.81-fold increased risk of mortality within one year compared to those without delay. Each minute delay in ECG acquisition may increase the risk of mortality by 3% within one year after STEMI (Table 3). This highlights the importance of early ECG acquisition for the long-term prognosis of STEMI. During the treatment course for patients with STEMI, therapeutic interventions, such as early administration of dual antiplatelet agents, anticoagulants, and vigilant monitoring, are initiated upon STEMI diagnosis, prior to angiographic assessment (Supplementary Figure 1). Current guidelines recommend early platelet inhibition as a fundamental component of pharmacologic treatment in the early stages of STEMI, with expected benefits including enhanced platelet inhibition after primary PCI and a lower incidence of stent thrombosis.[3,21,22]

A recent systematic review and meta-analysis additionally also shows the importance of using upstream anticoagulation before PCI, which is associated with a lower 30-day mortality risk, a lower incidence of in-hospital cardiogenic shock, and improved reperfusion of the infarct-related artery.[23] Early ECG completion enables prompt diagnosis of STEMI and timely initiation of antiplatelet agents, anticoagulants, and intensive care, which are crucial for achieving coronary artery reperfusion, preventing thrombosis following primary PCI, and minimizing myocardial damage post-infarction.[22,23] Consequently, as observed in this study, not only is short-term mortality improved, but long-term mortality as well. Our findings also support the importance of prehospital ECG, which has been shown to reduce DTB time and improve short-term mortality.[24,25] Additionally, when combined with prehospital dual antiplatelet therapy, these measures may further improve long-term outcomes in STEMI patients.[26]

Our study also revealed an association between cath lab arrival-to-balloon time and one-year mortality following STEMI, indicating that each minute of delay in this interval may increase the mortality risk by 2% within the first year (adjusted HR 1.02) (Table 3). Although the effect size was small, this finding may be reasonable. In addition to pharmacologic treatment in the initial stages of STEMI, prompt restoration of blood flow in the occluded coronary vessels is critical. While efforts to reduce DTB time has been explored,[27] research focused on decreasing the duration from cath lab arrival-to-balloon inflation remains limited. It is essential to consider various factors that may influence cath lab arrival-to-balloon time, including patient's vascular condition, the experience of the cardiologist, equipment preparation and readiness, and cath lab staff availability.[28,29] Ongoing research on developing new techniques and guiding catheters to reduce the time from needle insertion to balloon

inflation or mortality is imperative.[30] Healthcare facilities must assess and optimize these factors to ensure timely and effective delivery of care to patients undergoing PCI procedures for STEMI.

Apart from the DTB time intervals, age, triage acuity level, initial troponin-I levels, and a history of diabetes mellitus and hyperlipidemia were identified as independent predictors for one-year mortality in STEMI patients in our study. The adverse impact of age and diabetes mellitus on short- and long-term mortality in STEMI patients has been extensively documented.[11] Notably, we observed an association between a history of hyperlipidemia and reduced risk of one-year mortality (adjusted HR, 0.31, $P < .001$ in both models) (Table 3). Similar findings were also reported in previous research.[31]

One possible explanation for this is how a medical history of hyperlipidemia was defined, based on patients' prior medical records and whether they received lipid-lowering therapy, primarily statins.[31] In the Taiwan National Insurance program, the prescription of statins requires a confirmed diagnosis of hyperlipidemia. Therefore, we speculate that the reduced mortality risk observed in patients with a history of hyperlipidemia may be because these STEMI patients were receiving lipid-lowering therapy. Previous studies have found that patients with STEMI who were triaged as having lower acuity levels when they arrived at an ED experienced delays in ECG acquisition and reperfusion therapy.[17,32] However, after adjusting for DTB time intervals, our study found that lower triage acuity was actually associated with a lower risk of one-year mortality. This may be because patient with higher triage acuity (triage level 1) often present with unstable vital signs, which are associated with a higher risk of mortality.

Wanamaker et al investigated the relationship between troponin levels at presentation and in-hospital mortality in STEMI patients undergoing PCI. They demonstrated that in-hospital mortality increases with elevated troponin levels at presentation, irrespective of baseline clinical risk.[18] Our findings also revealed that initial troponin level is an independent predictor for one-year mortality in STEMI patients. Therefore, troponin levels in the early phase of STEMI may offer valuable long-term prognostic information in patients undergoing primary PCI.

LIMITATIONS

Our study has several limitations. Firstly, it is a single-center study with a small sample size, potentially limiting its generalizability to other populations. Secondly, being retrospective in nature, there is a possibility of unmeasured confounders and selection bias that could have affected the results. Thirdly, the study covers a nine-year period, during which changes in hospital staff, policies, and guidelines may have introduced confounding factors. However, our sensitivity analysis, which controlled for the years of patient recruitment, yielded similar results. Nevertheless, further multicenter, prospective studies are warranted to validate our findings.

CONCLUSION

Within the DTB interval, the time from door-to-ECG completion is crucial for one-year survival after STEMI, while cath lab arrival-to-balloon inflation may also be relevant. Strategies for improving long-term outcomes for STEMI patients should prioritize reducing the time from door-to-ECG acquisition. This could be attributed to the facilitation of early initiation of pharmacologic treatments, such as dual antiplatelet and anticoagulation therapy, in the initial stages of STEMI preceding PCI.

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Unlocking Cardiac Insights: Displacement of Aortic Root for Calculation of Ejection Fraction in Emergency Department in India

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Introduction: Assessing cardiac function is crucial for managing acute dyspnea. In this study we aimed to evaluate displacement of the aortic root (DAR) as a method for calculating ejection fraction (EF) in patients with undifferentiated dyspnea presenting to the emergency department (ED). The primary objective was to compare EF values obtained through DAR with the modified Simpson method, which is considered the criterion reference, within an Indian academic ED.

Methods: We conducted a prospective, cross-sectional study spanning two years (December 2019–December 2021). The study enrolled 110 consecutive ED patients ≥18 years of age, presenting with undifferentiated dyspnea and normal sinus rhythm. Ultrasound-trained investigators measured DAR using M-mode ultrasonography. Experienced echocardiographers, blinded to DAR, determined EF using the modified Simpson method. Statistical analyses included the Shapiro-Wilk test, McNemar test, and the receiver operating characteristic curve.

Results: The mean DAR measurement was 0.781 centimeters, with an average calculated EF of 54.4%. The EF calculated using DAR did not differ significantly from EF calculated using the modified Simpson method. Comparative analysis revealed DAR's superior sensitivity (86.21%) compared to mitral annular plane systolic excursion (48.28%) and end-point septal separation (45.45%). The DAR method exhibited high accuracy (area under the curve = 0.958) with a cut-off value 0.706 (sensitivity 88.7%, specificity 93.1%).

Conclusion: Evaluating displacement of the aortic root to calculate ejection fraction in undifferentiated dyspnea demonstrated high accuracy, sensitivity, and agreement with the modified Simpson method, which is considered the criterion reference. Its simplicity and non-invasiveness makes it a valuable initial screening tool in emergency settings, with the potential to reshape cardiac assessment approaches and optimize patient care pathways in the ED. [West J Emerg Med. 2025;26(2)191–199.]

INTRODUCTION

Background

Assessing cardiac function, particularly ejection fraction (EF), is crucial for managing acute dyspnea.[1–3] Echocardiography is the current standard for calculating EF, but displacement of the aortic root (DAR) has emerged as a potential tool for EF calculation in patients with undifferentiated dyspnea.[2,3] The DAR method quantifies alterations in left ventricular (LV) volume throughout the cardiac cycle, providing a surrogate measure for estimating EF.[3] End-point septal separation (EPSS) measurement is a relatively straightforward skill that an emergency physician can acquire with minimal experience, even when confronted with regional wall motion abnormalities.[4,5] However, measurement of LV end-systolic and end-diastolic diameters using 2D or M-mode echocardiography can pose challenges to the emergency physician in clinical practice. Tracing the endocardial border of the heart in an echocardiogram during diastole and systole is often difficult and time-consuming, especially where the wall is poorly defined.[6–10] This approach provides clinicians with multiple options for assessing LV systolic function, catering to varying levels of expertise and clinical settings.

Mitral annular plane systolic excursion (MAPSE) assesses vertical mitral valve motion using M-mode echocardiography, measuring annular displacement towards the apex. Unlike other methods, MAPSE doesn't require optimal endocardial definition or clear LV apex visualization, enabling broad applicability. Diminished systolic mitral valve excursion, reflected in MAPSE measurements, reliably indicates LV systolic dysfunction. The MAPSE demonstrates strong correlations, particularly in non-critically ill patients, offering effective LV function assessment even in challenging imaging scenarios.[11–15] Emergency physicians are accurate at visual LV EF estimation without quantitative measurements, but objective measures can benefit early learners and facilitate communication.[6] However, EF calculation using the DAR method has not been done in an Indian population in the ED setting. This highlights the need for further studies to determine DAR's reliability and clinical applicability in the context of an Indian setting.

Importance

Given the current limited research on the utility of DAR in Indian academic ED settings, with this investigation we aimed to fill the gap by assessing DAR's reliability and clinical applicability. The study specifically focuses on patients with undifferentiated dyspnea, a population where EF estimation is crucial for appropriate management.

Goal of this Investigation

Our primary objective was to calculate the EF using DAR and then compare it with EF measurements obtained through the modified Simpson method, defined as the criterion reference by the American Society of Echocardiography (ASE).[9,16] The secondary objective was to identify the cut-off for DAR, which could predict LV dysfunction based on EF calculation. Additionally, we sought to compare the EF calculated from DAR with those obtained through EPSS and MAPSE. By evaluating DAR in comparison to the established methods, we aimed to provide insights into its potential as a reliable tool for EF estimation in the Indian setting.

Population Health Research Capsule

What do we already know about this issue?
While the modified Simpson method is the criterion reference to calculate ejection fraction, simpler and more rapid tools are crucial for assessing left ventricular (LV) function in emergencies.

What was the research question?
Can displacement of the aortic root (DAR) accurately estimate LV ejection fraction in the ED?

What was the major finding of the study?
The DAR cutoff of 0.706 centimeters showed high accuracy (AUC 0.958, $P < 0.001$), with 88.7% sensitivity and 93.1% specificity.

How does this improve population health?
The DAR method offers a rapid, non-invasive EF screening tool, enhancing timely diagnosis and improving care for patients with LV dysfunction.

MATERIAL AND METHODS

Study Design and Setting

This prospective, cross-sectional study was conducted across a span of two years, from December 2019–December 2021, within the ED of a teaching hospital in India. The hospital provides a broad spectrum of specialties, and its adult ED has approximately 37,200 visits annually. We obtained initial institutional research board/institutional ethics committee approval, with the registration number ECR/146/Inst/ KA/ 2013/RR-19, IEC: 1057/2019, dated May 8, 2020, and approval for study modifications on September 22, 2021. Additionally, the study is registered with the Clinical Trials Registry–India under the number CTRI/2020/10/028704, dated October 28, 2020. We adhered to ethical standards by obtaining informed consent and

ensuring the voluntary participation and compliance of all subjects involved in the study. We assessed the EF of 110 patients with undifferentiated dyspnea using different methods.

Selection of Participants and Methods of Measurements

We enrolled patients ≥18 years of age, presenting with undifferentiated dyspnea and normal sinus rhythm based on a convenience sampling. The following were excluded: patients intubated outside of a hospital; pregnant women; individuals with elevated cardiac biomarkers at presentation; those with atrial fibrillation, known valvular pathology or surgery, primary or metastatic carcinoma in the thorax; patients for whom the time between echocardiography to obtain EF using DAR and the modified Simpson method was more than 30 minutes; and those who did not provide consent. These factors could have influenced the accuracy and reliability of the EF measurements obtained through different methods. Demographic variables, including age and gender, were considered as potential confounding factors in this study.

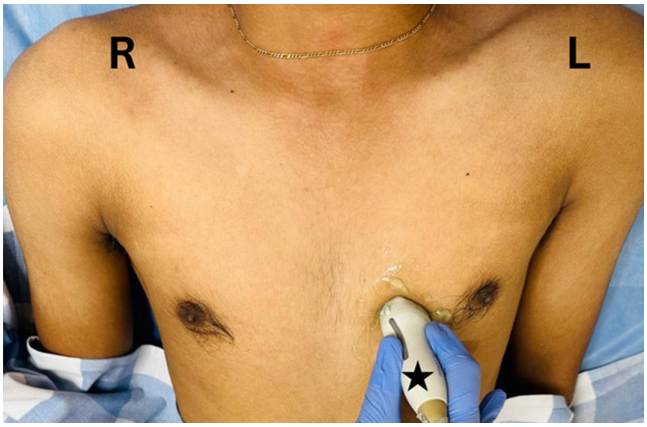

Figure 1. The probe is positioned in the parasternal long-axis view, with the transducer placed perpendicular to the chest wall at the third or fourth intercostal space, just to the left of the sternum, and the probe marker (black star) directed towards the patient's right shoulder.

After obtaining written informed consent, the emergency clinician conducted the bedside ultrasonography proctored by the expert in point-of-care ultrasound (POCUS). Using a 3.6-megahertz micro-convex transducer, the investigator, trained in POCUS during residency training as per the curriculum, employed a Philips CX 50 ultrasound machine (Koninklijke Philips NV, Amsterdam, Netherlands) to compute the EF using DAR. Initially, 2D echocardiograms of the parasternal long-axis view were captured for DAR measurement. This view was achieved by positioning the footprint of the transducer perpendicular to the chest wall at the third or fourth intercostal space, just to the left of the sternum with the pointer towards the right shoulder (Figure 1).[17] Optimum image required clear view of mitral valve leaflets and aortic valves. Subsequently, M-mode was placed just above the level of the aortic valve and DAR recordings were taken.[3] The maximum anterior DAR from the horizontal axis at end-systole was measured using the leading-edge technique and recorded in centimeters (cm) (Figure 2A). The computation of EF was then done, using the formula 20 + 44 * DAR (cm).

Following the DAR measurement, the investigator calculated the EF using EPSS determined by EF = 75.5 – (2.5 × EPSS), and using MAPSE calculated by 4.8 × MAPSE (millimeters [mm]) + 5.8 for men and 4.2 × MAPSE (mm) + 20 for women.[5,14,18–21] An experienced echocardiographer, blinded to the study procedure, evaluated LV EF using the ASE recommended Modified Simpson's rule for this measurement (Figure 2B).[9,16]

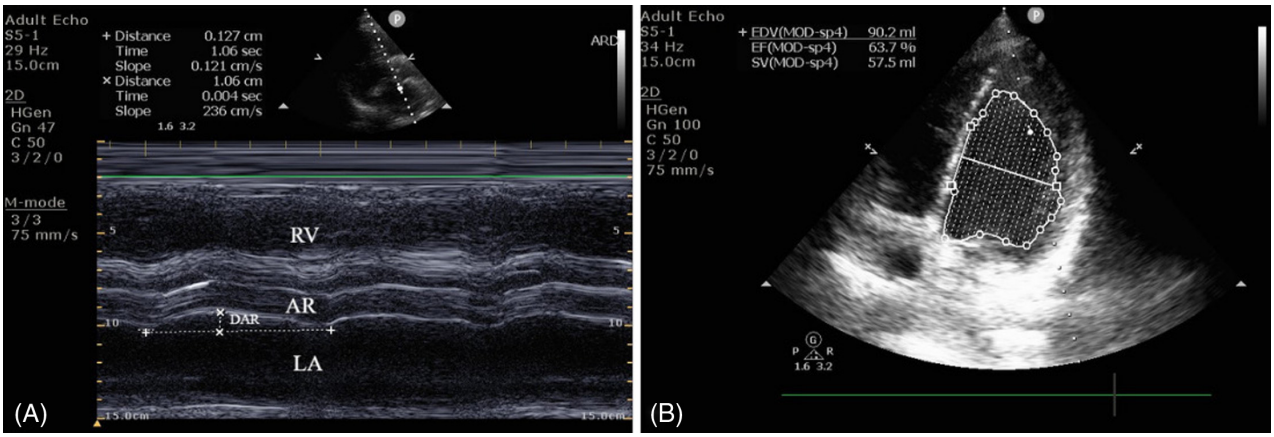

Figure 2. (A) We assessed ejection fraction (EF) at the bedside using M-mode ultrasonography, measuring the displacement of the aortic root (DAR) in the parasternal long-axis view. The recorded DAR for this patient was 1.06 cm. We calculated the EF using the formula (EF = 20 + 44 × 1.06), which resulted in 66.6%. (B) The echocardiographers calculated EF using the modified Simpson method [(EDV – ESV) / EDV], where [(90.2 – 32.7) / 90.2] × 100 resulted in an EF of 63.7%.

Outcomes

The study systematically categorized outcomes into two groups, delineating 'normal' EF as 50% to 70% and 'low EF' <50%.[22] The primary outcome measured significant difference in calculated EF between the DAR and modified Simpsons methods. The secondary outcome of the study was to determine cut-off value of DAR with high sensitivity and specificity through receiver operating characteristic (ROC) curve analysis. Secondary outcomes also included comparison of EF calculated from DAR with that calculated from EPSS and MAPSE.

Sample Size Calculation

With a desired margin of error of 10%, alpha error of 5%, and estimated proportion of 0.5, sample size was calculated to be 96. After considering the dropout rate of 15%, the final sample size was 110.

Analysis

We used SPSS Statistics, version 26.0 (IBM Corp, Armonk, NY) to analyse the data. The Shapiro-Wilk test assessed normality for continuously distributed data, and we executed group comparisons in the subsequent steps. An exact McNemar test was used to identify the statistically significant changes in EF calculated using the DAR and modified Simpson's methods. We calculated the Pearson correlation coefficient to measure strength and direction of the linear relationship between two tests. The ROC curve played a pivotal role in determining the optimal cut-off value for the validity measure of DAR.

RESULTS

A total of 135 patients underwent initial screening for participation in the study. Before the POCUS assessment, we excluded 25 patients based on predefined criteria: five due to external intubation; eight with elevated cardiac biomarkers; three with abnormal rhythm; four with valvular pathology; and five who declined to participate. Following that, a POCUS examination was conducted on 110 patients, with 10 excluded due to poor image quality (Figure 3). The demographic and clinical characteristics of 100 patients who underwent POCUS, including age, heart rate, mean arterial pressure, and the mean DAR values in relation to age, gender, and comorbidities are detailed in Table 1.

In this study we observed a mean DAR measurement of 0.781 cm (SD 0.277 cm) and an average calculated EF of 54.4% (SD 12.2%). The Pearson correlation coefficient was calculated to measure strength and direction of the linear relationship between two tests and was found to be 0.81, which suggests a strong positive relation between the results. The study conducted an exact McNemar test to identify statistically significant variations in abnormal and normal EF distribution between the EF calculated using DAR/ MAPSE/ EPSS and the EF measured by an

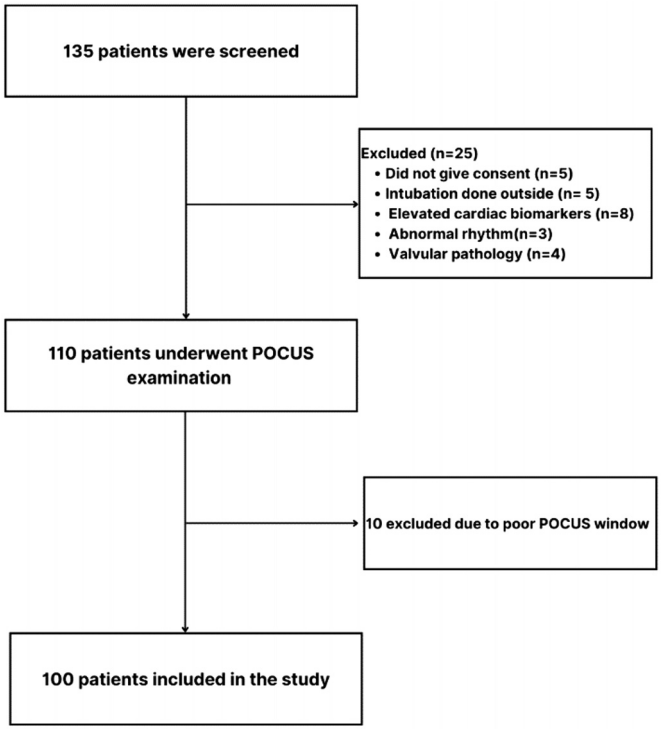

Figure 3. Consort patient flow diagram.
POCUS, point-of-care ultrasound.

echocardiographer (criterion reference), as outlined in Table 2. The statistical analysis revealed a lack of significant differences ($P = 0.39$) between the EF calculated using DAR and the EF measured by echocardiography.

We conducted ROC curve analysis, which demonstrated DAR's validity with a high accuracy reflected in an area under the curve (AUC) of 0.958 (95% confidence interval [CI] 0.914–1.000, $P < 0.001$) for predicting EF. The optimal cut-off point for DAR was identified as 0.706, providing a sensitivity of 88.7%, specificity of 93.1%, LR+ (likelihood ratio) of 12.86, and LR- of 0.12. (Figure 4). The Pearson correlation coefficient calculated for EF calculated by MAPSE and the modified Simpson method was 0.54 and that of EPSS and the modified Simpson method was 0.76. For calculated EF with MAPSE, 48.3% of patients were categorized as having abnormal EF, exhibiting a statistically significant difference compared to EF calculated by the modified Simpson method ($P = 0.01$) (Table 2). Similarly, calculated EF with EPSS demonstrated a comparable discordance, with 58.6% classified as abnormal, significantly differing from EF calculated by the modified Simpson method ($P = 0.01$) (Table 2).

Table 3 presents a comparative assessment of the efficacy of EF measurements using MAPSE, EPSS, and DAR against the criterion reference. The sensitivity of DAR is notably higher than MAPSE and EPSS, which suggests that it is a better screening tool. Calculated EF from

Table 1. Demographic and clinical characteristics with displacement of aortic root mean values in 100 patients on whom point-of-care ultrasound was performed.

Patient characteristics	N = 100
Patient age in years, mean (SD)	53.7 (16.4)
Male, n (%)	73 (73)
Heart rate, mean (SD)	92 (17.8)
Respiratory rate, min-max (SE)	20–36 (0.31)
MAP, mean (SD), mm Hg	90.6 (16.7)
Symptoms	
Fever, n (%)	33 (33)
Cough, n (%)	33 (33)
Chest pain, n (%)	14 (14)
Comorbidities	
Type II diabetes mellitus, n (%)	36 (36)
Systemic hypertension, n (%)	46 (46)
IHD, n (%)	16 (16)
Cardiomyopathy, n (%)	2 (2)
Oxygen requirement	
Nasal prongs (2L–4L), n (%)	26 (26)
Face mask (6L–10L), n (%)	59 (59)
Non-rebreathing mask (>10L), n (%)	14 (14)

Category	Subgroup	n (%), N = 100	Mean DAR	Standard deviation	*P*-value
Age group	< = 30 years	6 (6%)	1.04	0.05	
	31–40 years	12 (12%)	0.94	0.29	
	41–50 years	19 (19%)	0.83	0.26	
	51–60 years	18 (18%)	0.73	0.28	
	61–70 years	26 (26%)	0.68	0.29	
	71–80 years	16 (16%)	0.80	0.22	
	>80 years	3 (3%)	0.50	0.19	
Gender	Male	73 (73%)	0.78	0.29	0.76
	Female	27 (27%)	0.78	0.23	
Comorbidities	Type II diabetes mellitus (yes)	36 (36%)	0.72	0.30	0.16
	Type II diabetes mellitus (no)	63 (63%)	0.82	0.26	
	Systemic hypertension (yes)	46 (46%)	0.69	0.28	0.001
	Systemic hypertension (no)	54 (54%)	0.86	0.25	
	IHD (Yes)	15 (15%)	0.53	0.22	<0.001
	IHD (No)	85 (85%)	0.82	0.26	

min, minimum; *max*, maximum; *SD*, standard deviation; *SE*, standard error; *MAP*, mean arterial pressure; *IHD*, ischemic heart disease.

DAR obtained highest negative predictive value (NPV), suggesting a better ability to correctly identify patients with normal EF.

DISCUSSION

Dyspnea is a common presenting complaint in the ED, accounting for approximately 5% of all ED presentations in the Asia-Pacific region.[23,24] Emergency physicians frequently face the challenge of making swift diagnoses and developing treatment plans based on limited clinical information.[25,26] Point-of-care ultrasound has become a standard component of routine clinical examinations in the ED, enhancing the management of dyspnea by facilitating the diagnosis of its underlying causes.[27] Similarly, evaluating LVEF through echocardiography plays a crucial role in diagnosing and managing a wide range of patients in the ED,

Table 2. Comparative analysis of ejection fraction (EF) measurements using DAR, MAPSE, and EPSS* against actual EF by the modified Simpson method.

Calculated EF		Actual EF by modified Simpson method			
		Abnormal, n (%) N = 100	Normal, n (%) N = 100	Total, N (%)	*P*-value
Calculated EF with DAR	Abnormal	25 (25%)	8 (8%)	33 (33%)	0.39
	Normal	4 (4%)	63 (63%)	67 (67%)	
Calculated EF with MAPSE	Abnormal	14 (14%)	3 (3%)	17 (17%)	0.01
	Normal	15 (15%)	68 (68%)	83 (83%)	
Calculated EF with EPSS	Abnormal	17 (17%)	2 (2%)	19 (19%)	0.01
	Normal	12 (12%)	69 (69%)	81 (81%)	

EF, ejection fraction; **DAR*, displacement of aortic root; *MAPSE*, mitral annular plane systolic excursion; *EPSS*, end-point septal separation.

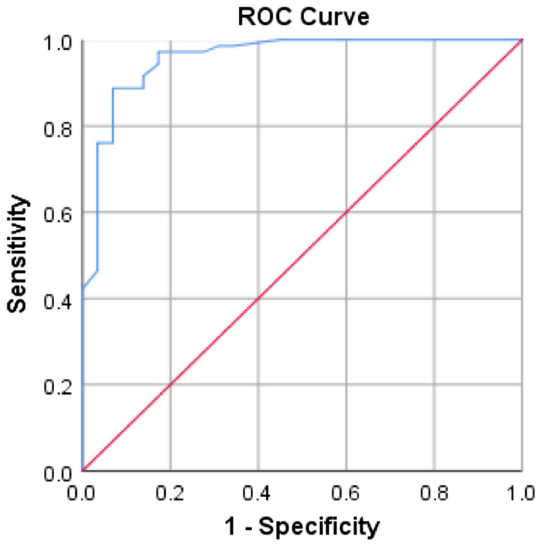

Figure 4. The ROC curve of the sensitivity of displacement of aortic root for ejection fraction when the cut-off value is 0.70 centimeters. Area under the ROC curve = 0.958 (95% confidence interval 0.914–1.000, P < 0.001 for predicting EF). *ROC*, receiver operating characteristic.

further emphasizing the importance of ultrasound in emergency care.[28] Most research in the ED has emphasized visual assessments of LVEF instead of relying on calculations derived from measuring the dimensions of the LV chamber across the cardiac cycle.[29–31]

This study addresses a crucial aspect of emergency care by exploring the assessment of LV function in patients with undifferentiated dyspnea. While the modified Simpson method remains the criterion reference, investigating the potential of DAR as an alternative method opens avenues for expedited and more accessible evaluations in time-sensitive environments like the ED. As a non-invasive and easily accessible tool, DAR has shown promise in accurately predicting LVEF, making it valuable for identifying patients at risk of LV dysfunction.[3,32] The DAR method showed an accuracy rate of 88% in correctly classifying LV dysfunction, demonstrating its clinical applicability in emergency settings. This rate surpasses the accuracy of MAPSE and EPSS assessments for LV dysfunction, including the 75% accuracy reported in a study by Schick et al.[33]

This study's robust methodology and compelling results substantially contribute to establishing the validity and clinical relevance of DAR. The DAR method exhibits good sensitivity (86.2%) and specificity (88.7%) and has a positive correlation with the values of EF obtained through the modified Simpson method. This sensitivity and specificity are consistent with the findings of Ünlüer et al, who reported 94.4% and 94.1%, respectively.[3] The increased sensitivity of DAR compared to EPSS and MAPSE in our study makes it a

Table 3. Comparative efficacy of ejection fraction measurements using MAPSE, EPSS, and DAR* against the criterion reference with 95% confidence intervals.

	Calculated EF with MAPSE (95% CI)	Calculated EF with EPSS (95% CI)	Calculated EF with DAR (95% CI)
Sensitivity	48.3% (39.2–57.4)	45.5% (36.2–54.8)	86.2% (79.7–91.4)
Specificity	95.8% (90.3–98.4)	97.0% (94.4–99.4)	88.7% (83.3–92.9)
PPV	82.4% (73.9–89.3)	88.2% (83–93.3)	75.8% (68.0–82.1)
NPV	81.9% (74.3–87.5)	78.3% (71.4–85.2)	94.0% (90.2–96.7)
Accuracy	82.0% (74.8–87.9)	80.0% (73.1–86.9)	88.0% ((82.2–92.8)

EF, ejection fraction; *MAPSE*, mitral annular plane systolic excursion, *EPSS*, end-point septal separation; **DAR*, displacement of aortic root; *CI*, confidence interval; *PPV*, positive predictive value; *NPV*, negative predictive value.

valuable tool for the early detection of LV dysfunction in emergency settings.These findings indicate that emergency physicians can use DAR as a valuable alternate tool for assessing the LV function at the bedside.[33] In the ED, where rapid decision-making is crucial, DAR can be incorporated as an initial screening tool to identify patients with compromised LV function, guiding further diagnostic testing, management, interventions or specialist referrals.

When comparing DAR with traditional methods, MAPSE showed a sensitivity of 48.3% (95% CI 39.2–57.4) and specificity of 95.8% (95% CI 90.3–98.4), while EPSS exhibited a sensitivity of 45.5% (95% CI 36.2–54.8) and specificity of 97.0% (95% CI 94.4–99.4). These results contrast with prior studies, such as that by McKaigney et al, who observed significantly higher EPSS sensitivity (83.3%) but much lower specificity (50.0%), and Schick et al, who reported MAPSE sensitivity of 42% and specificity of 89%.[18,33] The higher sensitivity (83.3%) and lower specificity (50.0%) of EPSS reported by McKaigney et al may stem from their comparison of EPSS with EF calculated using the Teichholz method. Folland et al found that EF calculated through the modified Simpson method demonstrated better correlation with radionuclide ventriculography than the Teichholz method, with correlation coefficients (r values) of 0.75 and 0.46, respectively. Furthermore, the ASE no longer recommends the Teichholz method for calculating LV volumes.[9,34] The higher specificity of MAPSE and EPSS in our study suggests that these measurements are more effective in confirming LV dysfunction than in detecting it, underscoring the utility of DAR's higher sensitivity for early identification.

The DAR offers a practical advantage in the ED setting due to the straightforward visualization of the aortic root compared to LV structures, making it easier to measure under challenging conditions. Furthermore, the motion of the aortic root resembles the left atrial volume curve, suggesting that its movement, influenced by its attachment to the cardiac skeleton, may reflect the dynamics of left atrial filling and emptying.[35–37] The observed correlation between DAR and stroke volume suggests that DAR measurements may calculate LVEF effectively, providing valuable insights into cardiac performance. Lower DAR values were consistently associated with conditions linked to reduced stroke volume and EF, highlighting DAR's relevance in assessing patients with undifferentiated dyspnea and potentially compromised cardiac function.

The DAR's high NPV enhances its reliability in excluding patients with normal EF, which is crucial for determining appropriate next steps in ED care. The EPSS exhibited the highest positive predictive value, emphasizing its role in confirming reduced EF. However, DAR's combined sensitivity and NPV make it a more comprehensive tool for initial screening, ensuring that patients with likely normal cardiac function are appropriately triaged. Despite its advantages, DAR should not be seen as a replacement for all echocardiographic assessments but rather as a complementary tool, especially in time-limited environments. Its heightened sensitivity compared to MAPSE and EPSS, combined with its rapid application, makes it a promising option for emergency physicians. However, further research and validation are required to establish DAR's broader applicability in diverse patient populations and settings.

LIMITATIONS

While the results are promising, this study has limitations. It was conducted within a single-center environment, potentially limiting the generalizability of the findings. A multicenter study involving diverse patient populations would provide more robust validation. Additionally, the study doesn't delve into the causes of dyspnea, which can vary widely and might influence the applicability of DAR in different scenarios. We excluded 9% of patients from this study due to a poor POCUS window. Patients enrolled in this study exhibited exclusively regular cardiac rhythms. Although each M-mode recording of the aortic root (AR) had the potential to encompass multiple cardiac cycles for DAR calculation, it is crucial to emphasize that the extent of AR displacement consistently remains notable across all cardiac cycles in individuals with regular heart rhythms. When patients exhibit irregular heart rhythms, a potential adaptation could involve calculating the average DAR measurement over three to five cardiac cycles. This adjustment could enhance the accuracy of measurements in such cohorts. Future research initiatives could delve deeper into investigating and addressing this particular aspect.

CONCLUSION

DAR emerges as an efficient and reliable method for rapid EF assessment, providing emergency physicians with a valuable tool for bedside evaluation of LV function, especially when time and resources are limited. This paves the way for integrating DAR into emergency protocols and routine emergency clinical practice. While these findings are promising, we acknowledge the need for prospective validation in a diverse patient population.

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Procedural Sedation in the Emergency Department – An Observational Study: Does Nil Per Os Status Matter?

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Introduction: Procedural sedation (PS) is commonly performed in the emergency department (ED). Nil per os (nothing by mouth) (NPO) guidelines extrapolated from standards for patients undergoing elective procedures in the operating room have been applied to ED PS patients. There has been no large study of ED PS patients comparing differences in adverse events and PS success rates based on NPO status.

Methods: From a cohort of consecutive ED PS patients of all ages in the 20 EDs of one hospital system—one quaternary ED, four tertiary EDs, six community hospital EDs, one rural ED, two pediatric EDs, and six freestanding EDs in two states in the Midwest and South—we conducted a retrospective analysis on a prospective database over 183 months from April 2000–June 2015. Primary outcome was the incidence of side effects and complications, which comprised the adverse effects. The side effects were nausea, vomiting, itching/rash, emergence reaction, myoclonus, paradoxical reaction, cough, and hiccups. Complications were oxygen desaturation <90%, respiratory depression (respiratory rate <8), apnea, tachypnea, hypotension, hypertension, bradycardia, and tachycardia. Normal vital signs were age dependent. Secondary outcome was successful sedation defined as completion of the procedure. We examined the association between adverse events and successful sedation with NPO status.

Results: Of 3,274 visits, exact NPO status was known in 2,643 visits. Comparison of NPO <8 hours in 1,388 patients vs ≥ 8 hours in 1,255 patients revealed side effects 5.5% vs 4.5% ($P = 0.28$); complications 11.9% vs 17.7% ($P < 0.001$); adverse events 16.3% vs 21.5% ($P < 0.001$), interventions 4.1% vs 4.4% ($P = 0.73$), and procedural completions 94.3% vs 89.7% ($P < 0.001$). After adjustment for age, sex, transfer status, American Society of Anesthesiology physical status classification, race, primary sedative, multiple sedatives, sedative plus analgesic, and primary analgesic, we found no association between NPO status and side effects ($P = 0.68$), complications ($P = 0.48$), or adverse effects ($P = 0.26$); however, procedural completion rate remained significantly higher for NPO < 8 hours ($P = 0.007$).

Conclusion: A nil per os status ≥8 hours may have similar or worse outcomes than NPO <8 hours, which is contrary to many suggested guidelines. Strict adherence to NPO guidelines in ED procedural sedation patients may not be necessary. [West J Emerg Med. 2025;26(2)200–209.]

INTRODUCTION

Emergency department (ED) patients frequently undergo procedural sedation (PS) and analgesia, which is designed to alleviate their pain and anxiety during diagnostic and/or therapeutic medical procedures.[1] Guidelines regarding fasting prior to performing PS, promulgated by various organizations for general anesthesia, are often followed by clinicians performing PS in the ED.[1–5] This concept has recently been challenged.[5] There has been some evidence in the pediatric population that adherence to such guidelines does not result in fewer adverse events during ED PS,[6–13] although some of the reports of pediatric PS have involved PS performed in locations other than the ED[6,7] or involved only one sedative instead of a range of sedative agents.[8,12] Such data is lacking for adult ED patients. Our goal in this study was to evaluate the effect of fasting on PS in the ED in all ages of ED patients, including the elderly.

Population Health Research Capsule

What do we already know about this issue?
Procedural sedation (PS) is a common ED procedure. Applying anesthesiology nil per os (NPO) guidelines for elective procedures to ED PS patients has been questioned.

What was the research question?
What is the incidence of adverse event and procedural completion rates for patients meeting vs not meeting NPO guidelines?

What was the major finding of the study?
NPO <8 vs ≥8 hours: adverse events 16.3% vs 21.5% P < 0.001, procedural completions 94.3% vs 89.7% P < 0.001.

How does this improve population health?
NPO ≥8 hours has similar or worse outcomes than NPO <8 hours, contrary to many suggested guidelines. Strict adherence to NPO guidelines in ED PS patients may not be necessary.

Importance

Studies in the literature on the effect of fasting on ED PS have focused on the pediatric population, with a surprising lack of studies in adults, including the elderly. A large-scale study of the incidence of adverse events and the need for interventions has not been described, thus representing a large gap in knowledge for a common practice.

Goals of This Investigation

Our goal in this study was to determine the impact of fasting guidelines on the side effects, complications, and need for interventions during ED PS in patients of all ages.

METHODS

Study Design and Setting

This was a cohort study of consecutive patients of all ages undergoing PS in the 20 EDs of one hospital system consisting of one urban, academic, quaternary ED, four tertiary EDs, six community hospital EDs, one rural ED, two pediatric EDs, and six freestanding EDs in two states located in the Midwest and the South. We performed a retrospective analysis on a prospectively collected database over 183 months from April 2000–June 2015. All patients who underwent parenteral PS in the ED, performed by attending emergency physicians (EP) were included. We excluded sedations done outside the ED and/or not administered by EPs.

Data Collection

A mandatory, four-page, standardized sedation form must be completed by the registered nurse, respiratory therapist, and attending physician on all patients undergoing PS throughout the hospital including the ED. This form includes pre-sedation assessment, post-sedation assessment (including readiness for discharge), and documentation of the PS itself. Documentation of the PS includes the continuous monitoring of vital signs: heart rate, respiratory rate, blood pressure; pulse oximetry, cardiac rhythm, respiratory therapy assessment, including capnography; and patient responses, medication administration, and patient interventions. All sedations including the sedation forms and electronic health record (EHR) notes are reviewed as part of the hospital quality improvement (QI) monthly meeting by a physician-led committee. The members of this committee were not involved in this study but are part of the hospital's QI process.

We performed this retrospective review with adherence to the 12 methodologic criteria as defined by Worster et al.[14] Data resulted from an electronic pull of information from the EHR. We did not use abstractors. Therefore, criteria 1, 4, 5, 6, 7, and 8 according to Worster et al were not applicable. The remaining criteria (2, 3, 9, 10, 11, and 12) were met. For criterion 2, case selection criteria were defined a priori. For criterion 3, variables were defined in the methods. For criterion 9, the health record database was described. For criterion 10, all patient visits in the EHR meeting criteria were included. For criterion 11, data used was part of a mandatory standardized sedation form, and the missing data was minimal. As discussed in our study flow diagram, we conducted a complete case analysis. For criterion 12, the institutional review board approved the study.

Outcome Measures

The primary outcome was the incidence of side effects and complications, which comprised the adverse effects. Side effects were nausea, vomiting, itching/rash, emergence reaction, myoclonus, paradoxical reaction, cough, and hiccups. Complications were oxygen desaturation <90%, respiratory depression with a respiratory rate <8, apnea, tachypnea, hypotension, hypertension, bradycardia, and tachycardia. The normal range of vital signs was age dependent. Successful sedation was completion of the procedure.

Statistical Analysis

Descriptive statistics of patient demographics and procedures are presented as count (percentage), median (Q_1–Q_3), or range. We explored bivariable associations of patient demographics and procedures with NPO status with either a Wilcoxon rank-sum test or a chi-square test, as appropriate. The NPO was originally recorded as a numeric value in patient charts and, thus, we explored NPO status three ways: (1) classified as exact NPO status known or unknown; (2) dichotomized at eight hours to align with clinical care guidelines; and (3) original scale to maintain full detail. We explored associations of NPO status with binary outcome measures using generalized estimating equations models, assuming a compound symmetry correlation structure to accommodate multiple ED visits per patient. This was performed both unadjusted and adjusting for year of visit, patient age group, sex, transfer status, American Society of Anesthesiology (ASA) physical status classification, race, primary sedative, use of multiple sedatives, use of sedative plus analgesic, and primary analgesic. The ASA is used to predict operative risk where ASA 1 is a normal healthy patient; ASA 2 is a patient with mild systemic disease; and ASA 3 is a patient with severe systemic disease that is not life-threatening. The ASA 4 is a patient with severe systemic disease that is a constant threat to life; ASA 5 is a moribund patient who is not expected to survive without the operation.[15] Reported are the resulting odds ratios, 95% confidence intervals, and associated *P*-values. Similar analyses were conducted to explore the association of NPO status with the need for medical intervention. We used a significance level of .05. Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC) statistical software.

RESULTS

Characteristics of Patients

There were 3,274 PS performed in the ED on 2,570 patients of all ages by emergency physicians in the ED (Figure 1). By age group there were 1,177 PS performed on pediatric patients (age ≤21 years), and 2,097 PS performed on adults (age >22 years), of whom 708 were geriatric (≥65 years of age) PS.

NPO Status: Known vs Unknown

The patients with NPO unknown were significantly older, with a higher acuity as denoted by higher ASA and by "more

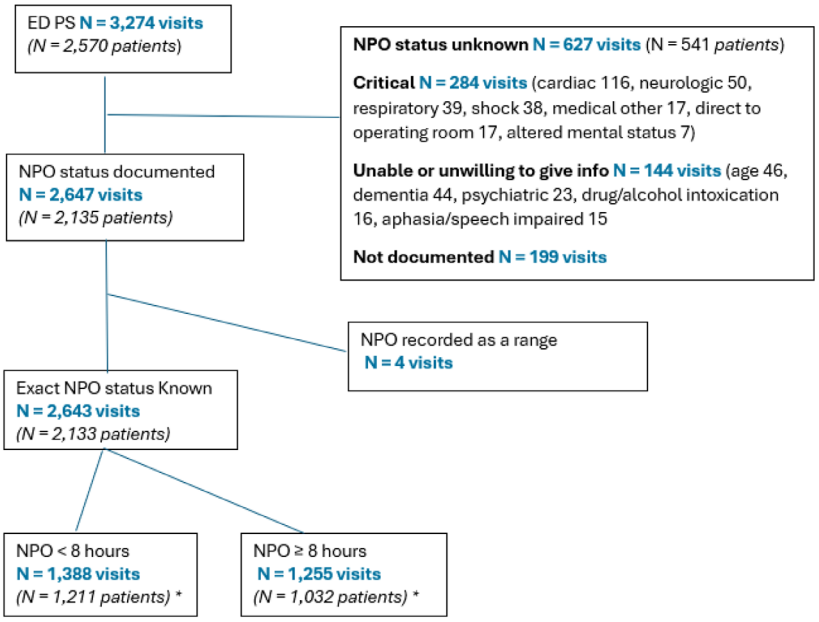

Figure 1. Study visit CONSORT diagram.
*Number of patients does not add up to higher level total as 110 patients had multiple visits with some visits classified as NPO <8 hours and ≥8 hours and thus those patients are counted in both subgroups. Number of visits is in bold and in blue color. Number of patients is in italics and parentheses.
ED, emergecy department; *NPO*, nil per os (nothing per mouth); *PS*, procedural sedation.

Table 1. Patient demographics, ASA and procedure characteristics.

Characteristic	Exact NPO known	Exact NPO unknown	*P*-value	NPO < 8 hours	NPO ≥ 8 hours	*P*-value
Study visits	2,643	631		1,388	1,255	
Age (years)						
Median (IQR)	37 (10–62)	53 (27–67)	< 0.001	26 (7–59)	46 (14–64)	< 0.001
Range	0.2 to 94	0.9 to 102		0.2 to 94	1.1 to 92	
Male	1500 (57%)	362 (57%)	0.78	795 (57%)	705 (56%)	0.58
Ethnicity			0.050			0.09
Black	786 (30%)	210 (33%)		431 (31%)	355 (28%)	
White	1816 (69%)	413 (66%)		931 (67%)	885 (71%)	
Other	41 (2%)	4 (1%)		26 (2%)	15 (1%)	
ASA category			< 0.001			< 0.001
ASA 1	952 (36%)	121 (19%)		589 (42%)	363 (29%)	
ASA 2	667 (25%)	160 (25%)		353 (25%)	314 (25%)	
ASA 3	904 (34%)	250 (40%)		391 (28%)	513 (41%)	
ASA 4	115 (4%)	78 (12%)		54 (4%)	61 (5%)	
ASA 5	5 (0.2%)	22 (3%)		1 (0.1%)	4 (0.3%)	
Procedure			< 0.001			< 0.001
Orthopedic procedures (total)	1610 (61%)	285 (45%)		798 (58%)	812 (64%)	
- Reduction of fracture	- 749 (28%)	- 100 (16%)		- 430 (31%)	- 319 (25%)	
- Reduction of dislocation	- 861 (33%)	- 185 (29%)		- 368 (27%)	- 493 (39%)	
Cardioversion	535 (20%)	206 (33%)		290 (21%)	245 (20%)	
Suturing/wound care	288 (11%)	38 (6%)		209 (15%)	79 (6%)	
EGD	55 (2%)	10 (2%)		19 (1%)	36 (3%)	
Lumbar puncture	35 (1%)	27 (4%)		16 (1%)	19 (2%)	
Foreign body removal	33 (1%)	4 (1%)		17 (1%)	16 (1%)	
Chest tube	16 (0.6%)	12 (2%)		5 (0.4%)	11 (0.9%)	
Hernia reduction	13 (0.5%)	7 (1%)		6 (0.4%)	7 (0.6%)	
Ventriculostomy	4 (0.2%)	13 (2%)		2 (0.1%)	2 (0.2%)	
CT scan	1 (0.04%)	8 (1%)		0 (0%)	1 (0.1%)	
Other	53 (2%)	21 (3%)		26 (2%)	27 (2%)	

ASA 1 is a normal healthy patient. ASA 2 is a patient with mild systemic disease. ASA 3 is a patient with severe systemic disease that is not life threatening. ASA 4 is a patient with severe systemic disease that is a constant threat to life. ASA 5 is a moribund patient that is not expected to survive without the operation.
ASA, American Society of Anesthesiology physical status; *NPO*, nil per os (nothing by mouth); *EGD*, esophagogastroduodenoscopy.

critical" procedures such as lumbar puncture, ventriculostomy, or cardioversion compared to orthopedic procedures or suturing (Table 1). When we evaluated the reasons for an unlisted NPO status these included that the patient was critical and admitted to an intensive care setting with diagnoses such as shock and/or respiratory distress or had been intubated or was undergoing emergency surgery. A significant number were unable to give reliable information about when they ate last due to medical reasons that included altered mental status, dementia, autism/developmental delay, and neurologic disorders. Another large group of patients were unwilling and/or unable to provide accurate information about their last oral intake for psychiatric reasons including acute psychiatric illness such as acute manic state or schizophrenia, or because they were experiencing substance or alcohol intoxication. There were also several young children brought in from day care or school by emergency medical services who were unaccompanied, at least initially, by an adult, such as their daycare provider or teacher or a parent, who could give information; or the adult with them had no information regarding their last oral intake. Thus, young age with lack of ability to tell time was another cause for an unknown NPO status. Additionally, some patients were only able to provide

a range of time such as "more than six hours ago." In total, there were 631 visits (19.3%) where the exact NPO was either not obtainable (13.2%) or not documented (6.1%). This emphasizes the fact that PS may need to be done in an ED without the luxury of knowing the last oral intake in about one of five patient presentations (Figure 1) (Table 1).

Adverse events and procedure completions

There was no significant difference for side effects, complications or adverse events between exact NPO status known vs exact NPO status unknown (Table 2). The incidence of side effects, which was primarily vomiting, was greater for NPO <8 hours at 5.5% than for NPO ≥8 hours at 4.5%, but this was not statistically significant. However, when NPO was considered numeric, it was found that as NPO time increases, the risk of a side effect, generally vomiting, significantly decreases. The complications and adverse events were significantly greater for NPO ≥8 hours than for NPO <8 hours both when NPO status was binary and numeric with complications at 11.9% for NPO <8 hours and 17.7% for NPO ≥8 hours and adverse events at 16.3% for NPO <8 hours and 21.5% for NPO ≥ 8 hours (Table 2) (Figure 2). The rate of procedural completions was significantly higher when NPO status was known (92.1% vs 86.1%) and when NPO <8 hours (94.3% vs 89.7%) (Table 2, Figure 2A). We did not find any instances of pulmonary aspiration as were noted in previous studies of ED PS.[5] We had one intubation out of 3,274 PS (0.03%).

Length of NPO categories is lower-bound inclusive. Thus, the first category consists of NPO values from zero to less than four hours, the second category consists of NPO values from four to less than eight, etc.

Interventions by NPO status

The need for intervention was relatively low overall at approximately 4%. The proportion of visits requiring intervention did not significantly differ when the exact NPO status was known (4.2%) vs unknown (4.0%) ($P = 0.70$) or when NPO <8 hours (4.1%) vs ≥8 hours (4.4%) ($P = 0.75$). Notably, there was only one intubation of 3,274 PS (0.03%). This was an elderly female with a history of hypertension undergoing reduction of a shoulder dislocation who received

Table 2. Side effects, complications, adverse events and procedure completions according to nil per os status.

	Exact NPO status			NPO binary			NPO numeric	
	Known	Unknown	*P*-value	NPO < 8 hours	NPO ≥ 8 hours	*P*-value	Odds ratio 95% CI	*P*-value
Study visits	2,643	631		1,388	1,255		2,643	
Side effects	5.0%	4.1%	0.36	5.5%	4.5%	0.28	0.96 (0.92, 0.99)	0.02
Complications	14.6%	13.8%	0.34	11.9%	17.7%	<0.001	1.03 (1.01, 1.05)	0.001
Adverse events	18.8%	17.1%	0.25	16.3%	21.5%	<0.001	1.02 (1.004, 1.04)	0.02
Any intervention	4.2%	4.0%	0.70	4.1%	4.4%	0.75	1.01 (0.97, 1.04)	0.63
Interventions respiratory	3.4%	3.5%	0.99	3.4%	3.5%	0.90	1.01 (0.97, 1.05)	0.77
Interventions other	0.8%	0.5%	0.35	0.7%	0.9%	0.65	1.02 (0.94, 1.10)	0.64
Procedure completed	92.1%	86.1%	< 0.001	94.3%	89.7%	<0.001	0.96 (0.93, 0.98)	0.001

	NPO categorized					
	0 to <2 hours	2 to < 4 hours	4 to < 6 hours	6 to < 8 hours	≥ 8 hours	*P*-value
Study visits	31	193	474	690	1,255	
Side effects	6.5%	5.7%	5.3%	5.5%	4.5%	0.87
Complications	16.1%	11.4%	12.9%	11.2%	17.7%	0.001
Adverse events	19.4%	15.5%	16.9%	15.9%	21.5%	0.02
Any intervention	0.0%	3.1%	4.9%	4.1%	4.4%	—
Interventions respiratory	0.0%	2.6%	3.6%	3.6%	3.5%	—
Interventions other	0.0%	0.5%	1.3%	0.4%	0.9%	—
Procedure completed	90.3%	94.8%	93.7%	94.8%	89.7%	0.002

NPO, nil per os (nothing by mouth).

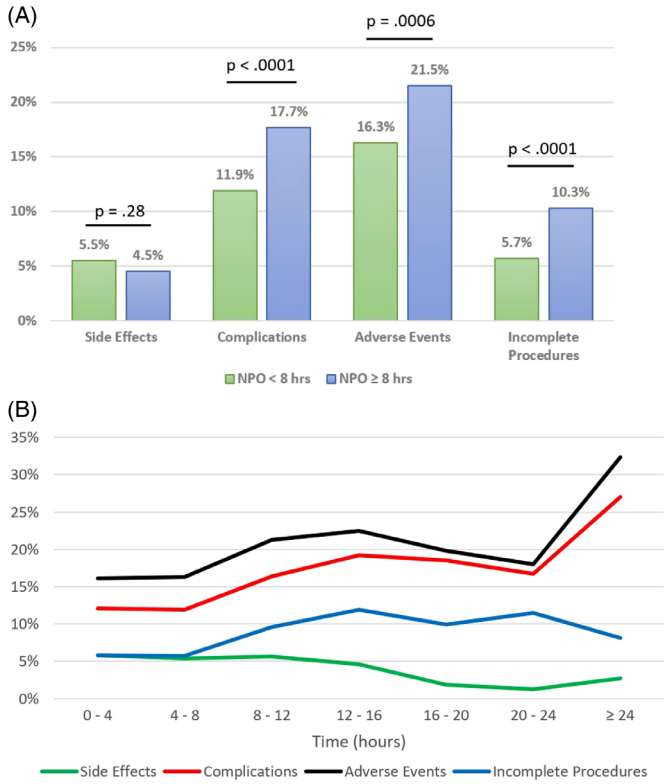

Figure 2. (A) Side effects, complications, adverse events, and incomplete procedures by nil per os group: <8 hours vs ≥8 hours. (B) Side effects, complications, adverse events, and incomplete procedures by nil per os.
NPO, nil per os (nothing by mouth).

propofol and hydromorphone. She experienced bradypnea. She was bagged and then intubated for fewer than five minutes. She was extubated in the ED without complications and discharged home. At follow-up in the office weeks later, she was well with no problems resulting from the intubation/ED visit (Table 3).

Demographic and procedural variables affecting adverse events

According to multivariate analysis, NPO status, year of visit, sex, whether transferred or not, race, and use of multiple sedatives were not significant factors associated with side effects, complications, or adverse effects. A higher ASA classification and older age group (adult/geriatric) were significantly associated with higher risk of complications and, thus, adverse events ($P < 0.0001$) but not side effects. The choice of primary sedative was significantly associated with the incidence of side effects, complications, and adverse events. Compared to propofol, the use of etomidate, ketamine, midazolam, or other sedatives all showed an increased risk of side effects, primarily vomiting; and the use of methohexital or etomidate showed a decreased risk of complications. The choice of analgesic was not associated with the incidence of side effects but was significantly associated with the occurrence of complications and adverse events. Compared to fentanyl, the use of hydromorphone, morphine, or oxycodone showed a decreased risk of complications. Using both a sedative and an analgesic was associated with a higher risk of side effects and adverse events (Table 4).

Side effects, complications and adverse events and interventions by fasting time

Of interest was the relationship between NPO duration and patient outcomes, specifically side effects, complications, overall adverse events, any interventions, respiratory interventions, and other interventions (non-respiratory). We explored several ways of defining NPO duration (Table 2). First, we compared NPO duration status known vs unknown and found no significant difference in any patient outcome. Next, we dichotomized NPO duration as <8 hours vs ≥8 hours and found a significantly higher rate of complications and overall adverse events in the NPO ≥8 hours group. When analyzing NPO duration as a numeric variable, we saw that each additional hour of NPO was significantly associated with a decrease in risk of side effects and an increase in risk of complications and overall adverse events.

Finally, we categorized NPO duration into two-hour intervals and compared each to the reference group of ≥8 hours. There were no significant differences in side effects when comparing the various NPO time intervals 0 to <2, 2 to <4, 4 to <6, and 6 to <8 hours to NPO ≥8 hours. Complications at NPO 2 to <4, 4 to <6, and 6 to <8 hours were significantly less than for NPO ≥8 hours. There were fewer complications in the NPO time interval 0 to <2 hours compared to NPO ≥8 hours, although this did not achieve statistical significance. However, it should be noted that the 0 to <2 hours NPO group contained only 31 visits (Figure 3, Table 2).

DISCUSSION

Studies regarding NPO status and ED PS in the pediatric population have found no association between NPO status and adverse events.[8–13] Surprisingly, to our knowledge, there have been no adult studies of NPO status and adverse events in ED patients from the United States and only two international studies. One small Australian study in pediatric and adult ED subjects with a somewhat atypical patient population consisting of predominately ASA 1 and 2 patients and an overwhelming majority (84%) of orthopedic patients with propofol being the only sedative found a 22.4% incidence of adverse respiratory events for not-fasted patients vs 19.5% for fasted patients and a 33.3% incidence of respiratory interventions for not-fasted compared with 24.6% for fasted patients.[16] Our study had more than eight times the number of patient encounters than in this study and included higher acuity patients with higher ASAs, a greater range of procedures performed, and a variety of sedatives and a more robust statistical analysis that considered other

Table 3. Interventions by nil per os status.

	Exact NPO known	Exact NPO unknown	NPO < 8 hours	NPO ≥ 8 hours
Study visits	2,643	631	1,388	1,255
Interventions	112 (4.2%)	25 (4.0%)	57 (4.1%)	55 (4.4%)
Airway maneuver				
Bag-valve mask	53 (2.0%)	16 (2.5%)	25 (1.8%)	28 (2.2%)
Non-rebreather mask	15 (0.6%)	2 (0.3%)	8 (0.6%)	7 (0.6%)
NPA	19 (0.7%)	1 (0.2%)	8 (0.6%)	11 (0.9%)
Jaw thrust/chin lift	13 (0.5%)	2 (0.3%)	6 (0.4%)	7 (0.6%)
Suctioning	4 (0.2%)	1 (0.2%)	2 (0.1%)	2 (0.2%)
Intubation	1 (< 0.1%)	0 (0%)	1 (0.1%)	0 (0%)
Airway Interventions only	91 (3.4%)	22 (3.5%)	47 (3.4%)	44 (3.5%)
Medications				
Medications only (including IVF)	15 (0.6%)	3 (0.4%)	9 (0.7%)	6 (0.5%)
Medications only (not including IVF)	5 (0.2%)	2 (0.3%)	5 (0.4%)	0 (0%)
IVF only	10 (0.4%)	1 (0.1%)	4 (0.3%)	6 (0.5%)
Atropine	1 (< 0.1%)	0 (0%)	1 (0.1%)	0 (0%)
Diphenhydramine	4 (0.2%)	2 (0.3%)	3 (0.2%)	1 (0.1%)
IVF	13 (0.5%)	1 (0.2%)	4 (0.3%)	9 (0.7%)
Naloxone	2 (0.1%)	0 (0%)	1 (0.1%)	1 (0.1%)
Methylprednisolone	1 (< 0.1%)	0 (0%)	1 (0.1%)	0 (0%)

NPO, nil per os (nothing by mouth); *NPA*, nasopharyngeal airway; *IVF*, intravenous fluids.

potential confounding factors. Our incidence of adverse events of 16.3% for NPO <8 hours and 21.5% for those fasted ≥8 hours is comparable to the Australian study.[16]

Our overall incidence of adverse events (18.4%) compares favorably with another study, also from Australia, in pediatric and adult ED patients that looked primarily at adverse respiratory events during ED PS. Taylor et al reported a higher 20.8% incidence of just airway events and found no association of fasting status with vomiting.[17] Our study is consistent with a prior report of elective PS in pediatric patients performed by an elective sedation service regarding predictors of complications for patients undergoing PS and another pediatric study of non-emergent sedations for research procedures, which both reported a higher rate of complications with higher ASA.[7,18]

When comparing by age group, pediatric patients had significantly fewer sedation-related complications and adverse events than adults, especially geriatric adults. Side effects, most commonly vomiting, were higher in pediatric patients than adults, which may at least be partly explained by the greater use of emetogenic sedatives, specifically ketamine, in the pediatric patients (Table 4). Ketamine as a sedative increases the risk of vomiting as compared with other sedatives.[10,11] The specific age group—pediatric, non-geriatric adult, and geriatric adult—affected the occurrence of side effects, complications, and adverse events. This age group factor for ED PS has not been evaluated previously by robust statistical analysis (Table 4).

We found in our unadjusted analysis that fasting ≥8 hours was associated with a slightly lower incidence of side effects, mostly vomiting, and a statistically significantly greater occurrence of complications and adverse events (Table 2). This differs from the previous pediatric ED PS studies that did not find an association between adverse events and NPO status.[8–13] In one pediatric study, there was a nonsignificant increased incidence of vomiting with increased fasting time, but the comparison was of those fasted <1 hour vs those fasted ≥3 hours.[12] In an Australian study that included adults, there was no significant difference in the incidence of adverse procedure-related events based on the time they last ate/drank.[17] One variable that might account for the various results could be different patient populations: pediatric vs adult patients, and varying acuity of patients, although other factors, such as medications (sedatives, analgesics) and procedure being done, could also play a role.

Our research adds to the data, primarily in the pediatric population, indicating that compliance to fasting guidelines similar to those for elective surgery does not significantly decrease the incidence of adverse events during procedural sedation. Our study documents that such adherence to the recommended fasting guidelines may result in a greater incidence of adverse events during PS. Recently, graded

Table 4. Multivariate analysis of nil per os group and side effects, complications, and adverse events.

	Side effects			Complications			Adverse events		
	Odds ratio	95% CI	*P*-value	Odds ratio	95% CI	*P*-value	Odds ratio	95% CI	*P*-value
NPO < 8 hours vs. NPO ≥ 8 hours	0.93	0.64–1.34	0.68	1.09	0.86–1.39	0.48	1.13	0.92–1.39	0.26
Year	0.98	0.94–1.03	0.41	1.00	0.97–1.03	0.95	0.99	0.96–1.02	0.43
Pediatric vs adult/geriatric	1.29	0.67–2.48	0.43	0.20	0.10–0.40	<0.001	0.39	0.25–0.62	<0.001
Male vs female	1.13	0.78–1.62	0.52	0.83	0.65–1.06	0.14	0.90	0.73–1.12	0.34
Transfer	1.10	0.69–1.75	0.68	1.15	0.82–1.59	0.42	1.03	0.78–1.36	0.85
ASA	1.00	0.77–1.32	0.98	1.79	1.48–2.15	<0.001	1.55	1.33–1.81	<0.001
Race (ref = other)			0.61			0.48			0.44
Black	0.49	0.15–1.58		0.57	0.20–1.66		0.66	0.28–1.52	
White	0.47	0.15–1.52		0.65	0.23–1.85		0.73	0.32–1.66	
Primary sedative (ref = propofol)			<0.001			<0.001			0.001
Methohexital	2.40	0.93–6.16		0.52	0.29–0.93		0.60	0.36–1.00	
Etomidate	3.99	2.27–7.03		0.48	0.35–0.66		0.68	0.51–0.91	
Ketamine	4.04	2.12–7.68		1.09	0.58–2.05		1.87	1.23–2.85	
Midazolam	2.56	1.21–5.45		0.76	0.50–1.15		0.91	0.62–1.33	
Other	12.14	3.22–45.85		0.25	0.03–2.49		1.21	0.32–4.58	
Multiple sedatives	1.16	0.73–1.84	0.54	1.09	0.80–1.49	0.57	1.19	0.90–1.56	0.22
Sedative + analgesic	6.67	1.42–31.24	0.02	2.92	0.76–11.24	0.12	3.43	1.01–11.64	0.048
Primary analgesic (ref = fentanyl)			0.47			<0.001			0.007
Meperidine	0.64	0.14–2.86		1.59	0.77–3.27		1.40	0.72–2.75	
Hydromorphone	2.20	0.97–4.98		0.50	0.30–0.84		0.66	0.42–1.05	
Morphine	1.07	0.60–1.89		0.59	0.41–0.85		0.67	0.49–0.93	
Oxycodone	5.27	1.11–25.09		0.11	0.01–0.87		1.17	0.35–3.96	
Other/unknown	6.20	1.24–31.03		1.82	0.47–7.02		2.34	0.68–8.06	

Models fit are generalized estimating equations assuming compound symmetry correlation structure. ASA 1: normal healthy patient. ASA 2: mild systemic disease. ASA 3: severe systemic disease but not life-threatening. ASA 4: patient with severe systemic disease that is a constant threat to life. ASA 5: moribund patient who is not expected to survive without the operation.
ASA, American Society of Anesthesiology physical status; *NPO*, nil per os (nothing by mouth); *CI*, confidence interval.

fasting precautions based on various factors including patient characteristics, comorbidities, the procedure, and the sedation technique have been suggested.[5]

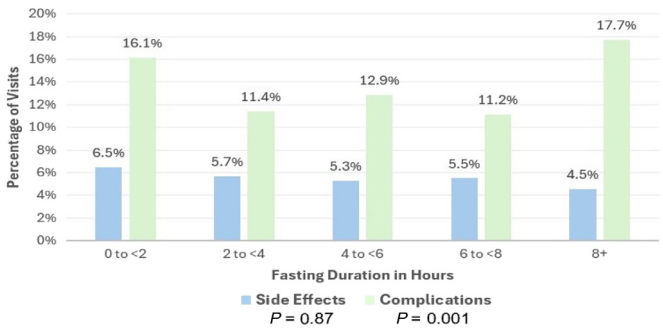

Figure 3. Fasting time and adverse events by fasting duration in hours.

There could be several reasons why fasting may have a negative effect. Hypoglycemia has been described in an adult diabetic patient who was fasting prior to a procedure.[19] Patients going without PO intake may become dehydrated and hypotensive. Future studies would be helpful in collaborating whether the statistically significant negative impact of fasting prior to ED PS that we found, both on decreased PS success rates and on an increased incidence of adverse events, is specific to a certain patient population, such as higher acuity adults with multiple comorbidities and higher ASAs.

LIMITATIONS

This study has several limitations. These results were based on the findings from one hospital system, which may limit its generalizability. However, 20 hospital EDs with

many diverse locations in urban, suburban and rural settings, and varying geographic locations in two different states, were included. Moreover, we included all ages of patients with varying comorbidities, ASAs, and multiple diagnoses undergoing PS performed by many different physicians over 15.25 years using various sedatives and analgesics and had a high number (over 3,000) of ED PS.

Although this was a retrospective study, the recording of data was done prospectively at the time of the ED PS primarily by the nurses, the respiratory therapists, and the ED attending physician on a standardized four-page form used throughout the hospital on which staff has been in-serviced multiple times on a regular basis as part of the hospital-wide QI program. Data such as vital signs and rhythm strip monitoring are recorded continuously throughout all procedural sedations, and because such information is included on the form it seems highly unlikely that any adverse event such as hypo- or hypertension, bradypnea or apnea, or a low pulse oxygen saturation would not have been recorded. In addition, the ED EHR chart completed by the emergency physician in attendance during the sedation and ED visit was also reviewed. Moreover, all information was recorded prospectively, which makes it doubtful that any significant data or occurrence was missed.

Hospital policy requires that a minimum of three personnel be present throughout the ED PS: an ED registered nurse; an ED respiratory therapist; and an ED attending physician. Others such as a consultant or resident are usually present as well. This makes it improbable that this group of individuals would overlook or not record any adverse event.

Fasting was not documented in about one-fifth of patients, which could affect the validity of this study. The primary reason for this was the critical condition and higher ASA of some of our patients and the emergent nature of the procedural sedations (Figure 1). Other factors that may have contributed to missing data include the time constraints from a busy ED with high patient volumes and, perhaps, the impression that this data was not essential given the depth of sedation anticipated and the controversy over NPO status for ED PS.

Our incidence of NPO not listed is comparable with other studies. One study in a pediatric ED had fasting times not documented in 25.4% of cases, although they had younger, "healthier" patients with fewer comorbidities, lower ASAs, and fewer dangerous procedures such as ventriculostomy or cardioversion.[13] Another study from pediatric sedation services that included scheduled sedations and sedations in non-ED settings reported 22.4% of NPO unknown.[6]

Because the NPO cutoff time of eight hours is consistently mentioned in the various guidelines and the literature, we used this eight-hour period, as well as the 2-, 4-, and 6-hour cutoff times [2,4,7,8,13] (Figures 2A, 3 and Tables 2–4). A recent consensus statement did not make a distinction between NPO time for solids (light meal) vs liquids (non-human milk or formula) and used the same cut-off time for all these PO intake types in healthy infants and children.[5] Moreover, the guidelines/consensus statements have varied widely over time especially for liquid PO intake. For example, one recent guideline recommends a NPO of four hours for breast milk.[2] Another consensus statement gives no NPO restriction for breast milk if no risk factors, two hours if some risk factors, and four hours if moderate risk factors.[5] Another guideline also did not differentiate between solids or liquids and stated "no milk or solids after midnight."[4] Because of the lack of consistent NPO times,[2–5] based on different PO intake, age, and risk factors over the years, particularly for PO liquid intake, and the lack of differentiation between solids and liquids in various guidelines/consensus statements,[4,5] we used NPO for any PO intake in our analysis.

Observers were not blinded to the medications administered or fasting times, which could have led to bias. However, observers were unaware of this study. Our sedation form has a blank for the time of last PO intake but does not specify whether liquids or solids were consumed, although this was recorded in some instances.

CONCLUSION

To our knowledge this is the largest ED procedural sedation cohort that included adults, particularly geriatric patients and higher acuity patients, analyzed with the most robust statistical analyses to evaluate the association among nil per os status and adverse events. We identified a significant increase in complications and adverse events and incomplete procedures for those NPO ≥8 hours vs NPO <8 hours. These results indicate that delaying sedation to meet established fasting guidelines may worsen outcomes for patients of all ages, including adults in the ED, and is not indicated.

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Immune Checkpoint Inhibitor-associated Pneumonitis: A Narrative Review

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Immune checkpoint inhibitors (ICI), such as pembrolizumab, nivolumab, durvalumab and ipilimumab, have significantly enhanced survival rates for multiple cancer types such as non-small cell lung cancer, melanoma, Hodgkin lymphoma, and breast cancer, and they have emerged as an adjunct or primary therapy for malignant disease. Approximately 40% of patients with cancer on ICI therapy experience side effects called immune-related adverse events (irAE). While not the most common, pulmonary toxicities can be rapidly progressive, potentially fatal, and pose a three-fold increased risk for requiring intensive care unit-level of care. Pneumonitis is a focal or diffuse inflammation of the lung parenchyma, and clinical manifestations may be highly variable. While the onset is generally observed 6–12 weeks after the initiation of therapy, drug toxicity can develop rapidly within days after the first infusion or many months into therapy. Pneumonitis symptoms can be subtle or non-specific; therefore, a thorough and systematic evaluation considering other possible etiologies is crucial. Moreover, extrapulmonary findings, such as skin lesions, colitis, or endocrinopathies, should raise suspicion for irAE as drug toxicity can affect multiple organs simultaneously. Due to the significant overlap of clinical features between ICI-associated pneumonitis and respiratory infections, it can be challenging to differentiate the two conditions based on clinical presentation alone. A multidisciplinary approach to management is recommended for the treatment of ICI-associated pneumonitis, and classification of severity helps to guide interventions. Treatment options in more severe cases include systemic immunosuppression. Given the increased use of ICIs and greater probability that patients with ICI-associated pneumonitis will be seen in the emergency department, we aimed to provide a comprehensive framework for the diagnosis and management. In addition, identifying potential challenges in diagnosis and/or other contributors of respiratory symptoms and radiographic manifestations is highlighted. [West J Emerg Med. 2025;26(2)210–218.]

INTRODUCTION

Patients with cancer frequently require care in emergency departments (ED) owing to acute presentations of malignant disease, cancer-associated complications, therapy-related adverse events, and/or other coexisting comorbidities. Fortunately, mortality has improved among many cancer types.[1,2] In particular, immune checkpoint inhibitors (ICI) have significantly impacted survival rates, used alone or as supportive therapy to conventional cancer treatments.[3] Given the efficacy of ICIs, it is likely that emergency physicians will see increasing numbers of cancer patients on ICIs in the years to come.[4]

Immune checkpoint inhibitors, such as pembrolizumab, nivolumab, and ipilimumab, work by blocking checkpoint protein-binding. This inhibitory signal removal allows T-cells to attack cancer cells. Approximately, 40% of patients

on ICIs experience side effects called immune-related adverse events (irAEs).[5] Patients with irAEs often present with subtle and non-specific symptoms that may mimic other diagnoses; therefore, detection of irAEs can be challenging. Furthermore, they can involve (almost) every organ system. Patients diagnosed with irAEs in the ED generally present with higher-grade toxicities, and 3.5% of patients with grade 3 irAEs require hospitalization and corticosteroid treatment.[6] Delays in identification of irAEs may result in worsened prognosis and longer hospital lengths of stay.[6,7]

While toxicities of the pulmonary system are not the most common irAE, they occur in up to 10% of patients.[8] When present, pulmonary toxicities can be rapidly progress; they are potentially fatal and associated with a substantially increased risk for requiring intensive care unit-ICU level care.[9,10] Thus, prompt recognition of ICI-related pneumonitis is paramount. In this review we aimed to provide a review of the clinical presentation, risk factors, diagnostic approach, and management of pulmonary irAEs in the ED.

CLINICAL PRESENTATION

Pneumonitis is focal or diffuse inflammation of the lung parenchyma, and clinical manifestations may be highly variable.[8,11] Onset of pneumonitis from ICIs is usually 6–12 weeks after the initiation of therapy, but drug toxicity can develop rapidly within days of the first infusion or many months into therapy.[8,11–14] Shorter time to onset of irAEs is seen in patients with lung cancer compared to other types of malignancy, perhaps due to comorbid pulmonary disease, particularly underlying interstitial lung disease.[15] The severity of symptoms associated with ICI pneumonitis can range from asymptomatic with only radiographic changes to life-threatening, fulminant respiratory failure (Figure 1). Common symptoms may include exertional dyspnea, cough, fatigue, and decreased activity tolerance; hypoxemia may present acutely or insidiously. Fever and/or chest pain, when present with other respiratory symptoms, should prompt a search for other etiologies, including pneumonia.

Because the symptoms of pneumonitis can be subtle or non-specific, a thorough evaluation is crucial in reaching the correct diagnosis. Competing diagnoses, such as respiratory infections, cardiogenic pulmonary edema, disease progression of the underlying malignancy, and other drug-related complications must be considered. Moreover, extrapulmonary findings, such as skin lesions, colitis, or endocrine disorders, should raise the suspicion of irAEs, as drug toxicity can affect multiple organs simultaneously. Additional information from computed tomography (CT) of the chest (Figure 2) and bronchoscopy is usually incorporated to exclude alternative diagnoses.

Separate from pneumonitis, infusion reactions are adverse reactions unrelated to the mechanism of action of ICIs. Although relatively uncommon, they have been shown in 4% of patients treated with programmed cell death 1 (PD-1) or program death-ligand 1 (PD-L1) antibodies and in 2–6% of patients treated with ipilimumab (cytotoxic T-lymphocyte antigen or CTLA-4 inhibitor).[16,17] The onset of symptoms can occur within any time frame during the infusion or up to one hour after the infusion. Symptoms include chest tightness, wheezing, rigors, rash, pruritus, tongue swelling, dizziness, tachycardia, hypotension/hypertension, or anaphylaxis. Infusion reactions are typically mild to moderate and usually resolve with the cessation of infusion and supportive care. However, severe reaction such as anaphylaxis can occur; therefore, premedication with

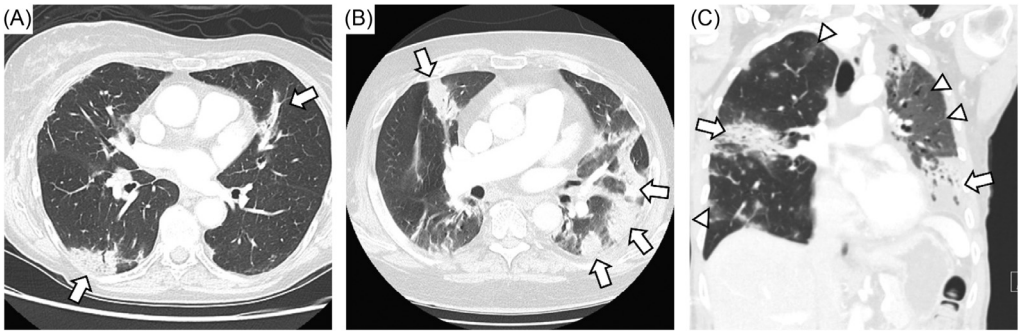

Figure 1. Representative case of immune checkpoint inhibitor- (ICI) associated pneumonitis. A) Elderly woman with melanoma treated with ICI presented with patchy bilateral consolidative opacities without any respiratory symptoms (Grade 1). B) Elderly man with melanoma affecting scalp underwent surgery followed by neoadjuvant ICI presented with persistent dry cough. Computed tomography of the chest (CT chest) revealed multifocal consolidative opacities. He underwent bronchoscopy with biopsy of lymph nodes and bronchoalveolar lavage without evidence of malignancy or infection. He was diagnosed with Grade 2 ICI-associated pneumonitis, and he improved with oral steroids. C) Middle-aged woman with triple negative breast cancer on ICI presented with cough and dyspnea with exertion not improved on outpatient oral steroid therapy. On physical exam she was noted to be tachypneic and hypoxic on room air. Coronal CT chest revealed consolidative opacities on the right and left along with ground-glass infiltrates on the left upper lobe. She was admitted and treated for Grade 3 ICI-associated pneumonitis with intravenous methylprednisolone (1 mg/kg) followed by infliximab. She improved and was discharged on prolonged steroid taper.

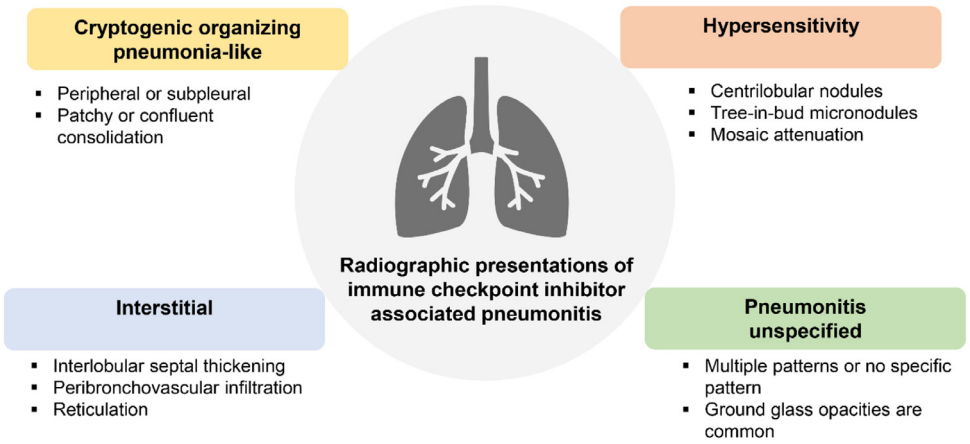

Figure 2. Radiographic manifestation of immune checkpoint inhibitor-associated pneumonitis.

glucocorticoids and antihistamine should be used when the patient has had prior reactions.[18]

RISK FACTORS

The clinical profile of irAEs is dependent on the affected organ and the ICI agent used. For example, CTLA-4 agents are more likely to cause colitis and dermatitis than pneumonitis or thyroiditis.[19] While the pathophysiology of ICI-related pneumonitis is not fully understood, potential risk factors have been reported and can be categorized as treatment-related, patient-related, and tumor-related factors, and the presence or absence of them can modify one's risk of developing pneumonitis induced by the treatment.

Treatment-related Factors

There are different degrees of pulmonary toxicity depending on whether ICIs are used as a single agent vs in combination with another ICI agent, targeted therapy, or radiation. In general, pneumonitis occurs more frequently in patients treated with PD-1 inhibitors, as compared to patients treated with PD-L1 inhibitors or with CTLA-4 inhibitors.[16,20,21] Further, PD-1 and PD-L1 inhibitors cause pulmonary toxicity more often than CTLA-4 inhibitors.[22] For example, in patients with advanced non-small cell lung cancer (NSCLC), a combination of PD-1 and CTLA-4 inhibitors (nivolumab/ipilimumab) resulted in a higher response rate and better progression-free survival time than those receiving chemotherapy alone.[23] However, pneumonitis, particularly high-grade pneumonitis, occurred more often with combination therapy than ICI monotherapy or chemotherapy, suggesting a synergistic effect in inducing lung inflammation.[11,22,24] Furthermore, the risk of pneumonitis may increase when ICIs are used in combination with epidermal growth factor receptor-tyrosine kinase inhibitors (EGFR-TKI) NSCLC. Specifically, patients treated with osimertinib (EGFR-TKI), followed by a PD-1 or a PD-L1 inhibitor, are at a high risk of pneumonitis.[25,26]

Pneumonitis after thoracic radiation is well documented, raising the concern of enhanced pulmonary toxicity with the combination of ICIs and radiation therapy.[27,28] In general, radiation doses correlate with the risk of lung injury. An observational study illustrated that more patients developed ICI-related pneumonitis in the group that received curative intent radiotherapy than the group that received palliative intent radiotherapy.[29] Other studies have noted that mean lung dose is a significant risk factor for pneumonitis, with or without ICI.[30,31] Radiation-recall pneumonitis is an inflammatory reaction that occurs within previously irradiated fields following exposure to certain chemotherapy (taxanes, anthracyclines, alkylating agents, antimetabolites, or pyrimidine analogs) or other medications (tamoxifen, simvastatin, levofloxacin, or isoniazid), often months to years apart from previous radiation exposure.[32,33] Radiation-recall pneumonitis induced by ICI agents has been reported in case reports.[34,35] In contrast to the common radiographic patterns associated with ICI pneumonitis, radiation recall pneumonitis is generally confined to area of prior thoracic radiation.

Chemotherapy may also enhance one's risk for ICI pneumonitis. The PACIFIC study demonstrated striking survival benefits with durvalumab (PD-L1 inhibitor) as adjuvant therapy after chemoradiation.[36] However, a higher incidence of pneumonitis was also found in the durvalumab group (34%) compared to the placebo group (25%). Therefore, patients with advanced NSCLC treated with concurrent chemoradiation and ICIs are much more likely to develop pneumonitis than with concurrent chemoradiation alone. In general, higher radiation doses also increase the risk of lung injury.

Patient-related Risk Factors

Pre-existing lung conditions, particularly interstitial lung disease (ILD), have been recognized as an independent risk factor for lung injury after ICI therapy.[11,13] Patients with ILD were previously excluded from clinical trials due to

concern of potential exacerbation with immunotherapy. Therefore, the efficacy and safety of ICI use in patients with underlying interstitial abnormalities has been an active area of interest. Multiple retrospective studies have demonstrated that patients with ILD who received ICI therapy were more likely to develop ICI pneumonitis. Patients with NSCLC have a higher rate of pre-existing ILD than other solid tumors, owing to the fact that both lung cancer and ILD are closely associated with smoking and other factors such as advanced age.[37] Patients with NSCLC and pre-existing lung diseases including ILD and chronic obstructive lung disease (COPD), can have impaired survival once pneumonitis develops.[8] The risk for pneumonitis may also be higher in patients with interstitial lung abnormalities without clinical ILD.[15] Considering the association between ILD and lung cancer, ICI-related complications are a major concern in this patient population given the shifting paradigm favoring ICI therapy.

Additional patient-related risk factors to consider include autoimmune diseases and smoking. Retrospective studies showed that patients with autoimmune disease may have higher rates of immunotoxicity, including flares of their pre-existing autoimmune conditions and/or irAEs related to ICI therapy.[38,39] In a multicenter cohort study, 71% of patients with autoimmune conditions, such as rheumatoid arthritis and psoriatic arthritis, were noted to have flares or irAEs, which were mostly manageable with glucocorticoids.[40] Whether smoking is directly or indirectly linked to ICI-related pneumonitis is unclear, especially when considering the close connection between smoking, ILD, and lung malignancy. In one study, patients with lung cancer and tobacco exposure more than 50 years had higher incidence of all-grade pneumonitis.[41]

Tumor-related Risk Factors

Certain tumor types and histology are at higher risk of ICI-related pneumonitis. One meta-analysis on clinical trials of ICI agents (PD-1, PD-L1, and CTLA-4) from 2003–2015 found that pneumonitis was more likely to occur in NSCLC and renal cell carcinoma as compared to melanoma.[42] Another study reported higher rates of pneumonitis in patients with NSCLC treated with PD-1 antibody.[24] Additionally, squamous cell carcinoma, a subtype of NSCLC that is typically found in patients with smoking history, was shown to be more associated with pneumonitis when compared to other subtypes of NSCLC.[43] However, other studies have not demonstrated a link between NSCLC subtype and pneumonitis risk.[8] This discrepancy may be because squamous cell cancer is more common in patients who smoke, and patients who smoke have a higher rate of pneumonitis that may be mediated by the presence of interstitial lung abnormalities or clinical ILD.

DIAGNOSTIC APPROACH

Evaluation of the cancer patient with respiratory symptoms, fever and/or hypoxia can be challenging, and a broad differential is needed (Figure 3). There are many other conditions that may be difficult to distinguish from ICI-associated pneumonitis or with which an irAE may coexist. Because the symptoms of pneumonitis can be subtle or non-specific, a thorough evaluation is crucial in reaching the correct diagnosis. Competing diagnoses, such as respiratory

Process	Differential	Diagnostic testing
	▪ Bacterial pneumonia ▪ Fungal pneumonia ▪ Viral pneumonia	▪ Cultures (sputum, blood, urine) ▪ Respiratory viral panel ▪ Leukopenia, neutropenia or lymphopenia ▪ Non-invasive serum and urine biomarkers for infection ▪ Bronchoscopy with bronchoalveolar lavage
	▪ Pericardial effusion or tamponade ▪ Myocarditis (irAE) ▪ Pulmonary edema ▪ Cardiac ischemia ▪ Arrythmia	▪ Echocardiogram ▪ Cardiac biomarkers (troponin, N-terminal prohormone brain natriuretic peptide) ▪ Electrocardiogram (low voltage, ST-T wave changes)
	▪ Pneumothorax ▪ Pleural effusion ▪ Pulmonary embolism ▪ Malignant tracheobronchial disease ▪ COPD/asthma exacerbation ▪ Diffuse alveolar hemmorhage	▪ Physical exam (wheezing, decreased breath sounds, subcutaneous crepitus) ▪ Computed tomography of chest with/without contrast ▪ Point-of-care ultrasound ▪ Pulmonary function testing ▪ Bronchoscopy
	▪ Radiation-induced lung injury ▪ Chemotherapy- or targeted-therapy induced lung injury	▪ Clinical history, timing of symptoms ▪ Computed tomography of chest with/without contrast
	▪ Progression of malignant disease ▪ Synchronous (new) malignancy	▪ Clinical history, timing of symptoms, laboratory data, biopsy ▪ Computed tomography of chest with/without contrast
	▪ Other inflammatory or autoimmune process	▪ Clinical history, timing of symptoms, laboratory data, biopsy ▪ Computed tomography of chest with/without contrast

Figure 3. Differential diagnosis for immune checkpoint inhibitor-associated pneumonitis.
COPD, chronic obstructive pulmonary disease; *irAE*, immune-related adverse events.

infections, cardiogenic pulmonary edema, disease progression of the underlying malignancy, and other irAE must be considered. As mentioned previously, extrapulmonary findings, such as skin lesions, colitis, or endocrine disorders, should raise the suspicion irAE as drug toxicity can affect multiple organs simultaneously.

Pneumonitis associated with ICI is a clinical diagnosis, and both malignant and infectious etiologies should be excluded.[44] Physical exam findings can be normal or may include rhonchi or rales on auscultation. Unfortunately, there are no pathognomonic symptoms or radiographic findings that confirm ICI-associated pneumonitis; therefore, a systematic diagnostic approach is needed to exclude other clinical possibilities (Figure 4).[45,46] Current guidelines recommend thorough evaluation including CT chest with (angiography if concern for pulmonary embolism) or without contrast and bronchoscopy to exclude alternative diagnoses. Laboratory tests may show leukocytosis and/or elevated inflammatory markers potentially supporting a diagnosis of irAE, but these are non-specific. Pneumonitis is graded based on radiographic and/or clinical severity (Table) and helps to direct further management.

Due to the significant overlap of clinical features between ICI-associated pneumonitis and respiratory infections, it can be challenging to differentiate the two conditions based on clinical presentation alone. Per American Society of Clinical Oncology guidelines, a thorough infectious workup, including nasal swab for respiratory viral pathogens, sputum

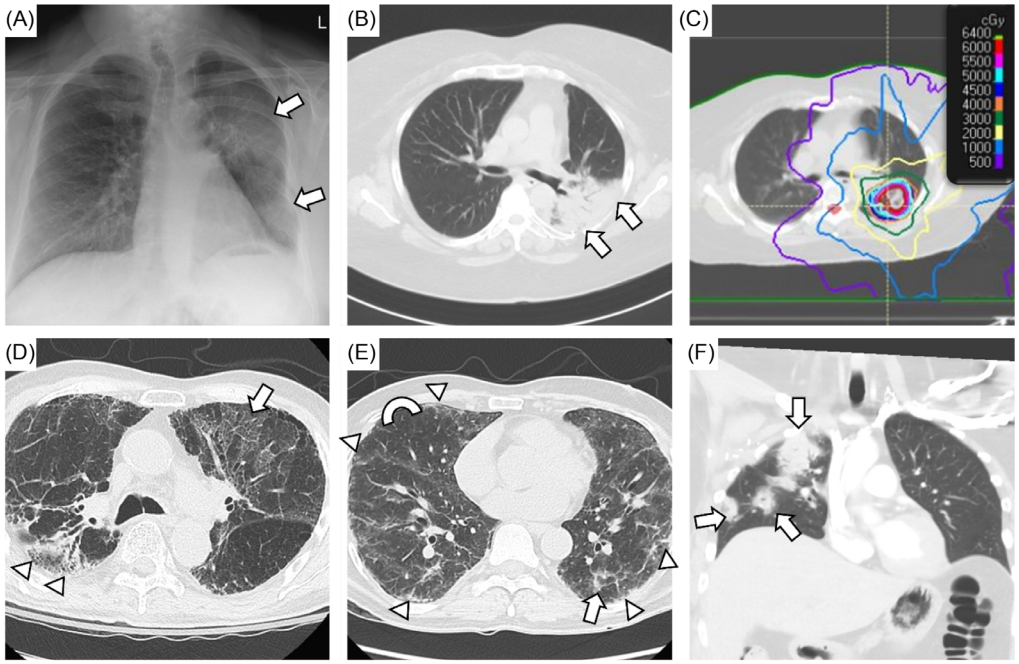

Figure 4. Challenging cases of possible immune checkpoint inhibitor (ICI) pneumonitis. A-C) Middle-aged woman with metastatic renal cell carcinoma treated with cabozatinib and nivolumab and radiation to the left upper lobe. She presented with cough and dyspnea with exertion (Grade 2) six months after radiation therapy was completed. Chest radiograph reveals new infiltrates in the left lung (arrows), and computed tomography of chest (CT chest) demonstrates dense consolidation in the left upper lobe with air bronchograms (B, arrows). Her infiltrates corresponded to radiation field (C). She was diagnosed with radiation-related lung injury and improved with oral steroid; however, ICI-associated pneumonitis could have also contributed. D) Elderly man with non-small cell lung cancer who underwent definitive chemoradiation therapy to the right upper lobe followed by pembrolizumab. He was hospitalized after a fall, and he was noted to have low oxygen saturations. CT chest revealed post-treatment changes in the right upper lobe (arrowheads) and bilateral ground-glass upper lobe infiltrates (arrow) in the setting of diffuse emphysematous changes. He was treated for chronic obstructive pulmonary disease (COPD) exacerbation with empiric antimicrobial therapy and oral steroids. His steroids were prolonged given lack of clinical improvement, so ICI-associated pneumonitis was also a concern. Bronchoscopy was not feasible due to significant oxygen requirement. E) Middle-aged man with papillary thyroid cancer who had undergone resection and treatment with carboplatin and paclitaxel. He was subsequently treated with pembrolizumab and presented with cough and dyspnea with exertion. He also had history of vocal cord dysfunction with paralyzed left vocal cord and aspiration risk. CT chest revealed diffuse peripheral and subpleural thickening (arrowheads), ground-glass opacities (arrow), and mosaic attenuation (semicircle showing contrast). He underwent bronchoscopy with lavage, and he was treated empirically for infection and with IV steroids for possible drug-related pneumonitis. Other potential etiologies included aspiration pneumonia, interstitial lung disease, and COPD exacerbation. F) Middle-aged woman with HER2-positive breast cancer treated with pembrolizumab hospitalized for fever, cough and dyspnea with exertion. Coronal CT chest reveals patchy opacities (arrows) affecting the right upper, middle, and lower lobes. Bronchoscopy was performed, and no obvious infection was found. She was treated with empiric antimicrobial therapy and iIV steroids for presumed ICI-associated pneumonitis. She was discharged on oral steroids therapy with *Pneumocystis jirovecii* prophylaxis.

Table. Common terminology criteria for adverse events for immune checkpoint inhibitor-associated pneumonitis.[46]

Grading	Symptoms	Number of lobes involved (on CT)	OR	Percentage of lung parenchyma involved (on CT)
Grade 1 – mild	Asymptomatic	One		<25%
Grade 2 – moderate	Symptomatic	More than one		25–50%
Grade 3 – severe	Severe symptoms	All lobes		>50%
Grade 4 – life-threatening	Life-threatening respiratory failure	All lobes		>50%

CT, computed tomography.

culture, blood culture, and urine culture, is recommended for grade 2 and above pneumonitis. Patients receiving ICI agents are not necessarily at higher risk of infection. In a single-center study, patients with lung cancer treated with both ICI and chemotherapy had a similar rate of infection (15%) as the control group treated with chemotherapy alone (22%).[47] However, patients treated with immunosuppressive agents for irAEs, such as corticosteroids or tumor necrosis factor (TNF) inhibitors, are at higher risk for opportunistic infection and tuberculosis reactivation. Overall, the incidence of infection in patients with lung cancer receiving ICI therapy ranges between 15–20%.[47,48] The incidence of infection varies with different tumor types. Bacterial pneumonia is the most common type of infection and risk factors include diabetes, COPD, and neutropenia. Prior colonization or infection with *Pseudomonas aeroginosa* or recent exposure to parenteral antibiotics are indications to select antimicrobial agents targeting *Pseudomonas* species.[49]

MANAGEMENT

A multidisciplinary approach to management is recommended for the treatment of ICI-associated pneumonitis, and classification of severity (Table 1) helps to guide interventions.[50–52] It is imperative to involve infectious, pulmonary, and/or oncologic consultants early to determine the most appropriate treatment, especially for complex cases with multiple etiologies. Treatment options generally consist of temporary ICI cessation with regular clinical reassessment, and in more symptomatic cases, systemic immunosuppression may be required.[53] For grade 1 (asymptomatic) pneumonitis, ICI agents may be withheld when there is radiographic evidence of pneumonitis progression, but in many cases the ICI agent can be continued with close clinical and radiologic reassessment for development of respiratory symptoms. If the patient remains asymptomatic, steroids are not typically administered. For grade 2 (mildly to moderately symptomatic) pneumonitis, steroids, such as prednisone or methylprednisolone administrated orally or intravenously, are given at 1–2 milligrams per kilogram per day (mg/kg/d) following infectious workup to exclude other potential etiologies. If symptoms do not improve after 48–72 hours, a higher dose of steroids should be considered. Mild grade 2 cases can be treated with the lower dose of 1 mg/kg if the response to treatment is rapid. For grade 3 or higher (severely symptomatic), prednisone or methylprednisolone are given at 1–2 mg/kg/d with close monitoring.[50] If no clinical improvement occurs within 48–72 hours, other immunomodulators (discussed in the **Special Situations** section below) should be considered to prevent further respiratory decompensation. It is recommended to obtain evaluation from consultants before administration of immunosuppressants, such as steroids, as these agents can have large impact on the overall clinical outcome. In general, cases of pneumonitis grade 3 and higher result in permanent ICI discontinuation. Dosing and tapering course of steroids for ICI pneumonitis are largely extrapolated from treatment guidelines for hypersensitivity pneumonitis and cryptogenic organizing pneumonia.[54,55] Current guidelines recommend a short corticosteroid taper over 4–6 weeks. However, retrospective studies have shown that pneumonitis may recur after improvement of symptoms or persist without improvement despite steroid treatment. Shorter courses of therapy may result in a higher chance of recurrence, but optimal steroid taper lengths have not been studied.

Empiric antibiotics in patients presenting with respiratory symptoms while receiving ICI therapy is reasonable while further investigation is underway. One caveat is that the human microbiota plays an important role in the responses to cancer therapy.[56] Antimicrobial use is known to alter the gut flora and has been shown with associated negative outcomes in patients receiving ICI therapy.[57] Therefore, the appropriate and judicious use of antibiotics should be considered while infectious workup is carried out.

SPECIAL SITUATIONS

Steroid refractory ICI-associated pneumonitis is characterized by a lack of improvement, typically, after 48 hours of corticosteroid treatment. Patients who develop steroid refractory pneumonitis tend to have worse clinical outcomes due to infectious complications or pneumonitis itself. When corticosteroids are ineffective in treating ICI pneumonitis, further immunomodulation may be required. Treatment guidelines suggest treating with agents such as intravenous immunoglobulin, anti-TNF agents, mycophenolate, or cyclophosphamide. However, data on the

use of these agents is limited and mostly derived from case series or reports.[58] In these studies, although some patients achieved clinical improvement with the addition of immunomodulators, the overall outcome was mostly poor.[59,60] The choice of selecting these immunomodulators in treating steroid refractory ICI pneumonitis depends on the patient's comorbidities and the clinician's or the center's experience. Of note, a negative interferon-gamma release assay, such as QuantiFERON, is often obtained before initiating anti-TNF agents due to the risk of tuberculosis reactivation. However, given that anti-TNF agents are typically given as 1 or 2 doses instead of long-term therapy, the short-term benefit of treating severe pneumonitis usually greatly outweighs any risk of reactivating indolent infections.

Reintroduction of ICI Therapy After Pneumonitis

In general, patients who develop grade 2 pneumonitis and have recovered (ie, return to grade 1 pneumonitis), should be considered as eligible for reintroduction of ICI therapy. Only a few studies have assessed the rate of recurrent pneumonitis after ICI reintroduction. In a cohort of 107 patients who developed pneumonitis, 45 underwent re-challenge and of these, nine (20%) developed recurrent pneumonitis while 11 (24%) developed a different irAE.[61] In a pharmacovigilance study including 452 irAEs occurring with ICI reintroduction in which recurrence status was verifiable, pneumonitis, colitis, and hepatitis were associated with an increased risk of recurrent irAE in adjusted analyses.[62] While pneumonitis grade 3 and higher generally precludes ICI reintroduction, successful re-challenge has been reported.[63] In general, these cases are rare, and ICI reintroduction in this scenario requires that the benefit with ICI clearly outweighs the high risk of recurrent and possibly severe pneumonitis.

Steroid-dependent Pneumonitis

In some cases, pneumonitis does not resolve despite adequate corticosteroid therapy. In one form, Naidoo and associates have suggested an entity of chronic pneumonitis defined as a) pneumonitis that persists or worsens with steroid tapering; and b) requires more than 12 weeks of immunosuppression after ICI discontinuation.[14,64] Two percent of patients with NSCLC and melanoma treated with anti-PD-L1 agents develop chronic ICI-associated pneumonitis.[13] Steroid-dependent pneumonitis is a sub-type where pneumonitis recurs without some form of immunosuppression. There is little to guide the treatment of this form of pneumonitis, and uncertainty exists about the optimal non-steroidal immunosuppression, length of immunosuppression, cadence of steroid taper, and cancer outcomes in this scenario. While this form of pneumonitis rarely occurs, strategies can include treatment with low-dose steroid therapy or use of other immunomodulators such as mycophenolate mofetil before eventual attempting to taper.

CONCLUSION

While immune checkpoint inhibitor-associated pneumonitis is less common than other adverse effects from ICIs, the potentially fatal consequences if missed makes diagnosis and prompt management by emergency physicians crucial. Associated risk factors are patient, tumor, and/or treatment related. Maintaining a high index of suspicion is important when evaluating patients with a history of ICI treatment presenting with respiratory symptoms. Workup in the ED involves imaging and lab work to rule out competing diagnosis such as infection and cardiac etiologies. Severity of ICI-pneumonitis is based on a grading system that considers clinical and radiographic findings; once suspected, prompt collaboration with oncologists and specialists is ideal, as treatment involves the initiation of high-dose steroids in the ED and possible cessation of ICI treatment. The integral role of the emergency physician in the timely diagnosis and management of ICI-associated pneumonitis is vital to improve patient outcomes.

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Cardiac Computed Tomography Measurements in Pulmonary Embolism Associated with Clinical Deterioration

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Introduction: Most pulmonary embolism response teams (PERT) use a radiologist-determined right ventricle to left ventricle ratio (RV:LV) cut-off of 1.0 to risk-stratify pulmonary embolism (PE) patients. Continuous measurements from computed tomography pulmonary angiograms (CTPAs) may improve risk stratification. We assessed associations of CTPA cardiac measurements with acute clinical deterioration and use of advanced PE interventions.

Methods: This was a retrospective study of a PE registry used by eight affiliated emergency departments. We used an artificial intelligence (AI) algorithm to measure RV:LV on anonymized CTPAs from registry patients for whom the PERT was activated (2018–2023) by institutional guidelines. Primary outcome was in-hospital PE-related clinical deterioration defined as cardiac arrest, vasoactive medication use for hypotension, or rescue respiratory interventions. Secondary outcome was advanced intervention use. We used bivariable and multivariable analyses. For the latter, we used least absolute shrinkage and selection operator (LASSO) and random forest (RF) to determine associations of all candidate variables with the primary outcome (clinical deterioration), and the Youden index to determine RV:LV optimal cut-offs for primary outcome.

Results: Artificial intelligence analyzed 1,467 CTPAs, with 88% agreement on RV:LV categorization with radiologist reports (kappa 0.36, 95% confidence interval [CI] 0.28–0.43). Of 1,639 patients, 190 (11.6%) had PE-related clinical deterioration, and 314 (19.2%) had advanced interventions. Mean RV:LV were 1.50 (0.39) vs 1.30 (0.32) for those with and without clinical deterioration and 1.62 (0.33) vs 1.35 (0.32) for those with and without advanced intervention use. The RV:LV cut-off of 1.0 by AI and radiologists had 0.02 and 0.53 *P*-values for clinical deterioration, respectively. With adjusted LASSO, top clinical deterioration predictors were cardiac arrest at presentation, lowest systolic blood pressure, and intensive care unit admission. The RV:LV measurement was a top 10 predictor of clinical deterioration by RF. Optimal cut-off for RV:LV was 1.54 with odds ratio of 2.50 (1.85, 3.45) and area under the curve 0.6 (0.66, 0.70).

Conclusion: Artifical intelligence-derived RV:LV measurements ≥1.5 on initial CTPA had strong associations with in-hospital clinical deterioration and advanced interventions in a large PERT database. This study points to the potential of capitalizing on immediately available CTPA RV:LV measurements for gauging PE severity and risk stratification. [West J Emerg Med. 2025;26(2)219–232.]

INTRODUCTION

Established pulmonary embolism (PE) risk-stratification guidelines employ binary assessments of hemodynamic stability and right ventricular dysfunction (RVD) using imaging modalities and troponin.[1] The main imaging modalities of RVD are echocardiography and computed tomography pulmonary angiogram (CTPA). Comprehensive echocardiography provides multifaceted RVD assessments; however, it rarely confirms diagnosis of PE and may not be immediately available. A CTPA diagnoses PE and identifies limited parameters of RVD, usually as right ventricle (RV) dilatation. Radiologists usually report on RVD as a binary variable of RV to left ventricle diameter ratio (RV:LV) using a range of cut-offs from 0.9 to 1.5.[2–7] Right ventricular dysfunction on CTPA, when expressed as a continuous variable, may be a better predictor than its binary version.

Consistent reporting of RVD measurements may be labor intensive for radiologists. Artificial intelligence (AI) algorithms have been developed to assist radiologists' workflow by simultaneously interpreting presence of filling defects and measuring cardiac chamber sizes.[8,9] While RVD by CTPA or echocardiography is an independent predictor of acute clinical deterioration,[10] there have been inconsistent results regarding its relationship with 30-day mortality.[4,6,11–13] Echocardiography studies have shown that as RVD severity increases, both risk of clinical deterioration and use of advanced interventions increase.[14]

We aimed to characterize the association of AI-derived CTPA cardiac measurements with in-hospital clinical deterioration (primary outcome) in a registry of patients with intermediate- to high-risk PE. The secondary objective was to compare retrospectively derived AI measurements in patients with or without use of advanced interventions (secondary outcome). For our exploratory objectives, we compared 1) radiologist vs AI-derived CTPA categorization of RV:LV and 2) AI vs echocardiography measurements. If, by retrospective study, we were to show that AI-derived CTPA measurements are strongly associated with acute clinical deterioration, then capturing immediately available CTPA cardiac measurements within clinical workflow could improve PE risk stratification.[15]

Population Health Research Capsule

What do we already know about this issue?
Pulmonary embolism (PE) response teams focus on patients with right ventricular dysfunction using CT findings of right ventricle to left ventricle (RV:LV) ratio of 1.0 or greater.

What was the research question?
What CT RV:LV measurements are associated with acute clinical deterioration?

What was the major finding of the study?
The optimal cut-off for RV:LV on CT was 1.54 with an odds ratio of 2.50 (1.85–3.45) for acute clinical deterioration.

How does this improve population health?
A RV:LV threshold of 1.5 on CT may improve PE risk stratification and inform use of inpatient resources.

METHODS

Study Setting and Design

We conducted a retrospective analysis of data in our Clinical Outcomes Pulmonary Embolism Research Registry (COPERR). The COPERR is populated with adult patients identified as intermediate- or high-risk PE at presentation to any of eight Atrium Health emergency departments (ED) in North Carolina. We extracted data for registry patients who were treated between June 6, 2018–August 31, 2023. In November 2023, we requested a retrospective, remote AI analysis of CTPAs with confirmed index PE from this population of registry patients.

Selection of Participants

Using the COPERR database, we identified adult patients (≥18 years) presenting to a participating ED who had 1) acute symptomatic PE as the primary ED diagnosis (by positive CTPA) and 2) intermediate- or high-risk PE classification. The PE risk was classified by emergency clinicians using European Society of Cardiology (ESC) guidelines[1] and our PE response team's (PERT) "Code PE" pathway (Supplemental Figure 1). The latter shows the structure, function, and logistics of PERT activation, triaging, multispecialty notification, and considerations for advanced PE interventions based on PE severity and bleeding risk. For the exploratory objective, we included above-mentioned patients with comprehensive transthoracic echocardiography (TTE) and RV-focused measurements completed within 24 hours of PE diagnosis.

We included patients with intermediate- or high-risk PE at ED presentation with CT images of 1-mm slice thickness available for AI analysis for the primary objective and with any AI analysis for the secondary objective. We excluded the following: patients with PE diagnosed only by high-probability ventilation/perfusion nuclear imaging; those whose point-of-care TTE findings were highly suspicious of PE but PE was not confirmed by CT; and those whose CTPA

was not for index PE. We also excluded CTPAs that could not be analyzed by AI algorithm.

Data Collection and Processing

Data entered in COPERR and available for analysis included demographics; clinical presentation features (including initial and worst vital signs within three hours of ED presentation); comorbidities; PE risk factors; criteria used for PE risk stratification; radiologist report of RV:LV; TTE measurements, dates, and times; PERT notification dates and times; laboratory measurements; PE-related outcomes and interventions; and adverse events.[14,16,17] Trained data extractors retrieved information from the electronic health record and entered data in the registry.

During real-time clinical care of index PE hospitalization, RV:LV was measured by board-certified radiologists, and TTE was performed by certified cardiac sonographers from an echocardiography laboratory accredited by the Intersocietal Commission for the Accreditation of Echocardiography Laboratories. Given this was a retrospective study, the radiologists and sonographers were not aware of the study or its objectives. Radiologists measured RV:LV on the minor cardiac axis on CTPA. Measurements were at the widest points between the inner free wall of each ventricle to the inner wall of the ventricular septum. Radiologists used RV:LV cut-off of 1.0, with less than 1.0 considered negative for RV dilatation.

Sonographers used standard or RV-focused apical views to measure end-diastolic RV inner diameter at the base. The LV basal end-diastolic measurements were performed in the parasternal long axis view. Images were uploaded into a secure local server and portal system Merge Cardio (Merative LP, Ann Arbor, MI [formerly IBM Watson Health]). Board-certified cardiologists interpreted images and measurements and were blind to study and clinical outcomes. Only initial echocardiography measurements for index PE hospitalization were used in this study.

For each registry patient included in the study, we exported the fully anonymized digital imaging and communications in medicine (DICOM) file for each CTPA to share with the AI vendor for analysis. We transferred DICOM data from our study center to the server of an AI operating system (Aidoc, Tel Aviv, Israel) using encrypted secure file transfer protocol. Prior to transfer, all data were de-identified per the safe harbor de-identification protocol defined by the Health Insurance Portability and Accountability Act. The *de-identified accession number* was extracted from the DICOM header of shared studies. The study center used the key pair of *de-identified accessions* and *identified accessions* computed at the data anonymization step to re-identify data for the study.

The Aidoc PE algorithm is FDA cleared via the 510(k) premarket notification pathway required of all AI software medical devices. Aidoc's use in detecting PE on CTPAs has been previously reported.[8,18] The prototype of the PE detection algorithm was developed using input from anonymized, 1-mm series of CTPA reconstructions and based on a deep convolutional neural network comprising a Resnet architecture and trained and validated on over 25,000 CTPAs taken from many institutions. Aidoc algorithms had specific CTPA inclusion criteria, including slice thickness, kernel, and contrast phase to allow analysis. Aidoc has two software components: one for software analysis of CTPA DICOM files, and another for real-time analysis and reporting of interpretations to clinicians and radiologists. Only the first component was used in this study. The AI analyses of CTPAs and measurements were not performed during real-time clinical care.

Each CTPA was analyzed by two AI algorithms independently. For the first algorithm, if a PE was detected, AI determined whether the PE was a central clot or not. Central clot was defined by the following locations: pulmonary trunk; saddle (bifurcation of the main pulmonary artery trunk); right or left main pulmonary arteries or lobar pulmonary arteries. For the second algorithm, AI measured each RV and LV largest diameter (between inner walls) as a number and calculated the ratio of RV to LV. This was produced in a four-step process, including ventricular detection, ventricular segmentation, interventricular septum detection, and caliper positioning and measurements. The AI algorithm also identified patients with large central PEs. It is important to note a subsegmental PE did not provide a positive result. This was done to allow the AI-augmented clinical workflow to accurately identify acute PEs with RV dilatation as necessary conditions for intermediate- and high-risk PE classification.

The AI-based algorithm variables included the following categorical values: 1) Did the Aidoc algorithm analyze the data (yes or no); and 2) did the CTPA contain a PE (yes or no)? The AI-based continuous variables were RV basal diameter, LV basal diameter, and RV:LV. All data for AI-derived CTPA variables were matched to pertinent study IDs and uploaded into a standard electronic form within Research Electronic Data Capture (REDCap) tools at our institution.

Outcomes

The primary outcome was PE-related clinical deterioration, defined as a composite of one or more of the following clinical deterioration events within days of index PE hospitalization: death; cardiac arrest; sustained hypotension treated with vasoactive medications; or rescue respiratory intervention (mechanical or positive pressure ventilation).[14] The secondary outcome was use of advanced PE-specific interventions, including systemic thrombolysis, catheter-directed interventions, extracorporeal membrane oxygenation (ECMO), or surgical embolectomy.

Statistical Analysis

Sample size was determined by the number of patients eligible for study analysis. To determine association with PE-related clinical deterioration (primary outcome), we used various statistical methods. We used bivariable analysis with the Student *t*-test or chi square to stratify by primary outcome groups. We conducted multivariable analyses for the primary outcome in two ways. First, we used least absolute shrinkage and selection operator (LASSO) regression to develop two models, one with AI assessment variables only and one with all independent variables. We reported missingness of each variable and used complete case analysis. We expressed strength of association as odds ratios with 95% confidence intervals (CI). Second, we used random forest (RF) to statistically infer the strength of the association of all independent variables in the dataset and identify the top 20 predictors of PE-related clinical deterioration (primary outcome) in a variable importance plot.

For each model's prognostic performance on the primary outcome, we reported discrimination as area under the curve (AUC) and calibration as calibration plots with calibration statistics, including Brier, Brier scaled, intercept and slope. Performance for RF and LASSO logistic models was based on out-of-bag samples and 10-fold cross validation, respectively. Finally, to address the trade-off of false positives and false negatives, we used the Youden index to determine optimal RV:LV cut-offs and other AI-derived measurements for prognosis of clinical deterioration. For the selected optimal RV:LV and other AI cardiac measurements, we determined sensitivity, specificity, likelihood ratios, and AUC with 95% CI.

To determine association with the use of advanced interventions (secondary outcome), we used bivariable analysis with the Student *t*-test or chi square to stratify by secondary outcome groups. To measure reliability between AI-derived and radiologist CT classification of RV:LV ≥ 1.0 vs < 1.0, we used the Cohen kappa with its 95% CIs. We used suggested guidelines of Landis and Koch to describe the strength of agreement for the κ statistic: less than 0 = poor; 0 to 0.20 = slight; 0.021 to 0.40 = fair; 0.41 to 0.60 = moderate; 0.61 to 0.80 = substantial; and 0.81 to 1.00 = almost perfect.[19]

We reported mean and standard deviation time intervals in hours between PERT notification and TTE for the middle 95%. We used two methods to assess agreement between AI-derived CT cardiac and TTE measurements for RV, LV, and RV:LV. First, we used Pearson correlations with 95% CIs for continuous variables to test for magnitude and direction of linear relationships.[20] Second, we used Bland-Altman plots to depict the relationship of difference and mean for each pair of CTPA and TTE measurements.

Disclosures

Regarding the relationship with the company that developed and markets the AI-based PE algorithm used in this study, we declare that Aidoc had no role in the design of the study, the collection, analysis, and interpretation of data, or the preparation of the published manuscript. We further declare that we have not received and will not receive any compensation, direct or indirect, from Aidoc or any of its affiliates. We do not own stock in the company.

RESULTS

Study Flow

Figure 1 shows we screened 1,809 patients with CTPA-confirmed acute PE diagnosed in ED. Of these, 1,664 (92.0%) had CTPA associated with index PE diagnosis and anonymized DICOM files transferred for AI analysis. Radiologists provided categorical RV:LV classification for 1,467 of 1,664 (88.2%) CTPAs. The AI vendor analyzed 1,660 of the 1,664; four cases were excluded because of inadequate CTPA slice thickness for AI analysis. The AI assessment for central clot was successful in all (100%) CTPAs and 1,267 (76.3%) were found to have large central PE by the algorithm. The AI-derived cardiac measurements were obtained for 1,617/1,660 (97.4%). The AI failed to analyze 43 CTPAs because 1) they did not meet study inclusion criteria (i.e., slice thickness, kernel, contrast phase), or 2) the RV:LV algorithm was unable to detect appropriate landmarks to perform RV:LV analysis. Of 1,664 CTPAs, 733 (44.1%) had comprehensive TTE measurements during index PE hospitalization. Mean and SD for time interval between CTPA and TTE for the middle 95% was 13.6 (11.3) hours.

We were able to determine primary outcome responses for 1,639 unique patients (Table 1) and secondary outcome for 1,643 unique patients. Of the 1,639, mean age was 63.0 ± 16 years, 805 (49.1%) were male, 997 (60.8%) were White, and 190 (11.6%) had one or more components of the primary outcome. Four patients had more than one ED visit for acute PE during the 2018–2023 study period. We reported PE-related clinical deterioration (primary outcome) for first visit only.

Patient Characteristics

There were no significant differences between those with or without clinical deterioration for age, gender, race, or ethnicity. There were significant differences for mean values of vital signs. Patients who had PE-related clinical deterioration (primary outcome) had lower systolic blood pressure and oxygen saturation readings and higher respiratory rate and heart rates than patients without clinical deterioration. There was significantly increased use of systemic thrombolysis, ECMO, and surgical embolectomy in the primary outcome group. However, there were no significant differences in use of catheter-directed interventions between outcome groups. For categorical cardiac CTPA assessments, Table 1 shows radiologists' binary categorization of RVD using the RV:LV cut-off 1.0 was not significant between primary outcome groups. In

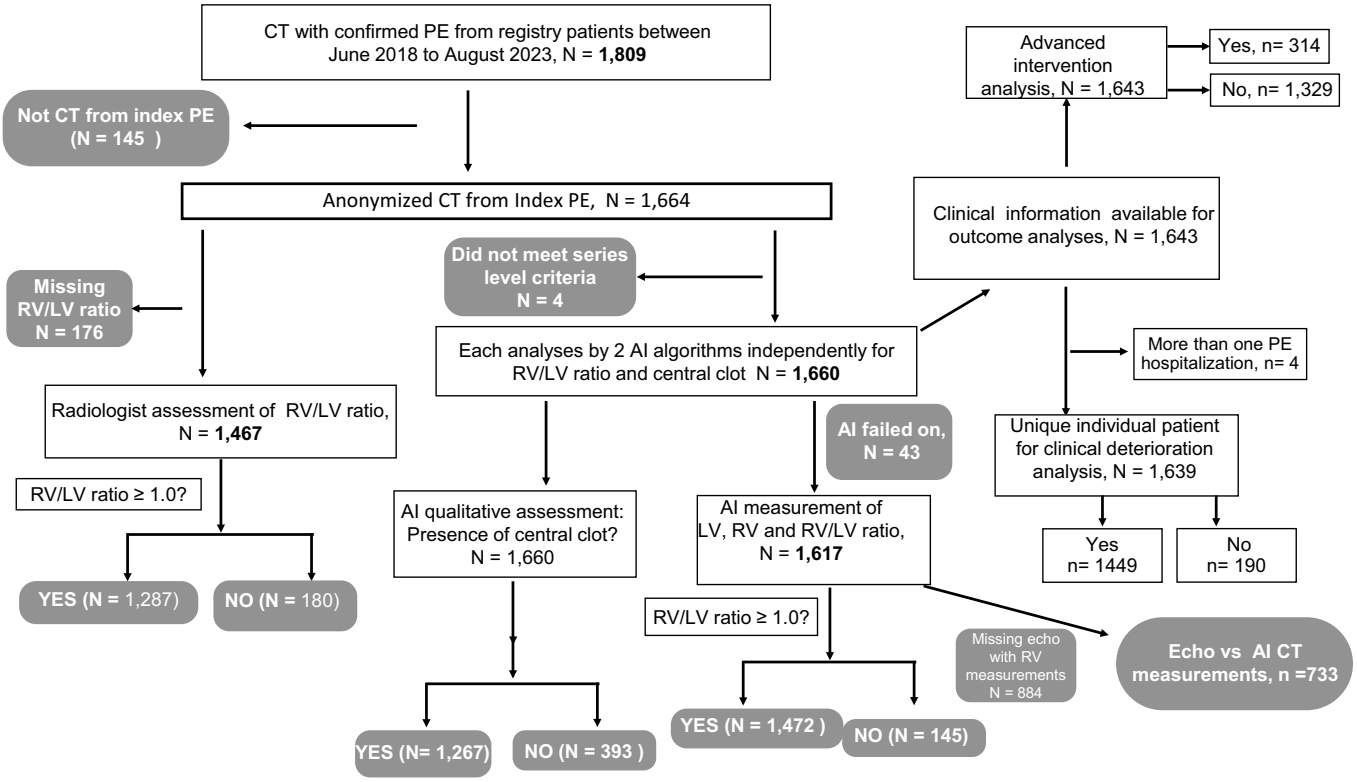

Figure 1. Study flow diagram*.
AI, artifical intelligence; *PE*, pulmonary embolism; *CTPA*, computed tomography pulmonary angiography, *RV*, right ventricle; *LV*, left ventricle.

contrast, AI-derived RV:LV binary categorization was significant. For mean AI-derived CTPA measurements, Table 1 shows significant differences in RV:LV, RV, and LV basal diameters between those with and without clinical deterioration.

For the 733 patients with TTE, TTE measurements were less than AI-derived CT cardiac measurements. Only LV basal diameter had significant differences between the primary outcome groups. Although mean RV basal diameter was above normal limits, the difference was not statistically significant for outcome-negative and outcome-positive groups.

Primary Outcome

Multivariable analyses with unadjusted LASSO for PE-related clinical deterioration (primary outcome) showed the most significant independent AI-derived predictors were RV:LV (19.28 [3.0–109.4]) and central clot by AI (2.4 [1.6–3.6]). Both the adjusted LASSO and RF models vetted all candidate database variables. Both RF and adjusted LASSO prognostic models had excellent discrimination and calibration metrics for prognostic accuracy (Supplemental Figure 2): For discrimination, adjusted LASSO and RF had AUC of 0.88 (0.85, 0.90) and 0.87 (0.84, 0.89), respectively. Both models were well calibrated with Brier scores of 0.07. The RF model was slightly less calibrated than the LASSO model on other calibration metrics.

Table 2 and Figure 2 show cardiac arrest at presentation was the top predictor of in-hospital clinical deterioration in both multivariable models (LASSO and RF). Admission to the intensive care unit, lowest systolic blood pressure, lowest oxygen saturation, and highest heart and respiratory rates were also top predictors in both models. The CTPA cardiac measurements were among the top 11 predictors selected by LASSO. Abnormal troponin was one of the top predictors by LASSO but had a lower influence on RF model accuracy than CTPA assessments. The CTPA cardiac measurements and findings of central clot location with RV:LV ≥ 1.0 were among the top 10 independent predictors of clinical deterioration in the RF model.

Table 1. Patient and imaging characteristics by pulmonary embolism-related clinical deterioration (primary outcome).

	Primary outcome (–) (n = 1,449)	Primary outcome (+) (n = 190)	Total N = 1,639	*P*-value
Age, years				
Mean (SD)	62.8 (16.0)	63.2 (15.4)	62 (15.9)	0.73
Race				
White	893 (61.6%)	104 (54.7%)	997 (60.8%)	0.41
Black	504 (34.8%)	81 (42.6%)	585 (35.7%)	
American Indian/Alaskan Native	12 (0.8%)	2 (1.1%)	14 (0.9%)	
Asian	5 (0.3%)	0 (0%)	5 (0.3%)	
Other	7 (0.5%)	0 (0%)	7 (0.4%)	
Pacific Islander/Native Hawaiian	1 (0.1%)	0 (0%)	1 (0.1%)	
Unknown	27 (1.9%)	3 (1.6%)	30 (1.8%)	
Sex				
Male	724 (50.0%)	81 (42.6%)	805 (49.1%)	0.06
Female	725 (50.0%)	109 (57.4%)	834 (50.9%)	
Ethnicity				
Non-Hispanic/Latino	1,347 (93.0%)	181 (95.3%)	1,528 (93.2%)	0.4
Hispanic/Latino	33 (2.3%)	3 (1.6%)	36 (2.2%)	
Unknown	69 (4.8%)	6 (3.2%)	75 (4.6%)	
Body surface area				
Mean (SD)	2.1 (0.328)	1.9 (0.338)	2 (0.331)	0.01
Intensive care unit admission				
No	759 (52.4%)	27 (14.2%)	786 (48.0%)	<0.001
Yes	686 (47.3%)	163 (85.8%)	849 (51.8%)	
Missing	4 (0.3%)	0 (0%)	4 (0.2%)	
Prior diagnosis of PE or DVT?				
No	1,118 (77.2%)	149 (78.4%)	1,267 (77.3%)	0.76
Yes	331 (22.8%)	41 (21.6%)	372 (22.7%)	
Family history of VTE?				
No	1,312 (90.5%)	180 (94.7%)	1,492 (91.0%)	0.07
Yes	128 (8.8%)	9 (4.7%)	137 (8.4%)	
Missing	9 (0.6%)	1 (0.5%)	10 (0.6%)	
Recent hospitalization (in 3 weeks)?				
No	1,260 (87.0%)	143 (75.3%)	1,403 (85.6%)	<0.001
Yes	187 (12.9%)	47 (24.7%)	234 (14.3%)	
Missing	2 (0.1%)	0 (0%)	2 (0.1%)	
Anticoagulation use?				
No	1,315 (90.8%)	170 (89.5%)	1,485 (90.6%)	0.60
Yes	131 (9.0%)	20 (10.5%)	151 (9.2%)	
Missing	3 (0.2%)	0 (0%)	3 (0.2%)	
Current or recent pregnancy (or miscarriage) within 6 weeks				
No	1,271 (87.7%)	173 (91.1%)	1,444 (88.1%)	0.96
Yes	12 (0.8%)	1 (0.5%)	13 (0.8%)	
Missing	166 (11.5%)	16 (8.4%)	182 (11.1%)	

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Table 1. Continued.

	Primary outcome (–) (n = 1,449)	Primary outcome (+) (n = 190)	Total N = 1,639	*P*-value
Recent limb immobilization (current or within 3 weeks)				
No	1,381 (95.3%)	173 (91.1%)	1,554 (94.8%)	0.02
Yes	64 (4.4%)	16 (8.4%)	80 (4.9%)	
Missing	4 (0.3%)	1 (0.5%)	5 (0.3%)	
Recent trauma (in the prior 4–6 weeks)?				
No	1,417 (97.8%)	185 (97.4%)	1,602 (97.7%)	0.91
Yes	32 (2.2%)	5 (2.6%)	37 (2.3%)	
Surgery required (mechanical ventilation or epidural) within 6 weeks?				
No	1,323 (91.3%)	167 (87.9%)	1,490 (90.9%)	0.16
Yes	126 (8.7%)	23 (12.1%)	149 (9.1%)	
Clotting disorders (protein C, S, factor V deficiency)?				
No	1,394 (96.2%)	181 (95.3%)	1,575 (96.1%)	0.52
Yes	44 (3.0%)	8 (4.2%)	52 (3.2%)	
Missing	11 (0.8%)	1 (0.5%)	12 (0.7%)	
Hormone replacement therapy				
No	1,354 (93.4%)	179 (94.2%)	1,533 (93.5%)	0.80
Yes	95 (6.6%)	11 (5.8%)	106 (6.5%)	
Known pulmonary hypertension				
No	1,382 (95.4%)	179 (94.2%)	1,561 (95.2%)	0.59
Yes	67 (4.6%)	11 (5.8%)	78 (4.8%)	
Chronic pulmonary disease				
No	1,199 (82.7%)	147 (77.4%)	1,346 (82.1%)	0.08
Yes	250 (17.3%)	43 (22.6%)	293 (17.9%)	
Congestive heart failure				
No	1,333 (92.0%)	169 (88.9%)	1,502 (91.6%)	0.19
Yes	116 (8.0%)	21 (11.1%)	137 (8.4%)	
Total Charlson comorbidity index				
Mean (SD)	1.4 (2.16)	1.9 (2.38)	1 (2.20)	0.003
Median [min, max]	0 [0, 14.0]	1.0 [0, 9.00]	0 [0, 14.0]	
Lowest systolic BP (within 3 hours), mm Hg				
Mean (SD)	121 (21.8)	97.1 (27.0)	118 (23.7)	<0.001
Lowest O_2 sat (within 3 hours), %				
Mean (SD)	93.1 (5.52)	85.5 (16.4)	92 (8.00)	<0.001
Missing	2 (0.1%)	1 (0.5%)	3 (0.2%)	
Highest HR (within 3 hours)				
Mean (SD)	106 (21.2)	120 (22.2)	108 (21.8)	<0.001
Median [min, max]	106 [11.0, 198]	121 [62.0, 178]	108 [11.0, 198]	
Highest RR (within 3 hours)				
Mean (SD)	24.4 (8.64)	31.3 (11.1)	25 (9.22)	<0.001
Median [min, max]	23.0 [14.0, 200]	30.0 [16.0, 103]	23 [14.0, 200]	
Missing	4 (0.3%)	2 (1.1%)	6 (0.4%)	

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Table 1. Continued.

	Primary outcome (−) (n = 1,449)	Primary outcome (+) (n = 190)	Total N = 1,639	*P*-value
Shock index greater than 1.0?				
No	1,080 (74.5%)	69.0 (36.3%)	1,149 (70.1%)	0.01
Yes	179 (12.4%)	23.0 (12.1%)	202 (12.3%)	
Missing	190 (13.1%)	98 (51.6%)	288 (17.6%)	
Advanced/escalated PE intervention?				
No	1,233 (85.1%)	92 (48.4%)	1,325 (80.8%)	<0.001
Yes	216 (14.9%)	98 (51.6%)	314 (19.2%)	
Type of advanced intervention: systemic thrombolysis				
No	1,377 (95.0%)	127 (66.8%)	1,504 (91.8%)	<0.001
Yes	72 (5.0%)	63 (33.2%)	135 (8.2%)	
Catheter-directed intervention				
No	1,337 (92.3%)	173 (91.1%)	1,510 (92.1%)	0.65
Yes	112 (7.7%)	17 (8.9%)	129 (7.9%)	
Right ventricular assist device				
No	1,449 (100%)	190 (100%)	1,639 (100%)	NA
Yes	0 (0%)	0(0%)	0 (0%)	
ECMO				
No	1,449 (100%)	185 (97.4%)	1,634 (99.7%)	<0.001
Yes	0 (0%)	5 (2.6%)	5 (0.3%)	
Inferior vena cava filter used				
No	1,411 (97.4%)	177 (93.2%)	1,588 (96.9%)	0.17
Yes	34 (2.3%)	8.00 (4.2%)	42 (2.6%)	
Missing	4.0 (0.3%)	5.0 (2.6%)	9 (0.5%)	
Computed tomography assessment of CT by radiologists				
RV:LV < 1.0	157 (10.9%)	24.0 (12.6%)	181 (11.0%)	0.53
RV:LV ≥ 1.0	1,153 (79.8%)	147 (77.4%)	1,303 (79.5%)	
Missing	135 (9.3%)	19 (10%)	155 (9.5%)	
RV:LV (AI)				
RV:LV ≥ 1	1,115 (77.2%)	132 (69.5%)	1,250 (76.3%)	0.02
RV:LV < 1	330 (22.8%)	58 (30.5%)	389 (23.7%)	
RV basal width, by AI, cm				
Mean (SD)	5.2 (0.73)	5.3 (0.71)	5 (0.730)	0.02
Missing	20 (1.4%)	6 (3.2%)	26 (1.6%)	
LV basal width, by AI, cm				
Mean (SD)	3.8 (0.72)	3.6 (0.77)	3 (0.732)	<0.001
Missing	20 (1.4%)	6 (3.2%)	26 (1.6%)	
RV:LV ratio, by AI				
Mean (SD)	1.3 (0.324)	1.5 (0.39)	1 (0.336)	<0.001
Missing	20 (1.4%)	6 (3.2%)	26 (1.6%)	

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Table 1. Continued.

	Primary outcome (–) (n = 1,449)	Primary outcome (+) (n = 190)	Total N = 1,639	*P*-value
Echocardiography RV basal width (ECHO)				
Mean (SD)	4.22 (0.811)	4.25 (0.814)	4 (0.812)	0.70
Missing	640 (44.2%)	110 (57.9%)	752 (45.9%)	
LV basal width (ECHO)				
Mean (SD)	4.1 (0.811)	3.9 (0.846)	4 (0.817)	0.004
Missing	153 (10.6%)	42 (22.1%)	196 (12.0%)	
RV:LV (ECHO)				
Mean (SD)	1.0 (0.272)	1.1 (0.332)	1 (0.278)	0.07
Missing	685 (47.3%)	116 (61.1%)	1 (0.278)	
RV:LV cut-off = 1.0 by cardiologist				
RV:LV ≥ 1.0	1,155 (79.7%)	147 (77.4%)	1,302 (79.4%)	0.72
RV:LV < 1.0	158 (10.9%)	24 (12.6%)	182 (11.1%)	
Missing	136 (9.4%)	19 (10%)	155 (9.5%)	
Abnormal troponin*	965 (66.6%)	163 (85.5%)	1,128 (68.8%)	<0.001
Initial troponin, ng/mL				
Mean (SD)	0.22 (1.45)	0.37 (0.92)	0.24 (1.4)	0.19
Missing	725 (50.0%)	98 (51.6%)	823 (50.2%)	
Initial high-sensitivity troponin, mean (SD), ng/mL	195 (606)	434 (1,420)	224 (756)	0.10
Missing	711 (49.1%)	88 (46.3%)	99 (48.17%)	

*We used troponin I or high-sensitivity troponin assays (Abbott, Abbott Park, IL) measured in ng/mL assay. Normal values for troponin I were less than 0.07 ng/mL. Normal values for high-sensitivity troponin were less than 12 for females and less than 20 for males. Abnormal troponin levels were higher than above-mentioned cut-offs.
AI, artificial intelligence algorithm; *CT*, computed tomography; *BP*, blood pressure; *DVT*, deep vein thrombosis; *ECHO*, echocardiography; *ECMO,* extracorporeal membrane oxygenation; *HR*, heart rate; *ng/mL*, nanograms per milliliter; O_2 *sat*, oxygen saturation; *RR*, respiratory rate; *LV*, left ventricle; *RV*, right ventricle; *RV:LV*, right ventricle to left ventricle diameter ratio; *VTE*, venous thromboembolism.

Table 3 shows optimal cut-offs of AI-derived cardiac CTPA measurements with prediction metrics for PE-related clinical deterioration as RV:LV 1.54 (OR 2.5 [1.85–3.45] and AUC 0.6 [0.66, 0.70]). These cut-off values had high negative predictive values (NPV) but low positive predictive values (PPV).

Secondary Outcome

Table 4 shows bivariable analysis of cardiac assessments stratified by use of advanced interventions (secondary outcome). Regardless of how cardiac measurements were derived, there were significant differences in cardiac measurements (whether continuous or categorical) between those with and without advanced interventions. For example, AI-derived CTPA RV:LV means with SDs were 1.62 (0.33) vs 1.35 (0.32) for those with and without advanced interventions (secondary outcome), respectively. With TTE, RV:LV means were 1.17 (0.29) vs 1.02 (0.27) for those with and without advanced interventions, respectively.

Exploratory Outcomes

There was agreement between AI and radiologists on RV:LV ≥ 1.0 for 1,224 cases and on RV:LV <1.0 for 67 cases (88% overall agreement [kappa 0.36, 95% CI 0.28–0.43], data not shown). The RV:LV means with SDs were 1.48 (0.31) and 0.86 (0.11), respectively. There was disagreement for 178 (12.1%) cases. RV:LV means were 1.23 (0.23) and 0.92 (0.05) when AI reported abnormal RV:LV vs RV:LV < 1.0, respectively. For comparison of AI-derived CTPA with TTE measurements, Pearson correlation coefficients for RV, LV, and RV:LV were 0.47 (0.42, 0.52), 0.58 (0.53, 0.62), and 0.50 (0.45, 0.55), respectively. All kappas were interpreted as moderate agreement per Landis and Koch guidelines. Supplemental Figure 3 shows strong negative bias with lower TTE measurements than CTPA measurements at presentation.

DISCUSSION

We found AI-derived RV:LV measurements on CTPA were significantly greater in PE patients experiencing clinical

Table 2. LASSO* regression models (unadjusted and adjusted) for pulmonary embolism-related clinical deterioration (primary outcome).

Unadjusted model with AI-derived CTPA assessments only			
	PE-related clinical deterioration (primary outcome)		
Predictors	***Odds ratios***	***Confidence interval***	***P-value***
RV:LV by AI	19.28	3.03–109.36	0.001
Central clot by AI	2.44	1.64–3.63	<0.001
RV diameter by AI	0.62	0.36–1.10	0.10
LV diameter by AI	1.46	0.68–2.93	0.31
Observations	1617		
R^2 Tjur	0.046		
Adjusted model with all variables considered			
	PE-related clinical deterioration (primary outcome)		
Predictors	***Odds ratios***	***Confidence interval***	***P-value***
Initial cardiac arrest requiring CPR	97.6	29.14–462.2	<0.001
ICU admission	4.43	2.77–7.96	<0.001
Abnormal troponin	2.34	1.42–7.96	0.001
CTPA central clot location with RV:LV >1.0, determined by AI	2.08	1.30–3.31	0.002
Previous hospitalization within 3 weeks	1.71	1.05–2.73	0.03
Total Charlson comorbidity index	1.10	1.01–1.19	0.02
Highest respiratory rate within 3 hours of presentation	1.02	1.00–1.05	<0.001
Lowest systolic blood pressure within 3 hours of presentation	0.97	0.96–0.98	<0.001
Observations	1,617		
R^2 Tjur	0.347		

**LASSO*, least absolute shrinkage and selection operator; *PE*, pulmonary embolism; *AI*, artificial intelligence; *CTPA*, computed tomography pulmonary angiogram; *RV*, right ventricle; *LV*, left ventricle; *CPR*, cardiopulmonary resuscitation; *ICU*, intensive care unit.

deterioration or receiving advanced intervention than those without these outcomes. There was significantly increased use of systemic thrombolysis, ECMO, and surgical embolectomy in the primary outcome group. In our models, which had strong discrimination and calibration, AI-derived RV:LV measurements were independent predictors of clinical deterioration, along with abnormal vital signs and cardiac arrest at presentation in one or both multivariable models. The optimal RV:LV cut-off of 1.5 had an odds ratio of 2.5 and AUC of 0.6 for PE-related clinical deterioration (primary outcome). The AI-derived RV:LV measurements performed better as predictors of primary and secondary outcomes than radiologists' or AI-derived categorizations using RV:LV cut-off of 1.0.

Other reports have focused on outcomes similar to ours. Beigel et al. performed a study evaluating 179 intermediate-risk PE patients for predictors of short-term death and advanced interventions.[21] Twenty-six patients required advanced intervention, which was significantly associated with echocardiographic evidence of severe RVD (42% vs 19%, $P < 0.01$) or higher RV:LV measurement on CTPA (1.9 ± 0.6 vs 1.46 ± 0.5, $P < 0.001$). The RV dilatation on TTE was an independent predictor for advanced interventions. This information further corroborates the importance of measurements to risk stratify PE patients. Unlike TTE measurements, cardiac CTPA measurements are immediately available at the time of PE diagnosis for risk stratification.[22]

Other studies that assessed how CTPA cardiac measurements are associated with clinical outcomes had mixed results. A retrospective study by Foley et al. involving 101 patients with CT-proven PEs of any severity at a single center showed strong agreement (intraclass correlation 0.83, [0.77–0.88]) between radiologists' and AI-derived CTPA measurements for RV:LV.[15] In this study, RV:LV ranged from 0.67–2.43, with 65% being ≥ 1.0. The optimal RV:LV cut-off for 30-day mortality was 1.18. The use of AI analysis in our study led to a change in risk stratification in 45% of patients. However, in a large prospective study of 1,950 CT-confirmed PEs by Beenen et al., RV:LV measurements by radiologists were not significantly different between those with and without short-term mortality.[23] Similar to the Foley et al. study, we found an elevated RV:LV had a strong association with in-hospital clinical deterioration in our

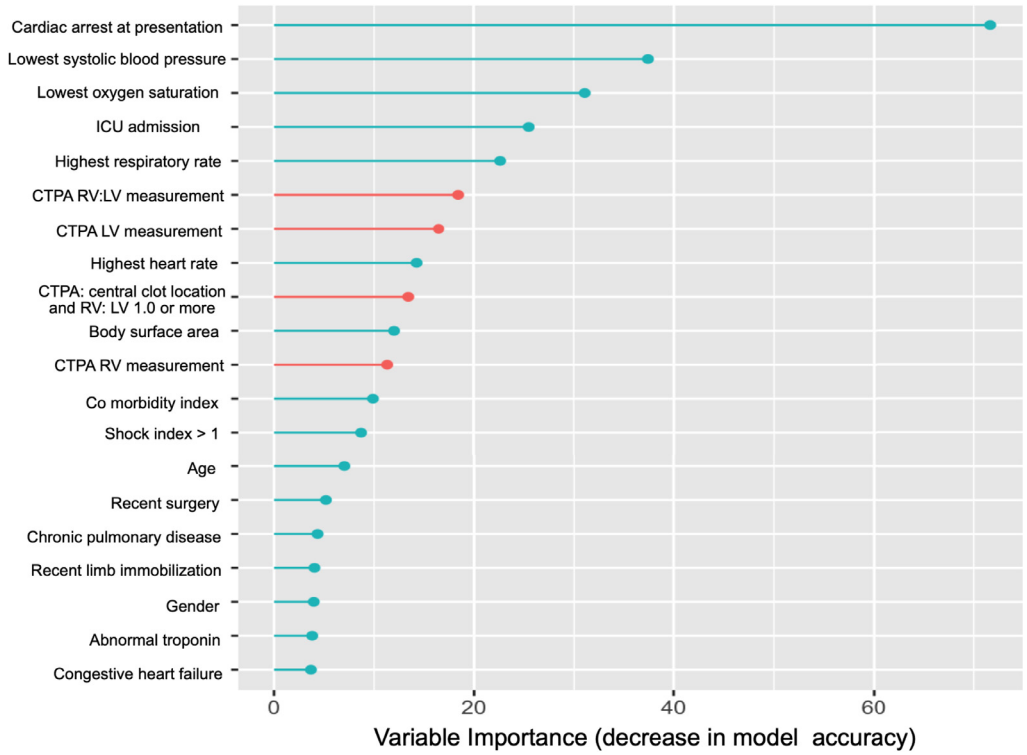

Figure 2. Random forest variable importance plot for predicting clinical deterioration.
CTPA, computed tomography pulmonary angiography; *LV*, left ventricle; *RV*, right ventricle; *ICU*, intensive care unit.

Table 3. Optimal cut-offs of artificial intelligence-derived cardiac CTPA* measurements with prediction metrics for pulmonary embolism-related clinical deterioration (primary outcome).

Variable	Cut-off	*P*-value	Sensitivity	Specificity	PPV	NPV	AUC	Odds ratio
RV:LV by AI	1.54	<0.001	0.52 (0.45, 0.59)	0.7 (0.67, 0.72)	0.18 (0.15, 0.22)	0.92 (0.9, 0.94)	0.63 (0.59, 0.68)	2.53 (1.85, 3.45)
RV diameter by AI, cm	5.30	0.03	0.57 (0.5, 0.64)	0.54 (0.51, 0.57)	0.14 (0.11, 0.16)	0.91 (0.89, 0.93)	0.56 (0.51, 0.6)	1.56 (1.15, 2.13)
LV diameter by AI, cm	4.02	<0.001	0.61 (0.54, 0.68)	0.62 (0.59, 0.64)	0.17 (0.14, 0.2)	0.93 (0.91, 0.94)	0.63 (0.59, 0.68)	2.58 (1.88, 3.54)

**CTPA*, computed tomography pulmonary angiogram; *AI*, artificial intelligence; *cm*, centimeter; *PPV*, positive predictive value; *NPV*, negative predictive value; *AUC*, area under the curve; *RV*, right ventricle; *LV*, left ventricle.

intermediate- and high-risk PE cohort. Our optimal RV:LV cut-off of 1.5 was higher than theirs.

A previous report showed fair agreement (kappa 0.4) for categorical assessments of RV dysfunction between CTPA and TTE.[22] Our study found moderate agreement of RV:LV measurements by CTPA and TTE. We believe our findings underscore the importance of using immediately available CTPA measurements of RVD for risk stratification and prognosis. However, at many institutions, RV measurements are not routinely performed or interpreted on CTPA. One study in a large regional healthcare system with 21 sites showed only 18.3% of 1,571 positive CTPA interpretation reports included RV measurements.[24]

The use of AI to detect PE and analyze CTPA cardiac measurements at time of PE presentation may improve risk stratification for PERTs and provide quality assurance to enhance radiologists' workflow. The diagnostic accuracy of AI should include a low number of false positives to minimize notification fatigue and potential for medication mismanagement. In a retrospective multicenter study, Cheik et al. evaluated diagnostic performances of the Aidoc PE algorithm on CTPAs and compared them with those of radiologists to determine impact of AI PE detection.[18] Of 1,202 patients included, the AI algorithm detected 219 suspicious PEs, of which 176 were true PEs, including 19 true PEs missed by radiologists. The highest sensitivity and NPVs were obtained with AI, while the highest specificity and PPV were found with radiologists. Our retrospective study focused on less subtle PE diagnoses; the AI analysis was specifically created to focus on non-segmental PE, and AI

Table 4. Cardiac assessments grouped by use of advanced intervention (secondary outcome).

	No advanced intervention (n = 1,329)	Advanced intervention (n = 314)	Total N = 1,643	*P*-value
CT assessment by radiologist				
RV:LV ≥ 1.0	1,031 (77.6%)	274 (87.3%)	1,305 (79.4%)	<0.001
RV:LV < 1.0	165 (12.4%)	17 (5.4%)	182 (11.1%)	
Missing	133 (10%)	23 (7.3%)	156 (9.5%)	
CT assessments by AI				
RV:LV > 1 (AI)				
RV:LV > = 1	967 (72.8%)	286 (91.1%)	1,253 (76.3%)	<0.001
RV:LV < 1	362 (27.2%)	28 (8.9%)	390 (23.7%)	
RV basal width (AI)				
Mean (SD)	5.14 (0.729)	5.55 (0.633)	5.22 (0.729)	<0.001
Missing	19 (1.4%)	7 (2.2%)	26 (1.6%)	
LV basal width (AI)				
Mean (SD)	3.93 (0.732)	3.53 (0.642)	3.86 (0.73)	<0.001
Missing	19 (1.4%)	7 (2.2%)	26 (1.6%)	
RV:LV (AI)				
Mean (SD)	1.35 (0.316)	1.62 (0.332)	1.40 (0.34)	<0.001
Missing	19 (1.4%)	7 (2.2%)	26 (1.6%)	
ECHO assessments				
RV:LV > = 1	1,031 (77.6%)	274 (87.3%)	1,305 (79.4%)	<0.001
RV:LV < 1	165 (12.4%)	17 (5.4%)	182 (11.1%)	
Missing	133 (10.0%)	23 (7.3%)	156 (9.5%)	
Echocardiography				
LV diameter (AI)				
Mean (SD)	3.93 (0.73)	3.53 (0.64)	3.86 (0.73)	<0.001
Missing	19 (1.4%)	7 (2.2%)	26 (1.6%)	
RV basal width (ECHO)				
Mean (SD)	4.15 (0.778)	4.55 (0.895)	4.22 (0.81)	<0.001
Missing	587 (44.2%)	165 (52.5%)	752 (45.8%)	
LV basal width (ECHO)				
Mean (SD)	4.19 (0.842)	4.02 (0.676)	4.16 (0.82)	<0.001
Missing	149 (11.2%)	47 (15.0%)	196 (11.9%)	
RV:LV (ECHO)				
Mean (SD)	1.02 (0.269)	1.17 (0.293)	1.05 (0.28)	<0.001
Missing	627 (47.2%)	177 (56.4%)	804 (48.9%)	

AI, artificial intelligence algorithm; *CT*, computed tomography; *ECHO*, echocardiography; *LV*, left ventricle; *RV*, right ventricle; *RV:LV*, right ventricle to left ventricle diameter ratio.

agreed that PE findings were present in all CTPAs. Artificial intelligence further analyzed ventricle measurements on CTPA and determined central vs non-central filling defects.

Although our comparison of CTPA RV:LV categorization by AI vs radiologists had 88% agreement, the kappa 0.34 is interpreted as fair agreement. Agreement was more likely when RV:LV was well above or well below the 1.0 cut-off; the two sources were more likely to disagree when RV:LV was closer to 1.0. It is unknown whether AI-derived CTPA measurements might "correct" radiologist assessments in real time for those close to the 1.0 cut-off or whether such a "correction" would have clinical significance on patient care

and outcomes. Even with an optimal RV:LV cut-off of 1.5, we note the low PPV for PE-related clinical deterioration. So, an RV:LV cut-off of 1.5 is not sufficient to be the sole determinant of decision-making about disposition or advanced interventions. Similar to another report, our study showed a combination of CTPA parameters (central clot location and RV:LV) had stronger associations with clinical deterioration than RV:LV alone (categorical or continuous).[22]

Incorporation of CTPA cardiac measurements in PE risk stratification may impact local/regional clinical practice or guidelines. Next steps may include prospective studies that include CTPA measurements as predictors of clinical outcomes and PERT risk stratification, and pragmatic comparisons of AI-assisted workflow vs traditional workflow in which CTPA cardiac measurements, clinical management metrics, and patient-centered outcomes are assessed.

LIMITATIONS

Our study had several limitations. First, we conducted a retrospective, remote AI analysis of CTPA with confirmed intermediate- and high-risk PE. We did not study real-time AI analyses on recently completed CTPAs. Our study design and inclusion criteria, therefore, do not lend to any interpretation about diagnostic accuracy of the AI platform on CT of patients with lower acuity PE or without PE. We cannot report on false positive or false negative interpretations, potential impact on PERT notifications or clinical management, or compare to previous reports of AI's diagnostic accuracy for PE. Theoretically, we have shown AI-derived measurements were better predictors of acute clinical deterioration than categorical radiologist assessment of RV:LV cut-off of 1.0. However, to show the impact of AI on patient care by clinicians, there would need to be pragmatic, randomized controlled trials comparing usual care vs AI-assisted clinical care. Prospective studies would enable reporting timeliness of AI analysis of CT and its effect on radiologist workload, physician notification of positive and significant findings, and impact of measurements on risk assignment, resource utilization, advanced interventions, and clinical deterioration.

Other limitations are specific to the exploratory objectives. Our study did not verify whether agreements between radiologist and AI for RV:LV $\geq$ 1.0 were correct; both interpretations could be incorrect. Study design could be improved by including a comparator, such as a reference standard (e.g., cardiac magnetic resonance imaging), use of an independent, blinded radiologist for separate measurements or to serve as an adjudicator, or earlier contemporaneous TTE measurements. For the second exploratory objective, we did not determine presence or absence of interventions in the interval between CT and TTE. The TTE and CTPA were performed at different times and often more than 12 hours apart. Therefore, the differences between these measured variables may be due to worsening or improving cardiac burden during the time intervals. Not all patients in the cohort had TTE. High missingness of TTE measurements was a limitation in comparison of them with the AI-derived CTPA measurements. The differences observed in these mean measurements may be due to different imaging modality or time interval between studies. The subgroup that had TTE likely represented those with higher acuity at presentation.

CONCLUSION

Right ventricle:left ventricle measurements of 1.5 or more on the initial CT pulmonary angiogram had strong associations with in-hospital clinical deterioration and advanced interventions in a large database of intermediate- and high-risk patients with pulmonary embolism. This study points to the potential of capitalizing on immediately available CTPA RV:LV measurements for gauging PE severity and for risk stratification.

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Monitoring the Evolving Match Environment in Emergency Medicine 2023

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Introduction: The 2023 National Residency Matching Program (NRMP) Match in emergency medicine (EM) left 554 spots and 132 EM programs unfilled. The Council of Residency Directors Match Task Force sought to characterize the programs that did and did not fill, learn more about their Supplemental Offer and Acceptance Program (SOAP) applicants, determine residency programs' needs for future NRMP Matches, and inquire what actions program leaders would like to see to promote a healthy future for training in EM.

Methods: We conducted a web-based survey of EM residency program leadership during March and April 2023. We generated descriptive statistics from these survey results. Thematic analysis was used for free-text responses.

Results: Of 287 programs, 160 (55.7%) responded to the survey, including 59 of 132 programs (44.7%) that did not fill in the Match. Unfilled programs were overall content with the quality of applicants in the SOAP. Programs expressed varying opinions on why fewer students are choosing EM. While most agreed there are concerns about the workforce (78.1%), even more spread exists on what actions should be taken to help support the future of residency training in EM.

Conclusion: Here we present data regarding the 2023 Match environment for EM and describe a residency program-level needs assessment and desire for action. Annual review of the Match data and residency program needs should be continued until we see improvement in the Match environment for EM. [West J Emerg Med. 2025;26(2)233–240.]

INTRODUCTION

The National Resident Matching Program (NRMP) Match for emergency medicine (EM) has evolved over the past several years. Historically, EM has been a competitive specialty with nearly 100% program match rates.[1] The 2022 EM Match represented a fundamental change compared to the historical data, with over 200 EM positions and over 60 residency programs unfilled.[2] This trend continued in the 2023 match, with 554 unfilled positions across 132 programs, although this trend improved as of the 2024 Match.[3,4] Table 1 displays several years of EM match data, which highlights the growth of residency programs, increasing

number of postgraduate year-1 positions, and variable number of applicants to EM residency programs.[5,6]

Several theories have been proposed to explain why fewer medical students are applying to EM. The 2030 jobs report left many concerned that there would not be enough work for all emergency physicians (EP),[7] while others have speculated that issues with boarding, drug and nursing shortages, burnout, the COVID-19 pandemic, concerns for future novel infectious diseases, and scope of practice of non-physician medical practitioners may contribute. These issues are currently under investigation by multiple groups, including the Council of Residency Directors in EM (CORD).[8]

CORD is an organization comprised of EM residency educators and program leadership providing resources and developing best practices for education in EM. In March 2022, CORD surveyed its members to understand what the organization could do to support its members following the 2022 Match.[9] Based on feedback from that survey, the CORD Board of Directors convened the EM Match Task Force. The primary objectives of this task force are to collect data and to intervene with regard to the increased number of unfilled EM residency positions.[10] The initial goal of the task force was to understand the factors that led to the increased number of unfilled spots, the quality of applicants to EM, as well as interview and rank-list behaviors of programs in the 2023 Match. Additional objectives included examining residency leadership opinions on the utility of preference signaling, readiness of Supplemental Offer and Acceptance Program (SOAP) candidates, and desired actions to improve the EM Match environment.

Considering these objectives, the CORD EM Match Task Force sought to elicit the needs and perceptions from EM residency program leaders as a first step toward developing targeted interventions to improve the EM Match environment. In this paper, the members of the CORD EM Match Task Force describe results of a survey conducted following the 2023 Match.

Population Health Research Capsule

What do we already know about this issue?
The 2023 Match for emergency medicine left 132 residency programs unfilled and 554 unfilled spots.

What was the research question?
We sought to determine residency programs' needs for future Matches and what actions program leaders desire to promote a healthy future for training in EM.

What was the major finding of the study?
Most respondents agreed that EM application numbers were down due to concerns about the workforce (78%), and the leading desire was to halt opening new programs (25%).

How does this improve population health?
These findings could improve population health by ensuring a healthy Match and training environment in EM.

METHODS

The CORD EM Match Task Force members developed a survey expanding upon the work of the 2022 Murano et al survey. Consensus methodology between task force members was used to develop and refine the survey. The survey was then distributed to EM residency program leadership (program directors [PD], assistant/associate program directors [APD], clerkship directors [CD], program coordinators [PC], chairs, and general faculty members) during the CORD Academic Assembly in March 2023 in Las Vegas, NV. Survey participation was voluntary and solicited via QR code during conference sessions. The survey was also distributed on the CORD Program Director Listserv to reach program leadership who did not attend the conference. The survey was web-based and used Qualtrics (Qualtrics International Inc, Provo, UT) for data collection.

The survey collected the respondents' residency program, their role within the program, and demographic information about the program (ie, length of training, location of

Table 1. Emergency medicine National Resident Match Program data 2019–2024.

Year	2019	2020	2021	2022	2023	2024
# residency programs	238	256	273	277	287	292
# PGY-1 positions	2,488	2,665	2,840	2,921	3,010	3,026
# applicants	3,048	3,323	3,734	3,081	2,765	3.547
# unfilled positions (%)	30 (1.2%)	13 (0.5%)	14 (0.5%)	219 (7.5%)	554 (18.4%)	135 (4.5%)
# unfilled programs (%)	15 (6.3%)	7 (2.7%)	9 (3.3%)	69 (24.9%)	132 (46%)	54 (18.4%)

EM, emergency medicine; *PGY*, postgraduate year.

program, sponsoring institutions). All program leaders were asked about the number and quality of applicants to their program as well as outcomes in the Match. For programs that did not fill and used the SOAP, we asked questions regarding the quality of applicants in the SOAP and sought feedback about the SOAP process. Additionally, all respondents were asked to identify why they thought fewer medical students are applying to EM and what additional actions they would like to see taken to improve the Match environment in EM. This study was reviewed by the Loma Linda University Institutional Review Board and given exempt status.

We analyzed data using Microsoft Excel 365 (Microsoft Corp, Redmond, WA) to calculate descriptive statistics. To avoid over-weighting perspectives from a single program, we sorted data to select a single response per program. We used the following order of consideration when more than one response was available per program: residency PD; PC; chair or vice/associate chair; APD; residency core faculty member; general faculty member. Free-text responses were coded using a thematic analysis between two authors (BM, MKu) for the SOAP qualitative data, and by two authors (BM, JM) for the interview uniformity, decreasing applicants, and future directions qualitative data. Simultaneous coding was allowed. Any disagreements between codes were resolved by two other authors (AS, MK), and if no agreement could be reached the response was not analyzed. For all questions, only three responses were discarded due to not being able to reach an agreement.

RESULTS

Filled and Unfilled Program Data

In total, 245 responses to the survey were recorded. Twelve (4.9%) were excluded due to incomplete responses, and 74 were discarded due to either duplicate responses or multiple responses being submitted from different representatives from the same residency program. There were responses from 160 of the 287 EM residency programs that exist nationally, representing a 55.7% response rate. Respondents from the programs included 109 PDs (67.7%), 33 APDs (20.5%), seven CDs (4.3%), six faculty members (3.7%), five PCs (3.1%), and one vice chair (0.7%). We compared demographic information of responding programs to all known EM programs based on the American Medical Association (AMA) Fellowship and Residency Electronic Interactive Database and the American Board of Emergency Medicine data, which is presented in Table 2.[11,12]

On average, program leaders reported interviewing 14.9 applicants per position (SD 4.76) in the 2022–2023 application cycle. Compared to the 2021–2022 application cycle, programs reported interviewing 18.7 more applicants total (range: −105 to +185, SD 40.16). Regarding creation of a rank order list (ROL), programs indicated that they placed a mean of 13.9 applicants on their ROL per position (SD 4.39). Compared to the prior application cycle, programs placed a mean of 15.6 more applicants on their ROL (SD 28.4). There were no statistically significant differences between filled and unfilled programs in terms of number of applicants interviewed per residency position ($P = 0.37$) or number of applicants on the ROL per position ($P = 0.55$), using two-tailed t-tests.

Compared to the 2021–2022 recruitment season, 46/131 respondents (35.1%) indicated that they made no significant changes in the consideration of the formation of their ROL, and 47% indicated that they included applicants with less desirable Standard Letters of Evaluation (SLOE) compared to prior years. Additionally, 39.7% indicated they included those with more "red flags" on their applications, such as standardized test failures, remediation of clerkships, or professionalism issues. A similar 39.7% indicated that they ranked applicants with a lower class rank compared to years prior, while 18.3% responded that they ranked more individuals with less leadership or volunteerism, and 12.9% indicated that they ranked more of those who they felt did not align with the mission or values of the program. Five programs (3.8%) stated that they considered more osteopathic applicants, and another five (3.8%) indicated that they considered more international medical graduates (IMG).

While preference signaling was new to EM this year, it has been used by other specialties, such as otolaryngology, since the 2020–2021 application cycle.[13] Emergency medicine programs had varying ways in which they used preference signaling during this application cycle. Table 3 provides details of how programs interpreted signal preferencing.

More than half of respondents felt applicant quality was either a little worse this year (9.7%) or substantially worse this year (42.5%). A minority (6.7%) felt applicant quality had improved this year. Perceptions of Match results were similar to perceptions of applicant quality. More than half felt their program's Match results were a little worse (39.4%) or substantially worse (19.7%) than the previous year. Notably, 11.4% felt their Match results were better than the previous year, and 30% indicated similar Match result quality to the prior year. A majority of programs indicated that they went lower down their rank list, with 75.2% indicating that they either went a little deeper or substantially deeper compared to prior years.

Unfilled Program and SOAP Data

Of the 132 unfilled programs, 59 (44.7%) of their program leaders responded to this survey. On average, programs had 4.8 positions unfilled (range 1–13, SD 2.87) out of an average cohort size of 10 residents per class (range 6–16, SD 3.42), yielding a mean vacancy rate per unfilled program of 47.8%. Of the responding programs that did not fill in the 2023 Match, 40.7% did not fill in the 2021–2022 application cycle. Program leaders reported receiving an average of 257 total

Table 2. Demographic information comparing all US emergency medicine programs to those that responded to the Council of Residency Directors Match Task Force survey regarding the 2023 match.

	All EM programs (N=287)	All responding programs (n=160)	Filled responding programs (n=101)	Unfilled responding programs (n=59)
Region				
Northeastern	86 (29.9%)	50 (31.3%)	27 (26.7%)	23 (39%)
Southern	91 (31.5%)	42 (26.3%)	31 (30.7%)	11 (18.6%)
Central	70 (24.3%)	39 (24.4%)	20 (19.8%)	19 (32.2%)
Western	41 (14.2%)	29 (18.1%)	23 (22.8%)	6 (10.2%)
Hospital setting				
Academic/university	97 (33.8%)	64 (40%)	50 (49.5%)	14 (23.7%)
Community	55 (19.2%)	41 (25.6%)	14 (13.9%)	27 (45.8%)
Hybrid	130 (45.2%)	44 (27.5%)	28 (27.7%)	16 (27.1%)
County		11 (6.9%)	9 (8.9%)	2 (3.4%)
Other (military, etc)	5 (1.7%)			
Training format				
PGY 1–3	233 (81.2%)	125 (78.1%)	78 (77.2%)	47 (79.7%)
PGY 1–4	54 (18.8%)	35 (21.9%)	23 (22.8%)	12 (20.3%)
Age of program				
<5 years	86 (29.9%)	24 (15%)	12 (11.9%)	12 (20.3%)
5–10 years	46 (16%)	23 (14.3%)	12 (11.9%)	11 (18.6%)
11–20 years	34 (11.8%)	25 (15.6%)	17 (16.8%)	8 (13.6%)
>20 years	121 (42.1%)	85 (53.1%)	57 (56.4%)	28 (47.5%)
Unsure	NA	3 (1.9%)	3 (2.9%)	0

EM, emergency medicine; *PGY*, postgraduate year.

Table 3. How residency programs used preference signaling.

More likely to interview applicants that signaled	32 (23.7%)
Minor change to interview selection process	24 (17.8%)
No change to interview selection process	24 (17.8%)
Interviewed most but not all applicants that signaled	13 (9.6%)
Interviewed all applicants that signaled	12 (8.9%)
Signal was used as a tiebreaker between similar applicants	12 (8.9%)
Signal was considered when inviting applicants from the waitlist	7 (5.2%)
Signal was used for out-of-region applicants	6 (4.4%)
Did not opt in	5 (3.7%)

Table 4. Top factors that programs believed contributed to not filling in the 2023 match.

Workforce concerns	39 (76.5%)
Geographic location of program	30 (58.8%)
Increasing number of EM spots	24 (47.1%)
Virtual interviews format	23 (45.1%)
New program	8 (15.7%)
Sponsoring institution (university vs CMG)	7 (13.7%)
Program specific factors (wellness, curriculum changes, etc)	6 (11.8%)
Social media issues	4 (7.8%)
New leadership	3 (5.9%)
Accreditation status	2 (3.9%)

EM, emergency medicine; *CMG*, contract management group.

SOAP applications (SD 130), or 53.6 applications per unfilled spot. Programs reported interviewing an average of 16.2 applicants per unfilled position in their program (range 5.8–40, SD 9.68); 83.3% of programs reported they were able to fill all unfilled positions in the SOAP. Table 4 outlines program perspectives on the underlying reasons why they felt their program did not fill in the Match.

Regarding applicants in the SOAP and their preparedness to practice EM, 35 leaders of unfilled programs gave information about their applicants. Eighteen (51.4%) stated that most applicants had completed at least one EM rotation but noted that it was after the time that ERAS applications

were due, leading to late consideration of EM as their desired medical specialty. Five respondents (14.3%) reported most applicants had completed one EM rotation but mentioned no details about the timing of that rotation. Only two respondents (5.7%) reported that the typical applicant had no or minimal exposure to EM. Interestingly, 20% of program leaders mentioned that many applicants had exposure to EM prior to starting medical school, such as working as a scribe or paramedic. Program leaders also reported that roughly 15% of applicants had at least one EM SLOE available for them to review.

Program leaders reported they were relatively content with applicants available to them in the SOAP, with 78% responding that they were either extremely or somewhat satisfied with the quality of applicants. In addition, 80% reported that SOAP applicants were either significantly or slightly better compared to the bottom quartile of their original ROL.

Program leaders were also asked what worked well regarding the SOAP process itself. Free-text responses underwent thematic analysis as described above with 37 recorded responses evaluated. Eleven (29.7%) stated that it was an opportunity for collaboration within their program leadership and faculty group. Ten (27%) mentioned that they thought their pre-planning strategy and organization during the SOAP worked well. Four respondents (10.8%) explicitly mentioned that the NRMP and Electronic Residency Application Service technology worked well. Additionally, 8.1% mentioned the strong quality of SOAP applicants available to them, 5.4% of respondents noted adequate support from CORD, and another 5.4% noted there was enough time to navigate the SOAP and interview applicants.

Conversely, program leaders were also asked about the challenges they faced during the SOAP, with 49 responses included in the following analysis. Twelve (34.7%) thought there were too many applicants and not enough time to review their applications and interview them. Ten (20.4%) disliked the format of SOAP offers, noting their desire for either additional rounds or that programs should be able to offer spots to more candidates. Six (12.2%) noted difficulties with disingenuity from applicants or violating NRMP SOAP rules. Three programs (6.1%) noted a lack of qualified applicants, while two (4.1%) noted concern over the applicant's interest in a career in EM. Finally, three programs (6.1%) responded that there were issues with the overall number of unfilled programs and competition between programs for SOAP candidates.

Qualitative Data About the Future of EM and Next Steps

The survey asked open-ended questions about standardization of the interview process: 41.2% of respondents indicated they would like to have a mandated return to in-person interviews, while 11.8% preferred a requirement for virtual interviews. Overall, 13.7% wanted interview uniformity among programs, and 3.9% voiced a desire for flexibility to allow programs to do what worked for them. Additionally, 9.8% stated they would like to have uniform cancellation standards for applicants. When asked directly, 74.3% responded reported they would like to see an interview cap enforcement. Of the 94 respondents who supported an interview cap for applicants, the mean suggested cap was 17.3 interviews per applicant (range 6–50, SD 6.7).

Table 5. Reasons why program leaders believe fewer students are applying to emergency medicine.

Workforce concerns	107 (78.1%)
Burnout	46 (33.6%)
Work environment	42 (30.7%)
COVID-19/pandemic	37 (27%)
Boarding	36 (26.8%)
Corporatization of EM	21 (15.3%)
Negative EP modeling	20 (14.6%)
Negative press	18 (13.1%)
Advising	14 (10.2%)
Lack of early exposure to EM	10 (7.3%)
Increased roles of non-physician practitioners	6 (4.4%)
Salary	5 (3.6%)

EM, emergency medicine; *EP*, emergency physician.

Program leaders were also asked why they thought fewer medical students were applying to EM. The most common response was that applicants were concerned about the future of the workforce, which 78.1% of respondents listed as a top concern. Further results for this question are listed in Table 5. Finally, program leaders were also asked what actions they would like to see taken to help support the future of training in EM. Results are shown in Table 6.

DISCUSSION

This study builds upon the work that was started by Murano et al following the 2022 Match. Here, we describe factors that educational leaders believe contributed to the decreasing number of applications to EM and to the increasing number of both unfilled programs and open residency positions. Results of this study are consistent with previous studies identifying geography, specifically location in the Northeastern and Central United States, as a characteristic of unfilled programs.[14] In fact, 58.8% of unfilled program leaders in this study believed geographic location was a major contributing factor to their program not filling in the 2023 Match. Another important factor identified by unfilled program leaders was the increasing number of EM spots. There were no statistically significant differences in the number of applicants interviewed per position, or

Table 6. Actions residency program leaders would like to see to help support the future of emergency medicine.

Halt opening of additional EM programs	32 (25%)
Increase RRC standards for EM	28 (21.2%)
Decrease number of programs	24 (18.8%)
Decrease number of total EM spots	24 (18.8%)
Positive messaging campaign	22 (17.2%)
Counter workforce study	16 (12.5%)
Close CMG-sponsored programs	8 (6.25%)
Mandate 4-year programs	5 (3.9%)
Improve work environment	4 (3.1%)
Applicant resources for finding program best fit	2 (1.5%)
Increase early exposure to EM	2 (1.5%)
Produce a "rating system" of EM programs	1 (0.8%)
Expand scope of EM	1 (0.8%)
Combat non-physician practitioner scope expansion	1 (0.8%)
Increase resources for international medical graduates	1 (0.8%)

EM, emergency medicine; *RRC*, Residency Review Committee; *CMG*, contract management group.

number of applicants placed on the ROL, by filled compared to unfilled programs. Therefore, widespread interviewing and ranking of more applicants by EM programs would likely not be helpful in improving the overall Match results because of the declining applicant pool and excess of training spots.

Virtual interview format has been supported by CORD since the beginning of the COVID-19 pandemic.[15] While this may help to decrease costs associated with residency interviews for applicants, lessen the carbon footprint associated with travel for interviews, and increase the amount of time available to focus on clinical exposure in medical school, it may also lead to students applying to and interviewing with more programs.[16] In the 2023 Match, students applying to EM applied to a median of 69 programs and interviewed at a median of 18.5 programs according to NRMP Charting Outcomes.[17] Comparatively, in 2019 the average US graduate applicant applied to 57 programs.[18] This increased number of applications makes it very difficult for program leaders to know which applicants are truly interested in their program vs those who applied and interviewed due to the ease of interviewing virtually. This sentiment is supported by the results of this survey, with 45.1% of unfilled program leaders stating that virtual interviews were a key contributor to why they were unfilled, and 41.2% of respondents voicing a desire to return to in-person only interviews, compared to only 11% who want to continue a virtual-only interview format.

Furthermore, a majority of program leaders were in favor of capping interviews (73.4%), with a mean suggested cap of 17 interviews. However, it is not currently known whether an interview cap is permissible or enforceable through the NRMP. Neither is it known whether an interview cap would disproportionately harm certain programs, such as more rural, smaller, or traditionally less competitive programs. Interview caps, however, have been used in other specialties. In response to virtual interviews and the COVID-19 pandemic, ophthalmology has employed interview caps for their match since the 2020–2021 application cycle and, in fact, just lowered the cap of interviews from 18 to 15.[19] Obstetrics and gynecology is also considering implementing an interview cap and, in a simulated environment, found that it increased the odds that less-competitive applicants would be offered interviews.[20]

Preference signaling was implemented for the first time in 2023 for EM, which was reported as a largely desired change in the Murano et al study. Programs used these signals in a variety of ways; however, the plurality of programs stated that receiving a signal made them more likely to offer an interview. Additionally, 17.8% relayed that it made no difference on the decision to interview, and only 3.7% of responding program leaders did not opt in to receive preference signals. Changes to preference signaling for the 2023–2024 match, including the increase from five to seven signals and the introduction of geographic preference signaling may affect how applicants and programs use signaling. Future research will be needed on preference signaling as it evolves to include geographic region signals instead of signals targeted at individual programs alone.

Other groups, such as the Emergency Medicine Resident Association, have speculated as to why fewer medical students are choosing EM as their intended specialty, with workforce projections, concern for increasing scope given to non-physician practitioners, and burnout topping the list.[21] The results of this study, which could be considered as consensus expert opinion, are in agreement with several of those speculations, with over 75% of program leadership believing concern for an oversupply of EPs is the leading cause of declining application numbers. Other top contributors from this survey include burnout, which according to the most recent AMA survey, places EM as the specialty with the highest rate of burnout, with 62% of EPs reporting burnout.[22] This degree of burnout and concern over the workforce likely contributes to why other respondents believed negative EP modeling (14.6%) and advising from EPs and medical school deans (10.2%) contributes to fewer students choosing EM. It is also important to note that a difficult work environment (lack of needed resources, nursing and drug shortages, difficult interactions with admitting teams and consultants), in-patient boarding in the ED, and the long-lasting stress that COVID-19 and concern for future novel infectious diseases

are also top reasons why education leaders believe fewer students are choosing EM.

Frequently, the situation of EM today is compared to the expansion of residency positions in anesthesiology in the 1980s and 1990s. During that time, residency spots nearly quadrupled, until concern about oversupply of anesthesiologists caused decreased applications to the specialty and eventual contraction of the number of spots.[23,24] Similarly, decreasing the number of EM trainee spots was a key theme for respondents when questioned about what actions they believed should be taken to address the increasing number of unfilled EM positions: 25% suggested not allowing any new programs to open; and 37.6% wanted to decrease either the number of overall programs or the number of residency positions. Many (21.2%) expressed the belief that increasing the Accreditation Council for Graduate Medical Education Residency Review Committee standards for EM is a way to accomplish this.

In addition to halting growth of EM residency programs and decreasing the overall number of EM trainees, respondents also voiced a desire to begin a positive messaging campaign about EM and its future, which CORD has already begun on social media.[25] Another suggested action was to counter the American College of Emergency Physicians 2030 workforce study (12.5%), which several others have already done, mainly citing a low attrition rate in the original study.[26] Lastly, it is important to note that the 2024 Match results for EM yielded fewer open spots and fewer unfilled programs compared to 2023. The CORD EM Match Task Force has ongoing work to determine how programs changed their recruitment strategies and how this could have affected the Match results, or whether this truly represents an improvement in the Match environment for EM.

LIMITATIONS

This was a voluntary survey subject to selection bias, as those with strong needs and opinions were more likely to complete the survey. In addition, because this survey was distributed both at the CORD Academic Assembly and through the CORD PD Listserv, sampling was limited to those programs involved within this organization. However, a 55.7% response rate from all EM programs suggests that this dataset represents a broad array of programs and ideas. Data collection began in March 2023 in the weeks immediately following the NRMP Match and SOAP. While this helped to increase the response rate and added to data validity, it may have made many of the free-text responses regarding actions that should be taken more emotionally charged.

Finally, this paper presents the opinions and voices of educational leaders in EM and may not represent the reality of the applicant pool to EM residency or the future of training in EM. Results reported here should not be taken as advice from CORD or from the EM Match Task Force.

CONCLUSION

Here we present data regarding the 2023 Match environment for EM and describe a residency program-level needs assessment and desire for action. Most program leaders believed that the decreasing number of EM applicants was due to concern over the EM workforce, burnout in EM, and difficulties with the work environment. A majority were in favor of interview caps. Program leaders also voiced a desire for overall fewer training spots in EM, among several other ideas. Annual review of the Match data and residency program needs should be continued until improvement occurs in the Match environment for EM.

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Personality Traits and Burnout in Emergency Medicine Residents

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Background: Burnout is prevalent in medical training, and some data indicates certain personality types are more susceptible. The criterion reference for measurement of burnout is the Maslach Burnout Inventory (MBI), which scores three factors: emotional exhaustion (EE); depersonalization (DP); and personal accomplishment (PA). Emotional exhaustion most closely correlates with burnout. Studies have yet to evaluate a link between burnout markers and certain personality traits in emergency medicine (EM) residents. The personality traits of openness, agreeableness, extraversion, conscientiousness, and neuroticism can be measured with a 50-item International Personality Item Pool (IPIP) Big 5 survey. Our goal in this study was to be the first to examine the relationship between personality traits and burnout among EM residents and guide future research on potential predictors of burnout and targeted interventions for resident well-being.

Methods: This was an observational, cross-sectional study conducted in March and April of 2023 in an urban, Level II trauma center, involving all EM residents at a three-year residency program. Two surveys, the IPIP and MBI-Human Services Survey, were distributed to all residents, and their responses were anonymous. We calculated raw/mean scores and standard deviations for each personality trait/burnout measure and compared them by the Pearson correlation coefficient.

Results: All 38 residents completed the surveys. A total of 31% of the cohort reported high exhaustion, 13% reported high DP, and 42% reported low PA. Two of 38 (5%) residents reported the combination of high EE, high DP, and low PA. There was a statistically significant negative correlation between conscientiousness and EE ($n = 38$; Pearson $r = -0.40$, $P < 0.001$) and a positive correlation between conscientiousness and PA ($n = 38$; Pearson $r = 0.36$, $P = 0.03$).

Conclusion: In our sample, residents who were more conscientious reported experiencing lower levels of emotional exhaustion and a greater sense of personal accomplishment. Programs may cautiously explore the potential of assessing resident personality traits as part of broader efforts to identify predictors of burnout, but further research with larger, multicenter, longitudinal samples is needed to corroborate these results. The small sample size and single-center design may limit generalizability of these findings, and the use of self-reported measures introduces the risk of response bias. [West J Emerg Med. 2025;26(2)241–245.]

INTRODUCTION

Burnout has emerged as a focal point for many residency programs, given its pervasiveness and severity throughout all phases of medical training.[1–3] Due to prolonged exposure to elevated stress levels, burnout manifests through symptoms such as irritability, fatigue, cynicism, and detachment. This phenomenon holds particular relevance within the realm of emergency medicine (EM), a field known to report elevated levels of burnout. The etiology of this problem within EM is multifaceted and related to factors such as working

environment (eg, physical layout and conditions, administrative tasks), shift work, violence in the workplace, exposure to infectious disease, patient volume, clinical variability, staffing, and the life-and-death decision-making inherent to the specialty.

The practice of EM hinges significantly upon interpersonal interactions, adding an additional layer of complexity to the phenomenon of burnout in the emergency physician. Because of the nature of EM, personality traits may play a more significant role in predicting burnout than in other settings. Existing investigations into this association are small-scale studies conducted with non-emergency physicians and have identified correlations of various measures of personality traits with burnout markers.[4–9] In general, high neuroticism, low agreeableness, low conscientiousness, low openness, and low extraversion are associated with burnout.[10] While certain personality traits may confer resilience or susceptibility to the challenges inherent in EM, the precise nature of this relationship remains underexplored within the EM literature.

The gold standard for burnout measurement is the Maslach Burnout Inventory (MBI), which measures emotional exhaustion (EE), depersonalization (DP), and personal accomplishment (PA).[11] Among these, EE has emerged as being most closely correlated with the presence of burnout.[12,13] Various adaptations of this inventory have been devised and validated, of which, the Human Services Survey (HSS) is the most applicable to healthcare workers.

Personality assessment within academic studies often relies on the framework of the "Big Five" traits, delineated by Goldberg (1992).[14] These traits encompass openness, agreeableness, extraversion, conscientiousness, and neuroticism. Openness can be understood on a scale of inventive/curious to consistent/cautious. Conscientiousness ranges from efficient/organized to extravagant/careless. Agreeableness ranges from friendly/compassionate to critical/rational. Extraversion is defined as outgoing/energetic vs solitary/reserved. Lastly, neuroticism ranges from sensitive/nervous to resilient/confident. Measurements of these traits have been adapted and validated for numerous research studies.[15–19] One form of this is the 50-item International Personality Item Pool (IPIP) representation of the Goldberg markers for the Big-Five factor structure.[20]

While these personality traits exhibit relative stability and maturation by the age of 30, their potential protective or predictive roles in mitigating burnout among resident physicians remain underexplored, particularly within the context of EM.[21] The scarcity of studies directly investigating this relationship in emergency physicians underscores the imperative for dedicated research initiatives aimed at elucidating the interplay between personality traits and burnout within the high-stress environment characteristic of EM. Consequently, our goal was to be the first to examine the relationship between personality traits and burnout among EM residents and guide future research on potential predictors of burnout and targeted interventions for resident well-being.

Population Health Research Capsule

What do we already know about this issue?
In non-emergency medicine settings, high neuroticism, low agreeableness, low conscientiousness, low openness, and low extraversion are associated with burnout.

What was the research question?
In emergency medicine residents, how do the "Big Five" personality traits correlate with burnout markers?

What was the major finding of the study?
Conscientiousness is negatively correlated with emotional exhaustion (Pearson $r = -0.40$, $P < 0.001$, while positively correlated with personal achievement ($r = 0.36$, $P = 0.03$, $N = 38$).

How does this improve population health?
Identifying burnout-predictive traits could help target interventions and support resident well-being and better patient care.

METHODS

This was an observational, cross-sectional study conducted in March and April 2023 that involved all EM residents in a three-year residency program at an urban, Level II trauma center. All residents were offered inclusion in the study via a single survey emailed to their work emails. A total of five emails were sent during the study months for recruitment. No other recruitment methods were used. Subjects were consented and completed two sequential online surveys administered in a single session: the 50-item IPIP representation of the Goldberg markers for the Big-Five factor structure and the MBI-HSS. The principal investigator (BF) selected the order of the surveys and administered the personality assessment first to avoid any potential priming effects from the burnout inventory. Additionally, the IPIP is more time intensive than the MBI and, thus, may require more attention. Answers were secured and anonymous.

We calculated raw/mean scores and standard deviations for each personality trait/burnout measure and compared them by Pearson correlation coefficient. Results were

analyzed by BF using Microsoft Excel (Microsoft Corporation. Redmond, WA) and Python (Python Software Foundation, Wilmington, DE). This study received institutional review board approval.

RESULTS

All 38 residents completed both surveys. The mean, SD, correlation coefficients and confidence intervals are reported in the Table. Thirty-one percent of the cohort reported high exhaustion, 13% reported high depersonalization, and 42% reported a low sense of personal accomplishment. Two of 38 (5%) residents reported the combination of high EE, high DP, and low PA. While there were no statistically significant differences in EE, DP, or PA across postgraduate year (PGY) levels, PGY-1 residents had higher overall mean scores of EE compared to PGY-2 residents and higher mean DP scores compared to both PGY-2 and PGY-3 residents. All PGY levels consistently reported high levels of PA.

There was a statistically significant negative correlation between conscientiousness and EE (Figure 1, $n = 38$; Pearson's $r = -0.40$, $P < 0.001$), which persisted across all PGY levels. Additionally, a near-significant positive correlation was observed between conscientiousness and PA (Figure 2, $n = 38$; Pearson's $r = 0.36$, P 0.03), which also persisted across all PGY levels. No other statistically significant correlations were found between personality traits and burnout measures, regardless of PGY level. For all correlations, we considered Bonferroni adjustment (alpha < 0.003).

DISCUSSION

The negative correlation between conscientiousness and EE suggests that certain personality characteristics may serve as protective factors against burnout in EM residents. This finding is consistent with previous research conducted in various occupational settings.[21] Conscientious individuals tend to be diligent, organized, and achievement oriented, traits that may buffer against the emotional toll of demanding work environments. In the context of EM where residents are frequently exposed to high-stress situations and long hours, the ability to maintain order and efficiency in their work may contribute to lower levels of EE. Furthermore, even though it was not below the Bonferroni adjusted alpha, there was a near-significant positive

Table. Correlation coefficient matrix with confidence intervals comparing the burnout factors of emotional exhaustion, depersonalization, and personal accomplishment with five key personality traits.

Variable	Openness	Conscientiousness	Extraversion	Agreeableness	Neuroticism
EE	−0.16	−0.46*	0.04	−0.02	0.08
	[−0.41, 0.21]	[−0.68, −0.17]	[−0.28, 0.35]	[−0.33, 0.3]	[−0.24, 0.39]
DP	−0.15	−0.27	−0.13	−0.11	0.19
	[−0.43, 0.19]	[−0.54, 0.04]	[−0.43, 0.19]	[−0.41, 0.22]	[−0.14, 0.47]
PA	0.09	0.36*	0.07	−0.09	−0.02
	[−0.23, 0.39]	[0.05, 0.60]	[−0.25, 0.38]	[−0.40, 0.23]	[−0.34, 0.29]

Values in square brackets indicate the 95% confidence interval for each correlation. * = $P < 0.05$.
EE, emotional exhaustion; *DP*, depersonalization; *PA*, personal accomplishment.

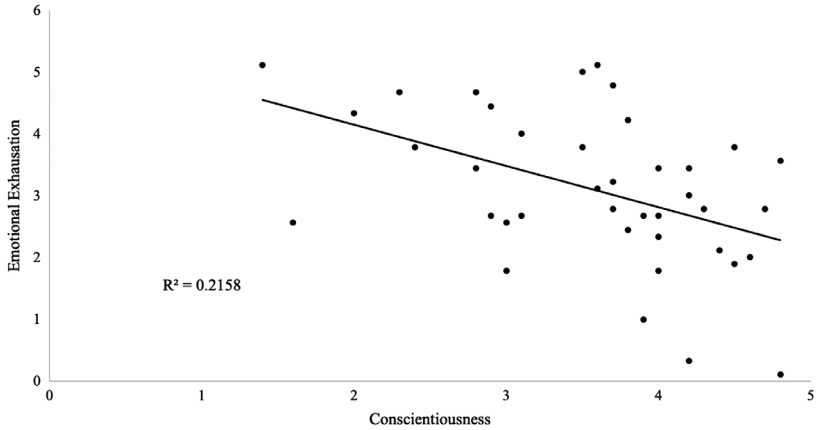

Figure 1. Negative correlation between conscientiousness and emotional exhaustion in emergency medicine residents ($n = 38$; Pearson's $r = -0.40$, $P < 0.001$).

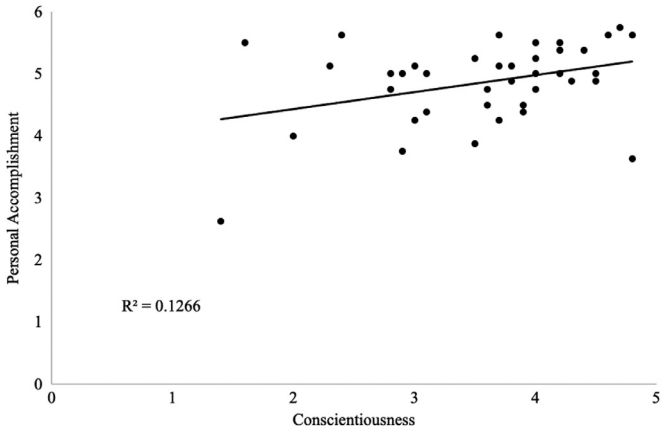

Figure 2. Positive correlation between conscientiousness and sense of personal accomplishment in emergency medicine residents ($n = 38$; Pearson's $r = 0.36$, $P = 0.03$).

correlation between conscientiousness and sense of PA, which seems to suggest that cultivating these traits in residents may even be protective of burnout and contribute to personal and professional satisfaction andcareer longevity.

Taken together, these results offer actionable insights that residency leadership can leverage to support the well-being and resilience of EM residents. Specifically, the identification of conscientiousness as a protective factor against EE suggests that interventions aimed at fostering conscientious behaviors among residents may help mitigate the risk of burnout. Conscientiousness has been identified as a trait that can be enhanced with interventions such as mindfulness and life-skills training.[22,23] More research is needed to determine which interventions are most effective and durable, but residency programs could consider incorporating targeted training sessions or workshops focusing on organizational skills, time-management strategies, and stress- management techniques to cultivate conscientious traits among residents. Additionally, while we used anonymous data in this study, residency leadership may consider implementing personality trait assessments as part of confidential resident evaluations or onboarding processes. Occult burnout may present with poor performance or even unprofessional behavior. Thus, personality trait assessment could be used to initiate conversations about burnout.

While personality traits may play a role in shaping individuals' susceptibility to burnout, organizational factors, workload, support systems, and coping mechanisms also exert significant influences. Future research should aim to explore these multifaceted interactions comprehensively, incorporating longitudinal studies to track the trajectories of burnout and personality development over time as they relate to EM residents. Additionally, qualitative research methods could provide valuable insights into the subjective experiences of residents and the contextual factors that contribute to burnout in EM training programs.

While this study provides valuable insights into the relationship between personality traits and burnout among EM residents, it represents just one factor among many. Addressing burnout in this population requires a multifaceted approach that considers both individual characteristics and systemic factors within the residency education environment. By gaining a deeper understanding of these dynamics, we can develop more effective interventions to support the well-being and resilience of EM residents.

LIMITATIONS

The small sample size and single-center design limit the generalizability of the findings to residents in other settings, such as rural or community hospitals. Selection bias is also an important consideration as residents may have chosen this specific program based on individual preferences, such as geographic location, which could introduce variability unrelated to clinical experience or program type. The timing of the study was chosen to align with a relatively lower period of stress in our residency program across all PGY levels, but the results may differ between the periods of the same academic year, calendar year, or clinical rotations. Additionally, response bias is a factor, as the measures evaluated here are self-reported and participants' responses may not accurately reflect their true characteristics. More longitudinal data will be needed to fully understand the nature of the correlations between burnout scores and personality traits observed in this cross-sectional study.

CONCLUSION

In our sample, residents who were more conscientious had lower levels of emotional exhaustion and a greater sense of personal accomplishment. Programs may cautiously explore the potential of assessing resident personality traits as part of broader efforts to identify predictors of burnout, but further research with larger, multicenter, longitudinal samples is needed to corroborate these results.

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Productivity and Efficiency Growth During Emergency Medicine Residency Training

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Introduction: Throughout training, an emergency medicine (EM) resident is required to increase efficiency and productivity to ensure safe practice after graduation. Multitasking is one of the 22 Accreditation Council for Graduate Medical Education (ACGME) EM milestones and is often measured through evaluations and observation. Providing quantitative data to both residents and residency administration on patients seen per hour (PPH) and efficiency could improve a resident experience and training in many ways. Our study was designed to analyze various throughput metrics and productivity trends using applied mathematics and a robust dataset. Our goals were to define the curve of resident PPH over time, adjust for relevant confounders, and analyze additional efficiency metrics related to throughput such as door-to-decision time (DTDT).

Methods: We used a retrospective, observational design in a single, tertiary-care center emergency department (ED) that sees approximately 110,000 adult patients per year; our study spanned the period July 1, 2019–December 31, 2021. A total of 42 residents from an ACGME-accredited three-year residency were included in the analysis. We excluded patients <18 years of age. Data was collected using a secure data vendor, and we created an exponential regression model to assess resident PPH data. Additional models were created accounting for patient covariates.

Results: We analyzed a total of 79,232 patients over 30 months. Using an exponential equation and adjusting for patient covariates, median PPH started at 0.898 and ended at 1.425 PPH. The median PPH by postgraduate (PGY) year were 1.13 for PGY 1; 1.38 for PGY 2; and 1.38 for PGY 3. Median DTDT in minutes was as follows: 185 minutes for PGY 1; 171 for PGY 2; and 166 for PGY 3.

Conclusion: Productivity and efficiency metrics such as PPH and DTDT data are an essential part of working in an ED. Our study shows that residents improve with number of patients seen per hour over three years but tend to plateau in their second year. Door-to-decision time continued to improve throughout their three years of training. [West J Emerg Med. 2025;26(2)246–253.]

INTRODUCTION

As a specialty dedicated to acute, unscheduled care, the practice of emergency medicine (EM) demands that clinicians not only practice exceptional medicine addressing a wide variety of complaints but do so quickly and efficiently. These skills are important in the setting of increasing patient volumes and illness severity[1] as well as the downward pressures on EM reimbursement.[2] In its position statement on emergency department (ED) staffing models, the American College of Emergency Physicians emphasized that determining appropriate and safe staffing models requires an understanding of emergency clinician efficiency.[3] Efficiency

metrics are used not only to ensure adequate staffing but also for emergency physician reimbursement.[4] Despite the central importance of physician efficiency in clinical practice, EM residency provides little structured education regarding efficiency, and many resident behaviors may affect efficiency.[5] Moreover, despite the use of robust tools to assess EM resident medical knowledge, clinical reasoning, and interpersonal communication, resident efficiency assessments are largely based on subjective evaluations from supervising physicians.[6]

Although efficiency is an important aspect of practicing EM, current literature suggests that there is wide variability in the measures used to assess clinician efficiency. In a recent scoping review by Anjum et al, patient volume and processing time were two of the most commonly reported metrics to assess productivity and efficiency, respectively.[7] Providing quantitative resident productivity and efficiency data may help with the clinical growth of residents and help residency administration structure staffing and curricula to better prepare residents for their future practice. Objective measurements of productivity may allow for implementation of interventions and support for residents who are performing below their peers and provide better customized learning experiences for higher performing residents.[8] It could also help residency clinical competency committees (CCC) to assess resident milestone achievement and ensure graduating residents are ready for independent practice.[9] Finally, understanding the range and normal trajectory of resident efficiency metrics may be useful to inform staffing model changes in the ED or measure the impact of efficiency-focused curricula.[10]

Previous studies have examined resident efficiency with regard to number of patients seen per hour (PPH) and relative value units; however, many of the studies were performed over a decade ago before the advent of accurate electronic health record (EHR) data.[11,12] There is a lack of data regarding the shape of resident productivity and efficiency growth over the course of training and the effect of patient mix on efficiency. To address this knowledge gap, we used a large administrative dataset to estimate resident productivity and efficiency over the course of training with the goal of defining a curve of resident productivity as well as estimating variability between residents over the course of their training.

Population Health Research Capsule

What do we already know about this issue?
Emergency medicine (EM) residents are expected to grow in both efficiency and productivity during training.

What was the research question?
Can a predictive model of EM resident productivity and efficiency growth be defined?

What was the major finding of the study?
Patients seen per hour plateaued: PGY 1, 1.13; PGY 2, 1.38, and PGY 3, 1.38. Decision times (in minutes) continued to improve: PGY 1, 185; PGY 2, 171; and PGY 3, 166.

How does this improve population health?
Ensuring that EM residents are trained in both efficient and productive patient care is essential to provide safe and effective care.

METHODS

Study Design

In this retrospective observational study we estimated EM resident productivity and efficiency in a cohort of consecutive adult ED patients over the course of 30 months from July 1, 2019–December 31, 2021. The Spectrum Health Institutional Review Board exempted this study as a quality improvement project.

Study Setting

This study was conducted in a single, regional, tertiary-care center ED, which is a Level I trauma center and comprehensive stroke center. It has an annual volume of approximately 110,000 adult patients per year and regional population of over one million. Patients <18 years of age are not treated in this ED; they are transported to the adjacent children's hospital unless they require emergent stabilization. We excluded from our analysis any patient <18 years of age in the dataset. Approximately half of the ED footprint is staffed by EM residents, who preferentially see higher acuity, more complex cases with an average admission rate of 42%. The residency program is a three-year training program accredited by the Accreditation Council of Graduate Medical Education. The EM residents work an average of 15 eight-hour shifts per month at this facility. On shift, residents are responsible for direct patient care with attending oversight. Senior residents do not directly supervise more junior residents. As residents progress into postgraduate year (PGY) 2 and PGY 3, they are expected to see higher acuity patients and more complexity. Non-EM residents work on this training site but account for less than 20% of the total residents and were not included in this analysis.

Data Source and Study Population

We used an administrative dataset that includes all ED visits at the study hospital. This is electronically extracted from the hospital EHR and contains patient-level

demographics, limited clinical data, throughput metrics, testing details, disposition, and treating clinicians. We included all adult patients treated by at least one EM resident during an ED visit. We excluded patient encounters for non-EM residents or patients who had no resident contact.

Exposures and Outcomes

Each patient in the dataset was assigned to the first resident who provided their clinical care. The primary exposure of interest was resident experience as measured by elapsed month of training (1–36). Resident experience was coded at the case level for each encounter by calculating the difference between the calendar month of the visit and the calendar month the resident started residency. Covariates included patient age, sex, Emergency Severity Index (ESI) triage acuity, attending of record, and final disposition (admission vs discharge). The primary productivity outcome was number of patients seen per hour (PPH). Because the administrative dataset did not contain resident shift lengths, we defined shifts by grouping consecutive cases seen by each resident until there was a four-hour gap between registration times. We calculated PPH by dividing this number of cases by the average shift length for residents (eight hours). The primary efficiency outcome was door-to-decision time (DTDT), defined as the time in minutes between ED arrival to disposition decision (placement of an admission or discharge order) as time-stamped in the EHR.

Statistical Methods

We examined associations between resident month of training and the two primary outcomes using mixed-effects regression models to account for differences in case mix and to quantify the variation in PPH that may be attributable to the individual residents or attendings. In these models, resident experience (in months), patient age, sex, ESI triage acuity, and admission status were treated as patient-level fixed effects while the resident and attending caring for the patient were treated as crossed random effects. This approach was used because residents work with various attendings and vice versa. These models allow for estimation of associations between patient-level characteristics and resident productivity as well as quantifying the contribution of resident- and attending-level variability using the intraclass correlation coefficient (ICC). This statistic may be understood as the proportion of variation in each outcome that is explained by a patient being cared for by an individual resident or supervised by an individual attending. This analysis was then repeated for each postgraduate year of training to examine whether the resident-level variability differed over the course of training. Additionally, to gain some understanding into variability over time, models were repeated in samples limited to each postgraduate year.

Next, using exponential regression we developed figures demonstrating the trajectory of resident productivity (PPH) and efficiency (DTDT) over the course of training. We then developed models using resident experience level as a lone predictor variable as well as models accounting for patient-level covariates (patient age, ESI triage acuity, and admit status). We developed exponential models using Python's script library (Python Software Foundation, Wilmington, DE) and mixed-effects regression models using Stata version 15 (StataCorp, College Station, TX).

RESULTS

A total of 79,232 patients encounters that involved a resident were identified over 30 months from July 1, 2019–December 31, 2021. The sample contained 42 distinct residents who worked an estimated 8,378 shifts and accounted for 806 resident-months of training. Characteristics of the patient population and the analyzed residents are presented in Table 1 and Table 2, respectively.

Resident Productivity Over Time

The bivariate associations between the exposures and resident productivity as well as the results of multivariable mixed-effects regression models are presented in Table 3. Patient-level factors associated with reduced PPH included older age, ESI acuity levels 2 and 3 (compared to acuity level 1), and hospital admission. Patient female sex demonstrated no statistically significant association with higher PPH in either unadjusted or adjusted models. Resident experience was positively associated with PPH such that each one month of increased experience was associated with 0.016 additional patients seen per hour ($P < 0.001$). Furthermore, while presence of a supervising attending explained very little of the

Table 1. Characteristics of the patient population.

Patient characteristics	Patient encounters N = 79,232 (%)
Age	
18 to 39	23,400 (29.5)
40 to 59	22,351 (57.7)
60 to 79	23,787 (30.0)
80 or greater	9,694 (12.2)
Female sex	40,617 (51.3)
ESI triage acuity	
Level 1	5,637 (7.2)
Level 2	40,280 (51.3)
Level 3	29,432 (37.5)
Level 4	2,887 (3.7)
Level 5	270 (0.3)
ED disposition	
Admit	29,734 (38.9)
Discharge	

ED, emergency department; *ESI*, Emergency Severity Index.

Table 2. Characteristics of resident population.

Resident characteristics	Unique residents N = 42 (%)
Female sex	18 (42.9)
Medical degree	
MD	31 (73.8)
DO	10 (23.8)
MBBS	1 (2.4)
Unique resident shifts	8,378
Resident months	806
Median resident PPH	1.4 (1.1–1.6)
PGY-1	1.1 (0.9–1.4)
PGY-2	1.4 (1.3–1.6)
PGY-3	1.4 (1.3–1.8)
Median resident DTDT (minutes)	174 (113–247)
PGY-1	185 (123–254)
PGY-2	171 (119–245)
PGY-3	166 (106–240)

PGY, postgraduate year; *PPH*, patients per hour; *DTDT*, door-to-decision time.

variability in the number of PPH (ICC = 0.036), resident of record accounted for over 14% of PPH variability (ICC = 0.145). Resident-level ICC statistics changed little across models limited to each postgraduate year (ICC 0.19, 0.23, and 0.15 for PGY 1, 2, and 3). While direct statistical comparisons of these ICCs were not possible, PGY-2 residents demonstrated the numerically greatest between-resident variability.

Results of the best-fit exponential model of resident productivity over time are presented in Figure 1. Resident productivity increases most rapidly during the first 12 months of residency with little meaningful change beyond the beginning of PGY-2 year. This relationship was consistent even after accounting for patient-level covariates (age, sex, ESI triage acuity).

Resident Efficiency Over Time

Bivariate associations between the exposure variables and DTDT and the results of multivariable mixed- effects regression models are presented in Table 4. As with models of resident productivity, age >60 years of age was associated with reduced efficiency (longer DTDT), as was ESI triage acuity 2–4 and hospital admission. Female patients had a six-minute longer DTDT compared to males ($P < 0.001$). When examining group-level contributions to variability in DTDT, neither attending (ICC = 0.008) nor resident (ICC = 0.012) accounted for a meaningful proportion of observed variability.

Results for exponential models of resident efficiency over time are presented in Figure 2. The rate of change observed in DTDT was less than and more gradual than the number of PPH over the course of residency

Table 3. Mixed-effects regression models demonstrating associations between patient characteristics and resident productivity as measured by patients seen per hour.

Covariate	Unadjusted coefficients	*P*-value	Adjusted coefficients	*P*-value
Resident experience (per 1 month increase)	0.012 (0.012 to 0.012)	<0.001	0.016 (0.016 to 0.017)	<0.001
Patient age (years)				
18 to 39	Reference		Reference	
40 to 59	−0.035 (−0.043 to −0.028)	<0.001	−0.015 (−0.022 to −0.008)	<0.001
60 to 79	−0.057 (0.065 to −0.049)	<0.001	−0.029 (−0.037 to −0.022)	<0.001
80 or greater	−0.065 (−0.074 to −0.054)	<0.001	−0.029 (−0.039 to −0.02)	<0.001
Patient sex (female vs male)	0.005 (0 to 0.011)	0.08	0.005 (0 to 0.01)	0.07
ESI triage acuity				
Level 1	Reference		Reference	
Level 2	−0.033 (−0.044 to 0.021)	<0.001	−0.024 (−0.035 to −0.013)	<0.001
Level 3	0.003 (−0.009 to 0.148)	0.64	−0.01 (−0.022 to 0.001)	0.08
Level 4	0.140 (0.121 to 0.158)	<0.001	0.093 (0.075 to 0.111)	<0.001
Level 5	0.219 (0.168 to 0.270)	<0.001	0.155 (0.109 to 0.202)	<0.001
Hospital admission (vs discharge)	−0.036 (−0.042 to −0.030)	<0.001	−0.022 (−0.028 to −0.016)	<0.001
Resident ICC			0.145	
Attending ICC			0.036	

ESI, Emergency Severity Index; *ICC*, intra-class correlation coefficient.

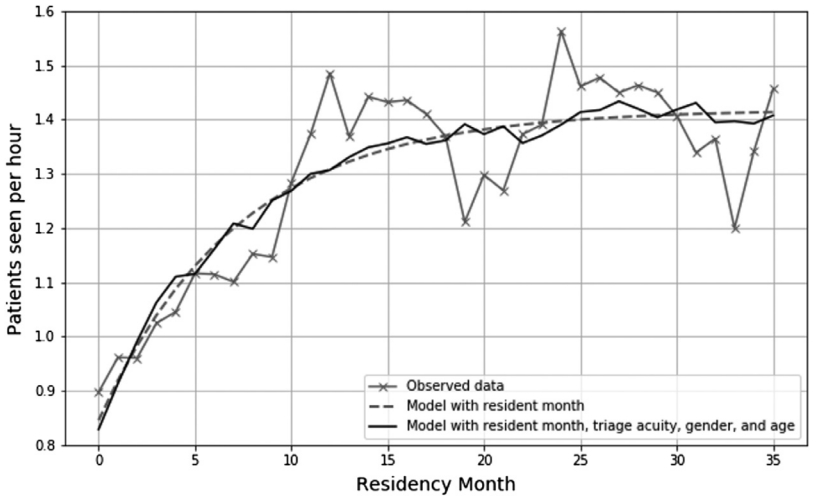

Figure 1. Residency productivity measured by patients seen per hour over the course of training.

training, with improvement levelling off during the PGY-3 year.

DISCUSSION

Throughout training, EM residents must develop skills in managing the complex needs of multiple patients such that they become both productive and efficient. These skills are undoubtedly important and are logical elements to evaluate over the course of residency training. Nevertheless, few existing competencies address these aspects of practice directly, and their assessment is primarily dependent upon subjective evaluation by attending physicians. In this analysis we sought to quantify resident productivity and efficiency in our institution over the course of residency training through examining the number of PPH and DTDT.

We observed that resident productivity increases dramatically during the first year of residency but levels off early in the PGY-2 year, similar to plateaus described in previous studies.[12–14] Patient-level factors such as older-age patients requiring hospital admission were associated with lower PPH, while patients triaged as lower ESI acuity (especially levels 4 and 5) were associated with higher PPH

Table 4. Mixed-effects regression models demonstrating associations between patient characteristics and resident efficiency as measured by door-to-decision time.

Covariate	Unadjusted coefficients	*P*-value	Adjusted coefficients	*P*-value
Resident experience (per 1-month increase)	−0.91 (−1.01 to −0.82)	<0.001	−0.44 (−0.56 to −0.31)	<0.001
Patient age (years)				
18 to 39	Reference		Reference	
40 to 59	12.33 (9.86 to 14.80)	<0.001	10.88 (8.52 to 13.24)	<0.001
60 to 79	10.33 (7.91 to 12.74)	<0.001	9.30 (6.91 to 11.69)	<0.001
≥80	9.89 (6.76 to 13.02)	<0.001	9.06 (5.98 to 12.14)	<0.001
Patient sex (female vs male)	6.37 (4.51 to 8.23)		6.51 (4.74 to 8.27)	<0.001
ESI triage acuity				
Level 1	Reference		Reference	
Level 2	103.06 (99.52 to 106.59)	<0.001	101.11 (97.61 to 104.60)	<0.001
Level 3	84.38 (80.75 to 88.00)	<0.001	87.74 (84.00 to 91.48)	<0.001
Level 4	12.09 (6.15 to 18.02)	<0.001	20.89 (14.91 to 26.87)	<0.001
Level 5	−8.09 (−24.55 to 8.37)	0.36	0.66 (−15.31 to 16.62)	0.94
Hospital admission (vs discharge)	−0.86 (−2.69 to 0.97)	0.36	4.26 (2.25 to 6.28)	<0.001
Resident ICC			0.012	
Attending ICC			0.008	

ESI, Emergency Severity Index; *ICC*, intra-class correlation coefficient.

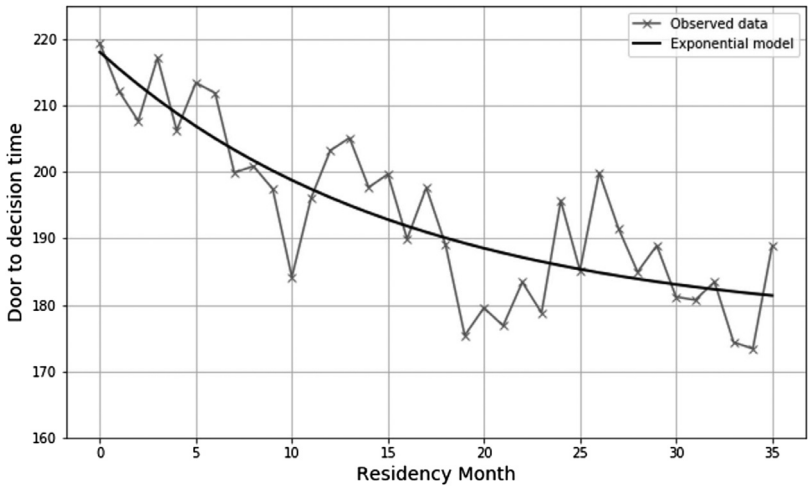

Figure 2. Residency productivity measured by door-to-decision time over the course of training.

similar to attending-based studies of PPH by Joseph et al.[15] After accounting for these relationships, the independent association between experience and productivity was actually stronger, suggesting that residents become more efficient over the course of training while also seeing a more difficult case mix.

We also observed significant between-resident variability. Overall, individual residents accounted for over 14% of observed variation in PPH after accounting for patient-level factors, while attending physicians contributed very little (3.6%). Furthermore, the degree of variability attributable to individual residents after accounting for case mix was highest for PGY-2 residents, but lower among PGY-1 and PGY-3 residents. This may suggest that residents begin and end their training at similar levels of productivity but may reach their plateau at different points during PGY 2. These findings suggest that productivity is in part an attribute of individual residents rather than case mix or attending staffing practices. Thus, there may be a role for designing education interventions for residents who demonstrate lower productivity by the end of PGY 1. While productivity appears to be an attribute of residents themselves, the improvement in ICC may suggest that residency training does help to reduce performance variability to some degree.

To examine resident efficiency, we chose to evaluate DTDT rather than other throughput makers such as ED length of stay, since DTDT is more likely to reflect resident behavior rather than system factors such as staffing and ED boarding. In contrast to PPH, this metric did not plateau early in residency but rather continued to improve over the course of a resident's training. As with PPH, patient-level factors were significantly associated with longer DTDT, including older age, ESI triage acuity 2 and 3, and admission status. Relative to other patient-level factors, resident experience level had a more modest relationship with DTDT such that a resident's experience alone accounted for an approximate 15-minute reduction over the 36 months of training. Furthermore, in contrast to PPH, only 1% of the unexplained variation in DTDT was attributable to the resident providing care (ICC = 0.012), and almost none of it was attributable to the supervising attending (ICC = 0.008). This may be partially explained by the fact that PPH is a metric that is inherently tied to residents, resulting in greater between-resident variation. Nevertheless, it is also likely true that structural limitations (eg, time to lab results, time to consultant phone call return) result in greater homogeny in completing ED workups that may explain this lower level of between-resident variability with regard to DTDT.

Using this data from this analysis raises numerous opportunities for residency administration and assisting residents in maximizing their performance and growth. Recognizing that there is a plateau in the number of PPH during training could help with staffing models to ensure appropriate resident coverage and manage expectations. One potential opportunity to leverage data might be for residency programs to monitor their productivity data several times during an academic year to ensure that their residents are progressing appropriately along the described curve. Residents who are not showing appropriate growth by the end of PGY 1 may benefit from tailored interventions or individualized learning plans. Another consideration relevant to both productivity and efficiency may be to provide residents with their own performance on these metrics in relation to their peers. In our institution, our CCC reviews resident productivity data such as PPH and DTDT twice per year for each residency class. This information is deidentified and distributed to each resident to review with their faculty advisor and program director. This information is frequently used to develop individualized learning plans to help with their patient efficiency and often used to advance their ACGME patient care-related milestones.

LIMITATIONS

Given that this was an observational analysis, it is important to acknowledge that these models do not prove a causal relationship between any of the potential predictors of PPH or DTDT and their respective outcomes. While PPH and DTDT are recognized benchmarks in many EDs, it is also important to remember that there are other ways to define productivity and efficiency, and several potential confounders may exist in this dataset.[16] More advanced residents may use their time in other ways such as peer-to-peer teaching, managing a larger volume of "signed-out" patients, more efficiency with on-shift documentation, and less time spent continuing patient care after their shift has ended. These possibilities may not tie directly to patient productivity but may provide value for both the residency and the individualized learner. It is certainly possible that the types of patients cared for by senior residents tended to be more complex even after accounting for ESI triage acuity, resulting in residual confounding. Further studies could evaluate some of these variables to account for why resident efficiency tends to plateau with number of PPH in their second year of residency.

Additionally, while our method of reconstructing shifts based on patient registration times likely results in a reasonably accurate summary, it remains possible that some patients were incorrectly assigned to a shift resulting in under- or overestimation of resident productivity. Finally, our institution diverts lower acuity patients to a "fast-track" area that is not staffed by residents. This likely accounts for the distribution of ESI triage acuity and admission rates, which are higher than a general ED population. Thus, the absolute productivity numbers should be interpreted with caution, and it is difficult to know how these results may compare across institutions.

Another important confounder that may reduce the generalizability of this analysis is the impact of the Covid-19 pandemic. Given that our dataset includes periods impacted by COVID-19, it is possible that this may have influenced resident productivity and efficiency.[17] There are mitigating factors that suggest our analysis was not adversely affected by the pandemic. First, since our analysis is defined by month of experience rather than calendar time, the impact of COVID-19 was spread equally among training months. Second, due to the module structure of our department, the teaching module is preserved for higher-acuity complaints and is less impacted by low ED volumes or boarding patients than other locations in the ED. We examined overall resident patients and PPH over the calendar duration of the study period and found no meaningful relationship between COVID-19 and non-COVID-19 periods (supplemental figure). Finally, residents were not restricted from managing patients under the investigation of COVID-19.

Lastly, it must be emphasized that productivity and efficiency, while important skills to the emergency clinician, should not supplant or overshadow the many other critical skills that require attention in residency such as acquisition of medical knowledge, effective communication, and the delivery of compassionate, empathetic, and equitable patient care.

CONCLUSION

This analysis confirms that resident productivity and efficiency improve over the course of residency training. Similar to the findings of previous research, productivity as measured by number of patients seen per hour appears to advance more quickly and reach a plateau by the PGY-2 year. However, efficiency as measured by door-to-decision time improves over the course of training. These relationships persist following adjustment for potential patient-level confounders and, in the case of PPH, are associated with individual residents. Interestingly, attending variability has little effect on PPH. These findings suggest that assessment of these metrics periodically during residency may be helpful in tailoring educational interventions to assist residents in developing these skills. Further study is needed to verify these findings and determine the impact of interventions designed to modify resident productivity and efficiency during training.

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Harder, Better, Faster, Stronger? Residents Seeing More Patients Per Hour See Lower Complexity

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Introduction: Patients seen per hour (PPH) is a popular metric for emergency medicine (EM) resident efficiency, although it is likely insufficient for encapsulating overall efficiency. In this study we explored the relationship between higher patient complexity, acuity on shift, and markers of clinical efficiency.

Methods: We performed a retrospective analysis using electronic health record data of the patients seen by EM residents during their final year of training who graduated between 2017–2020 at a single, urban, academic hospital. We compared the number of PPH seen during the third (final) year to patient acuity (Emergency Severity Index), complexity (Current Procedural Terminology codes [CPT]), propensity for admissions, and generated relative value units (RVU).

Results: A total of 46 residents were included in the analysis, representing 178,037 total cases. The number of PPH increased from first to second year of residency and fell slightly during the third year of residency. Overall, for each 50% increase in the odds of treating a patient requiring high-level evaluation and management (CPT code 99215), there was a 7.4% decrease in mean PPH. Each 50% increase in odds of treating a case requiring hospital admission was associated with a 6.7% reduction (95% confidence interval [CI] 0.73–12%; $P = 0.03$) in mean PPH. Each 0.1-point increase in PPH was associated with a 262 (95% CI 157–367; $P < 0.001$) unit increase in average RVUs generated.

Conclusion: Seeing a greater number of patients per hour was associated with a lower volume of complex patients and patients requiring admission among EM residents.
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INTRODUCTION

The 2019 American Board of Emergency Medicine Model of Clinical Practice recognizes task- switching and multiple patient care as core physician tasks,[1] and the Accreditation Council for Graduate Medical Education (ACGME) lists multitasking as Emergency Medicine Patient Care Milestone 7.[2] Emergency physicians (EP) must efficiently evaluate and treat a high volume of patients to effectively manage care in the emergency department (ED). Various metrics have been used to evaluate efficiency and quality of care provided in the ED by the ED staff as well as individual EPs (patient length of stay, ED admission rate, etc).[3,4] A metric commonly used by programs to measure efficiency in residents is the number of patients seen per hour (PPH). This metric is enticing because it is based on data that is easily retrievable and widely applicable across clinical sites.[5,6] However, it is currently unclear whether the number of PPH can adequately encapsulate efficiency in physician trainees. It is also

uncertain how residency programs should consider this metric when assessing their trainees, especially if not considered alongside other metrics.

A physician-in-training who sees more PPH could potentially be seen as more capable of independently managing the higher number of patients required for independent practice. This measurement is already commonly used when evaluating EM residents and is also frequently used to evaluate attending EPs.[5,6] However, it is unclear whether there are tradeoffs for residents that come with seeing a higher patient volume. It is likely that medical trainees are only able to handle a finite number of cognitive tasks before their performance is impaired and they are unable to take on additional tasks.

One method to conceptualize the relationship between how patient complexity and acuity impacts other aspects of patient care is through cognitive load theory.[7] In general, when cognitive load is too high, such as increased extraneous load from managing multiple patients or increased intrinsic load from managing very complex patients, overall cognitive performance may be impaired. This could decrease cognitive bandwidth for new patient-care tasks as well as limit germane load to allow for learning and illness-scheme creation.[7] Conversely, simple, straightforward patient presentations may not impose such a significant cognitive load, allowing cognitive resources to be deployed to see a higher volume of patients.[8,9] Prior studies have assessed resident efficiency in the ED in terms number of PPH as training progresses.[10] These studies have demonstrated that senior residents can see higher numbers of patients per hour compared to postgraduate year (PGY)-1 residents, which plateaus in the final year of training.[11]

Compared to advanced practice practitioners (APP) (physician assistants [PA] or nurse practitioners), residents see fewer PPH but generate a higher amount of relative value units (RVU). This suggests residents may see higher acuity patients or document more thoroughly.[10] The RVUs are an objective means of measuring the resources needed to provide medical care as a single metric.[12] Another means of estimating the resources needed to provide care are ED evaluation and management (E/M) Current Procedural Terminology (CPT) codes. These allow coders to use complexity in documentation as a surrogate marker of complexity of care provided. While RVUs and CPT codes are measures assigned following a patient's ED encounter, the Emergency Severity Index (ESI) is a means of estimating the acuity of the patient in terms of priority and resources allocation based on their initial presentation.

It is currently unknown how patient complexity and acuity may impact markers of clinical efficiency for ED residents. Our aim in this study was to better evaluate this relationship using multiple metrics to allow residency leaders to better contextualize greater resident efficiency in the ED.

Population Health Research Capsule

What do we already know about this issue?
Patients seen per hour (PPH) is commonly used by programs to measure efficiency in residents. It is unclear whether this adequately encapsulates efficiency.

What was the research question?
Can the use of multiple clinical metrics allow programs to better contextualize the meaning of resident efficiency in the ED?

What was the major finding of the study?
For each 50% increase in the odds of treating a high-complex case, there was a 7.4% (0.79–13.6%; P = 0.03) decrease in mean PPH.

How does this improve population health?
Residents who see more PPH may not treat as many complex patients, which could have implications for their readiness for independent practice.

METHODS

Study Setting

The study was conducted at a single three-year EM residency program associated with an urban, academic ED located in the Midwestern US. The hospital in which the ED is situated is a Level I adult and pediatric trauma, burn, stroke, and STEMI center. The ED has 43 adult beds and sees approximately 60,000 patient visits per year. During the study period, the residency had 12 PGY-1 positions each year.

The adult ED is divided into three separate treatment areas with two primary treatment teams. Each treatment team consists of a single attending physicians as well as 2–3 PAs or resident physicians. Shifts are nine hours in duration. Throughout most of the study period, patients were treated by the team of physicians designated to that treatment area. In 2019, the ED shifted to a model in which either treatment team could care for any patient in either treatment area. Each treatment team is staffed by residents of any PGY level with at least one senior resident (PGY-2 or PGY-3). All residents were encouraged to assign themselves to patients of any acuity level. During the study, PAs were employed in the ED and could take the place of a resident on shift (especially during weekly resident didactics). The APPs had no additional restrictions or privileges compared to residents in assigning themselves to patients.

As staffing is variable, there are no specific number of patients that each resident is required to see per shift. All residents staff directly with the attending; no residents supervise other residents. During expected peak times (of patient arrival), a triage team consisting of a single attending physician and a PA is also present and generally sees the lowest acuity patients; all residents are assigned approximately the same number of shifts but may freely trade shifts among themselves. While attending physicians can assign themselves to patients primarily (ie, no resident or APP assigned), this is a rare occurrence and typically occurs only during times of excessive patient volume or acuity.

Study Design and Population

We designed this study as a retrospective observational study using aggregated, resident case data extracted from the electronic health record (EHR) (Epic Systems, Verona, WI). Data for PGY 1–3 residents were extracted for four consecutive classes of residents who graduated between 2017–2020. To remove significant outliers we excluded residents if they did not graduate from the program within three consecutive years. We collected data on the characteristics of the patients seen as well as markers of residency efficiency for all available patient encounters during the study period (Table 1). Multiple metrics were used to provide a more accurate measure of patient complexity rather than a single metric in isolation. The research team was composed of a senior resident (TB) and a departmental data analyst (DH), as well as faculty educators (CJ, AN, BS). We chose the selected markers as they have been used as markers of resident clinical efficiency in other studies.[6,10]

Patient care was attributed to the first assigned resident, as this resident is typically the most cognitively and practically involved in the patient's care. Patients who are signed out to an oncoming ED team are shared equally among all oncoming residents. We excluded pediatric patient encounters (ie, patients <18 years of age) as pediatric cases have substantial differences in terms of the resources and cognitive load required to provide adequate care. Therefore, it was determined that the chosen efficiency metrics could not be meaningfully compared to adult patient encounters.[13] For example, the average length of stay between pediatric and adult encounters during the study period was 219 vs 362 minutes. Over the course of their training, residents complete a dedicated block of pediatric ED shifts during their first and second years and complete an additional 1–3 pediatric ED shifts during each adult ED rotation. We calculated the percentage of patient encounters compared to overall patient encounters.

Given the aggregated nature of the data that did not contain any patient protected health information or identifying resident data, no informed consent was collected. The data was extracted from the EHR by the departmental data analyst and was stored on a password-protected departmental server available only to members of the study team. No additional chart review was conducted on the included encounters. This study was determined to be quality improvement and exempt from formal review by our institutional review board.

Statistical Analysis

We calculated the PPH for each PGY-3 resident by using the total number of adult patient encounters for which they were the first resident assigned, divided by the total number of hours worked in the adult section of the ED. Residents were grouped based on the year of graduation. A two-sided significance level of $P < 0.05$ was used for all statistical tests. We performed all statistical analyses and graphics using R version 4.1.1 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria). We used negative binomial regression to assess the relationship between PPH and the odds of treating a patient who required admission, adjusted

Table 1. Emergency medicine resident metrics of efficiency and the characteristics of patients seen.

Metric	Description
Patient characteristics	
Emergency Severity Index (ESI)	Frequency of patient encounters matching each ESI score (1–5). This is a means of estimating time and resource allocation for a patient based on their initial presentation.
Evaluation and management (E/M) Current Procedural Terminology (CPT) codes	Frequency of patient encounters receiving each E/M CPT code (99281–99285). These represent a means of determining patient complexity based on meeting certain documentation criteria.
Hospital admission	Number of patient encounters in which an inpatient admission occurred
Efficiency metrics	
Relative value units (RVU)	Total number of work RVUs generated
Patients seen per hour	Total number of patients seen divided by total number of hours worked in the ED during PGY-3

ED, emergency department; *PGY*, postgraduate year.

for hours worked and patient complexity. All analyses were performed at the resident level.

To determine the relationship between ESI and PPH, we first dichotomized ESI into high and low severity. High severity included encounters from the third year of residency that were labeled ESI 1 and 2 and low severity included encounters that were labeled ESI 3, 4, and 5. The ESI 1 encounters were not separately analyzed as these are relatively rare compared to the overall number of patient encounters. We then calculated the odds of treating a patient with a high-severity ESI. The relationship between CPT codes and PPH was similarly calculated by dichotomizing CPT into more and less complex. More complex included the highest complexity CPT code (99285), and less complex included the remaining four codes (99281–99284). We did not consider CPT code 99291 as only attendings can bill for critical care, and there is significant variation within our attending group in the use of critical care billing. Therefore, we believed that this was less likely to be a resident-sensitive metric. We similarly calculated the odds of treating a patient with a more complex CPT. To assess significant differences among PGY that could introduce bias, we used the Kruskal-Wallis test and the Nemenyi procedure for post-hoc comparisons.[14]

We used RVUs as a proxy for shift complexity and regressed that as the response in a multivariable regression model using PPH, PGY, and the interaction between PPH and PGY as explanatory variables.

RESULTS

A total of 46 residents met inclusion criteria. One resident was excluded who had a non-consecutive training period, and another resident left the program prior to graduation at the end of their PGY-1 year. Overall, 1.6% of the total patient encounters were assigned 99291/99292 CPT codes and were excluded from that analysis. An additional 17.6% of total patient encounters, consisting of pediatric cases, were also excluded, leaving a total of 178,037 patient encounters. Average PPH data for the four included PGYs can be seen in Table 2. The average ESI during the study period was 2.8.

Current Procedural Terminology

Adjusted for class year, a 50% increase in the odds of treating a complex case was associated with the mean PPH decreasing 7.42% (95% confidence interval [CI] 0.79–13.6% reduction in mean PPH; $P = 0.03$). The relationship between PPH and odds of treating a high-complexity case can be seen in Figure 1.

Hospital Admission

Each 50% increase in odds of treating a case requiring hospital or intensive care unit [ICU]/intermediate care unit admission was associated with a 6.7% (95% CI 0.73–12%; $P = 0.03$) reduction in mean PPH. The relationship between PPH and odds of treating a case requiring admission can be seen in Figure 2.

Table 2. Patients seen per hour data for class years 2017–2020.

Class year	Academic year	Mean PPH (95% CI)
2017	2014–2015 PGY-1	1.20 (1.13–1.28)
	2015–2016 PGY-2	1.51 (1.42–1.61)
	2016–2017 PGY-3	1.52 (1.43–1.62)
2018	2015–2016 PGY-1	1.11 (1.05–1.16)
	2016–2017 PGY-2	1.50 (1.43–1.58)
	2017–2018 PGY-3	1.45 (1.39–1.52)
2019	2016–2017 PGY-1	1.08 (1.03–1.13)
	2017–2018 PGY-2	1.37 (1.31–1.44)
	2018–2019 PGY-3	1.26 (1.21–1.32)
2020	2017–2018 PGY-1	1.01 (0.96–1.05)
	2018–2019 PGY-2	1.33 (1.28–1.39)
	2019–2020* PGY-3	1.09 (1.04–1.14)

*May have been impacted by the COVID-19 pandemic.
CI, confidence interval; *PPH*, patients seen per hour; *PGY*, postgraduate year.

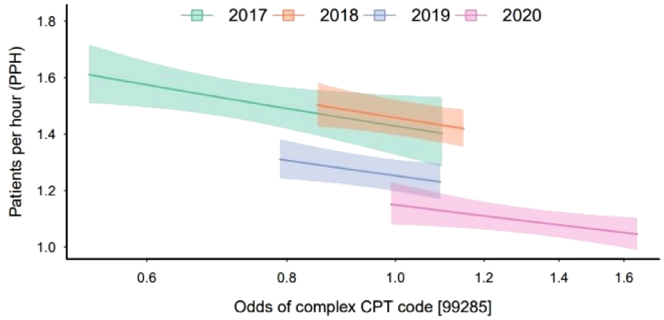

Figure 1. Relationship between odds of treating a high-complex case and mean patients seen per hour during postgraduate year-3, grouped by graduation year. Shaded regions represent 95% confidence intervals.
CPT, Current Procedural Terminology.

Emergency Severity Index

After controlling for PGY, there was no significant relationship observed between PPH and the odds of treating a high acuity case ($P = 0.30$).

Relative Value Units

The models suggested that each 0.1 point increase in PPH is associated with a 262 unit increase (95% CI 157–367; $P < 0.001$) in average work RVUs generated, with the association between average total RVU and PPH stable across the four years. See Figure 3 for the relationship between RVUs generated and PPH.

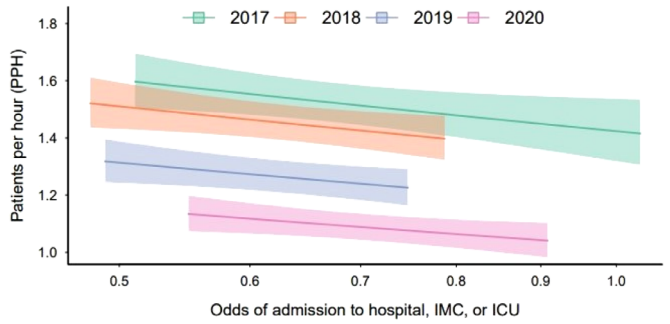

Figure 2. Relationship between odds of a case resulting in admission and mean patients seen per hour during postgraduate year 3, grouped by graduation year. Shaded regions represent 95% confidence intervals.
IMC, intermediate care unit; *ICU*, intensive care unit.

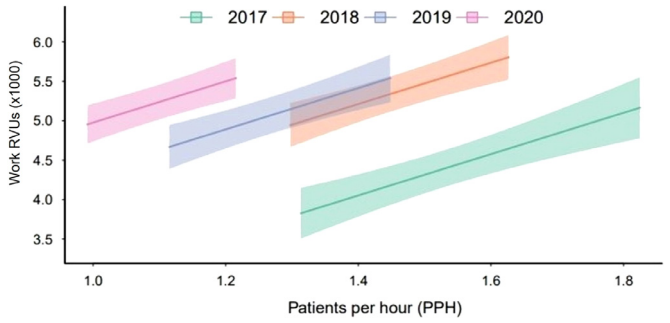

Figure 3. The relationship between relative value units generated and patients seen per hour during postgraduate year 3, grouped by graduation year. Shaded regions represent 95% confidence intervals.
RVU, relative value units.

DISCUSSION

Residents seeing higher numbers of patients saw fewer complex patients and fewer patients requiring an inpatient admission. We believe this study is the first to examine the association of patient complexity and acuity on the clinical efficiency with which EM residents operate. As suggested by cognitive load theory, we found that residents' capacity to pick up complex patients in this study was finite. More complex patients and patients requiring admission may impose more of a task load (eg, phone calls to consultants or admitting physicians, review of records, or longer history-taking) than patients with lower acuity. This greater cognitive load could result in a decrease in PPH as complexity goes up. This effect may be mitigated somewhat by a variety of effective clinical practices, such as partnering with nurses or assistance from their supervising attending. However, more research is needed to determine whether other factors, such as the incorporation of evidence-based efficiency practices or adding scribes for documentation, may affect resident efficiency.

Our data shows that PPH rises sharply between PGY-1 and -2 years and then plateaus between the PGY-2 and -3 years. This finding is in line with previous literature.[11] While the underlying cause of this finding is ultimately unknown, it may be secondary to changes in focus that occur between the latter years in training. For example, any further increases in the ability of PGY-3 residents to see additional patients over a PGY-2 resident may be offset by a focus on departmental flow, instruction of junior learners, or simply succumbing to "senioritis." It is also possible that the most senior residents preferentially selected the most critically ill patients in the ED and the increased complexity of these patients were the reason for the plateau.

We found no significant relationship between PPH and ESI. However, there was a negative relationship when evaluating PPH and CPT codes as well as the likelihood of caring for a patient who would need to be admitted. This may be because ESI is assigned at the beginning of the patient's treatment course, whereas CPT designation and admission decisions are made later in the patient's course (or after the conclusion of the encounter in the case of CPT). The ESI was also treated as a binary variable for analysis, with ESI 3 treated as a low-acuity patient. However, many of these patients may have a higher acuity illness; it is possible that this dichotomization eliminated a true effect that would otherwise have been seen. Therefore, it could reflect that ESI could not be used to accurately estimate the amount of resources and cognitive effort required to care for these patients.[15]

While we did not analyze the relationship between patient complexity and overall generation of RVUs, it remains an interesting avenue for future research. While it makes intuitive sense that the care of a single, more complex patient would generate more RVUs than a single, less complex patient, it is unknown whether RVU generation is balanced by the increased amount of time and cognitive load these patients often require. This was not done in the current study as this would also have depended on hospital crowding, which is a confounding variable we chose not to include.

Overall, our results suggest that the use of PPH as a surrogate measure of patient efficiency may paint an incomplete picture of resident performance. While the current study did demonstrate a statistically significant relationship between patient complexity and PPH, the clinical significance is unclear. The required number of patients seen during training represents a critically unexplored area of residency training. Experiential learning theory would suggest that seeing a greater number of patients would result in a higher level of competence, but this may be mediated by complexity or other factors. Residency leadership teams who plan to evaluate their residents on their ability to task switch between multiple patients (ACGME Milestone PC7) may wish to explore the use of other markers that may correlate with PPH. These may better capture the

complexity of the care provided, although further study is required before this can be considered best practice.

LIMITATIONS

An important limitation of this study is its single-center design. The results seen may be due to unique factors of the study site and, therefore, may not be generalizable to other sites. For example, the study site changed from a pod-based model in 2019, which may have restricted the efficiency of some residents, to a "free-for-all" model where residents could assign themselves to new patients as soon as they were ready. Additionally, there may have been subtle changes to the patient population seen by the residents over the years, or changes to the residency, that were not assessed in the current study. For example, the final year of the study data included a few months that were affected by the COVID-19 pandemic. This would only have impacted a small portion of the final year of training for the Class of 2020. However, it may have led to the discrepancy seen in PPH between the Class of 2020 and the other included classes as seen in Figure 3. It is interesting that this did not result in a substantial change in RVUs generated. No specific documentation interventions were implemented during this time and may simply represent general changes in documentation practices.

We did not factor in how patients who were taken in sign-out would affect the utilized metrics. It is likely that residents who were signed out patients requiring multiple additional actions (such as consultation calls, procedures, etc) would negatively impact their ability to take on new patients. These cases were excluded because it would have been unfeasible to account for how much additional work was required for these patients. For example, some patients, even those who were critically ill, may be signed out when all major diagnostic and therapeutic interventions have already been completed, and the patient is simply awaiting transfer to the hospital floor.

We did not consider patients who were specifically admitted to our step-down ICU units, or those who went directly to the operating room. While the rate of admission to these locations could certainly imply a level of complexity, the way this is determined varies greatly between institutions and would have added a significant layer of complexity to the current study. At our institution, we have two affiliated hospitals that we can admit patients to, each with different levels of capabilities and different criteria for ICU/stepdown unit status. This represents an interesting avenue of future study.

We also excluded patients assigned CPT codes 99291 and 99292 (which denote critical care) from our analysis of the relationship between PPH and CPT codes. This was done as critical care billing can only be done by the attending physician, and documentation practices for this are variable within our attending group. The overall percentage of patients who received 99291 or 99292 CPT codes was only 6%. However, these patients were not excluded entirely and would have been included in the analysis of other metrics apart from CPT. As stated earlier, the use of multiple metrics in this study was designed to overcome limitations in individual metrics alone.

It is possible that the presence of triage physician during peak hours of patient arrival may have impacted the metrics used in this study. While this was not specifically controlled for, the triage physician team primarily sees only the lowest acuity patients (eg, simple laceration repairs, ankle sprains, needlestick injuries) and was felt to not have a big impact on our chosen metrics. We did not wish to exclude shifts in which the triage physician was present as this timeframe represents the highest patient census in our ED. If an impact occurred, this would be expected to decrease the magnitude of the relationship between PPH and the chosen variables. Despite this, a significant effect was still demonstrated.

Finally, this numerical data does not completely encapsulate other factors that would influence a resident's overall efficiency. These factors could include their clinical abilities and medical knowledge. Because of this, we caution residency programs from looking at the variables investigated in this study in isolation when assessing their own trainees.

CONCLUSION

Residents caring for higher numbers of patients per hour were associated with fewer complex patients and patients who required inpatient admission.

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Push and Pull: What Factors Attracted Applicants to Emergency Medicine and What Factors Pushed Them Away Following the 2023 Match

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Introduction: Emergency medicine (EM) historically enjoyed a nearly 100% match rate. A rapid change saw 46% of EM programs with one or more unfilled positions after the 2023 Match. Much has been discussed about potential causes, and characteristics of unfilled programs have been investigated. We surveyed recent applicants to EM to further understand what continues to draw them to EM and what concerns deter them from choosing a career in EM.

Methods: A cross-sectional, mixed methods survey was distributed in the summer of 2023 to a convenience sample of respondents via the listservs of national EM resident and student organizations as well as clerkship directors in EM. We did not calculate response rate due to listserv convenience sampling. A total of 213 responses were received, representing 7.7% of the total number of EM applicants (2,765) in 2023. Applicants were asked to rank from 1 to 5 their experiences with EM and the characteristics of the specialty that were important in their career decision. We calculated means and 95% confidence intervals for quantitative results. We performed qualitative analysis of free-text responses to identify themes.

Results: Positive factors for applicants were interactions with EM faculty (4.29 on 1–5 scale) and residents (4.42) as well as clinical experiences in third-year (4.53) and fourth-year clerkships (4.62). Applicants continue to be drawn to EM by the variety of pathology encountered (4.66), flexible lifestyle (4.63), and high-acuity patient care (4.43). Most applicants (68.5%) experienced advisement away from EM. Of those who received negative advisement, non-emergency physicians were the most common source (73.3%). Factors negatively influencing a career choice in EM were corporate influence (2.51), ED crowding (2.52), burnout (2.59), presence of advanced practice practitioners (APP) in EM (2.63), and workforce concerns (2.85). Job concerns stemming from the 2021 EM workforce report were identified by respondents as the primary reason for recent Match results.

Conclusion: Applicants noted clinical experiences in the emergency department and interactions with EM attendings and residents as positive experiences. High-acuity patient care, variety of pathology, and flexible lifestyle continue to attract applicants. Applicants identified EM workforce concerns as the primary contributor to recent EM Match results. Corporate influence, ED crowding, burnout, and presence of APPs in the ED were also significant issues. [West J Emerg Med. 2025;26(2)261–270.]

INTRODUCTION

Emergency medicine (EM) has historically enjoyed a very competitive outcome in the National Residency Matching Program (NRMP, or "the Match") with >95% of programs filling their spots.[1] Beginning in 2022, however, a dramatic decline occurred leaving many programs unfilled.[2] This decline continued in 2023, with 46% of EM programs remaining unfilled.[3] Although 79.1% of those programs filled in the Supplemental Offer and Acceptance Program (SOAP),[4] this represents a tremendous change from previous years.

The cause of this change is likely multifactorial, with major contributing factors being the expansion of the number of residency positions, student perceptions of the future job market within EM, and the virtual interview format.[5,6] Other proposed etiologies of the decline include the corporate practice of EM (which occurs when a non-physician or corporation exerts control over the medical decision-making or collects reimbursement for the medical services of physicians),[7] the expanded use of advanced practice practitioners (APP) such as physician assistants and nurse practitioners in the emergency department (ED), and increased burnout following a global pandemic.[6] Concerns regarding the job market and expanded use of APPs are likely related to the 2021 EM workforce report by Marco et al, which proposed a range of potential outlooks based on various factors with the most publicized result being a projected oversupply of emergency physicians by 2030.[8]

Several factors affected which programs were more likely to go unfilled in the Match. Gettel et al found that programs accredited within the previous five years, as well as programs that were under for-profit ownership were more likely to go unfilled.[9] Another study found that predictors of not filling were having unfilled positions in the previous Match, a smaller program size, location in the Mid-Atlantic or East North Central area, prior American Osteopathic Association accreditation, and corporate ownership structure.[10] Overall, programs felt their match outcomes were worse than in previous years, but they perceived the quality of applicants as similar to previous years.[5]

Many factors influence a student's decision on which specialty to pursue including role models, financial incentives, gender, degree of patient contact, procedural skills, prestige, and lifestyle.[11–14] The factors most associated with a choice to specialize in EM include lifestyle, diversity of patient presentations, flexibility in choosing a practice location, work-life balance, and perceived job satisfaction.[15–19] Factors associated with earlier selection of EM include early exposure to the field, presence of an EM residency program at a student's medical school, prior employment in the ED, previous experience as a prehospital practitioner, and completion of a third-year EM clerkship.[16]

In this study we surveyed EM applicants from 2022 and 2023 to identify factors deterring or attracting them to the specialty as well as modifiable influences impacting their career decisions. To restore the competitive nature of EM in the Match, it is important to know what motivates medical students to select EM as a specialty in the current environment. It is additionally important to further understand the factors contributing to decreased interest in EM, so that we can continue to address these as a specialty.

Population Health Research Capsule

What do we already know about this issue?
Applicant and specialty characteristics attracting applicants to EM have been previously documented.

What was the research question?
What factors deterred and attracted applicants to EM during the 2023 Match?

What was the major finding of the study?
The 4th-year clerkship was the major attracting factor (mean 4.62, 95% CI 4.50–4.74), while corporate influence (mean 2.51, 95% CI 2.33–2.69) was the strongest deterring factor.

How does this improve population health?
These findings offer new insights into applicant perspectives of EM and specialty-choice considerations following the 2023 Match.

METHODS

The project was conceived by the Council of Residency Directors in Emergency Medicine (CORD) Match Task Force, which includes representatives from the American Academy of Emergency Medicine (AAEM), American Academy of Emergency Medicine Resident and Student Association (AAEM/RSA), American College of Emergency Physicians (ACEP), American College of Osteopathic Emergency Physicians (ACOEP), ACOEP Resident and Student Organization (ACOEP RSO), Association of Academic Chairs in Emergency Medicine (AACEM), CORD, Emergency Medicine Residents' Association (EMRA), the Society for Academic Emergency Medicine (SAEM), and SAEM Residents and Medical Students (SAEM RAMS). Task force members collaborated to design the survey instrument. The conclusions in this paper represent the views and opinions of the individual authors and do not represent the views of the organizations. The

study was approved by the Loma Linda University Health Institutional Review Board.

We performed a literature review using PubMed to collect studies investigating factors impacting residency applicants' specialty choice. Questions were adapted from prior published studies.[16,20] Current factors not previously investigated, such as COVID-19 or EM workforce projections, were added following an iterative process of consensus development within the research group. The survey was reviewed by the CORD Match Task Force members and edited. The survey was then pilot-tested by current medical students and residents. We analyzed the responses, and the survey was revised for clarity and brevity following the beta respondents' feedback.

Medical students were asked multiple-choice questions regarding their residency application strategy including whether they had applied to more than one specialty and, if so, which specialties they applied to. The survey participants were asked to rank specialty characteristics influencing their choice of EM as a career on a five-point Likert scale from strongly positive to strongly negative. They were also asked to rank the impact of prior experiences on their specialty choice on a five-point Likert scale from very positive to very negative. We investigated the impact of career advisement using multiple-choice questions with the option to select up to three responses. Finally, free-text response questions were asked to assess applicants' opinions about the causative factors leading to the 2023 EM Match results. Comment in this space was optional and not meant to reach saturation of themes; rather, it was meant to provide participants the opportunity to give additional details about their experiences.

We used a convenience sample of EM-bound medical students who applied in both the 2022 and 2023 Match and those who considered or are considering applying to EM in upcoming Match cycles. Survey respondents were sent a web-based survey via Qualtrics (Qualtrics International, Inc, Seattle, WA) in the summer of 2023. Reminder messages were distributed monthly during the data collection period. The survey was distributed through the listservs of current medical students interested in EM as identified by their membership in an EM national organization including AAEM/RSA, ACOEP RSO, EMRA, and SAEM RAMS. Surveys were also distributed through the SAEM Clerkship Directors in Emergency Medicine (CDEM) listserv to be sent to their recently matched applicants who matched into EM or had considered but ultimately decided not to pursue EM. Convenience sampling via listserv distribution did not allow for survey distribution quantification or response-rate calculation. Comparing the number of survey responses (213) to the number of applicants to EM in the 2023 Match (2,765) shows our survey responses were equal to 7.7% of the total number of EM applicants in 2023. The intended survey participants included medical students who 1) considered but ultimately did not apply to EM residency; 2) applied to EM as their only specialty choice; 3) dual applied to EM and an alternate specialty choice; or 4) entered EM through the SOAP.

A financial incentive of a $10 electronic gift card was given to the first 160 participants. Financial support for the study was provided by AAEM, AAEM/RSA, ACEP, ACOEP, AACEM, CORD, and SAEM.

We analyzed data using Microsoft Excel 365 (Microsoft Corporation, Redmond, WA) to calculate means and percentages. We calculated 95% confidence intervals (CI) using an online tool.[21] A phenomenological approach to qualitative analysis was used and free-text responses were coded by two authors with experience in qualitative analysis (JM, BM) after establishing a codebook through an iterative process to generate an understanding of the phenomenon of the EM match process in concert with the quantitative questions. Any disagreements between codes were resolved by a third author (MK).

RESULTS

We received responses from 213 individuals. Demographics are shown in Table 1. Most respondents (92.8%) had applied to residency already. Of those, 87.2% applied to EM in the Match. Respondents secured an EM residency position in the 2023 Match (69.5%), 2022 Match (9.6%), 2023 SOAP (12.3%), 2022 SOAP (0.5%), and by other means (5.3%). A small proportion of respondents (2.7%) were not entering EM residency.

In comparison to applicants securing a position in the 2023 Match, our sample was fairly similar with regard to gender breakdown (57.2% male, 39.9% female in our sample vs 54.8% male, 45.2% female in the Match) but oversampled osteopathic seniors (42.7% in our study vs 24.3% in the Match). Regarding application strategy, 70.1% applied to only EM residencies. Some individuals applied to more than one specialty with EM preferred (12.3%). The most common secondary specialties were internal medicine and family medicine. Applying to EM as the secondary specialty occurred in 2.1% of individuals with primary specialties being anesthesiology, interventional radiology, orthopedic surgery, and physical medicine and rehabilitation. Respondents who chose not to apply to EM at all made up 13.4% of responses. This group of individuals most commonly chose to apply to anesthesiology (39.1%), orthopedic surgery (17.4%), general surgery (17.4%), family medicine (13.0%), internal medicine, pathology, and preliminary year (each 8.7%). (Response option was "Select all that apply," response sum >100%).

Applicants most commonly chose to apply to EM in the third year of medical school (33.5%) or before medical school (33.0%). The remaining responses were evenly split among the pre-clinical years of medical school (6.8%), the fourth year of medical school (8.9%), after medical school (6.8%),

Table 1. Demographic data of survey respondents.

Characteristics	
Age (years) (n = 173)	N (%)
<25	1 (0.6%)
25–29	108 (62.4%)
30–34	47 (27.2%)
35–39	13 (7.5%)
40–44	2 (1.2%)
>44	2 (1.2%)
Gender identity (n = 173)	
Male	99 (57.2%)
Female	69 (39.9%)
Non-binary/third gender	1 (0.6%)
Prefer not to say	4 (2.3%)
Race (n = 177)	
American Indian/Alaska Native	1 (0.6%)
Asian	20 (11.3%)
Black/African American	10 (5.6%)
Hawaiian/Pacific Islander	0
White	132 (74.6%)
Other	8 (4.5%)
Prefer not to say	6 (3.4%)
Ethnicity (n = 173)	
Hispanic/Latino	18 (10.4%)
Not Hispanic/Latino	147 (85.0%)
Prefer not to say	8 (4.6%)
Medical school background (n = 211)	
MD in US	85 (40.3%)
DO in US	90 (42.7%)
US citizen IMG	28 (13.3%)
Non-US citizen IMG	8 (3.8%)
Medical school type (n = 171)	
Private	103 (60.2%)
Public	67 (39.2%)
Other	1 (0.6%)
Medical school geographic region (n = 171)	
Central (IA, IL, IN, KS, MI, MN, MO, MT, ND, NE, OH, SD, WI)	43 (25.1%)
Northeast (CT, DC, DE, MA, MD, ME, NH, NJ, PA, RI, VT)	29 (17.0%)
South (AL, AR, FL, GA, KY, LA, OK, MS, NC, SC, TN, TX, VA, WV)	70 (40.9%)
West (AK, AZ, CA, CO, HI, ID, NM, NV, OR, UT, WA, WY)	29 (17.0%)

IMG, international medical graduate; *MD*, Doctor of Medicine; *DO*, Doctor or Osteopathic Medicine.

and during SOAP (8.4%). Participants were exposed to EM in their medical school via required EM clerkships in the fourth year (42.1%), required clerkships in the third year (24.0%), EM electives in the fourth year (17.0%), and EM electives in the third year (11.1%). Table 2 shows the degree of influence each factor held in the applicants' choice of EM as a career. The most frequently cited positive influences were EM residents on shift (4.42 on a 1–5 scale), EM attendings on shift (4.29), the fourth-year EM clerkship (4.62), and third-year EM clerkship/elective (4.53). Prior experience in the ED in a non-physician role (4.43), in emergency medical services (EMS) (4.52) or as a scribe (4.55), were identified less frequently but as very positive factors.

Job concerns/workforce report (65.8%), burnout (56.7%), increased use of advanced practice practitioners (APP) (50.8%), and corporate influence in EM (42.5%) were the most-cited reasons for advising applicants away from EM. Emergency department crowding (12.5%) and EM experience during the COVID-19 pandemic (5.8%) were less commonly cited concerns. Participants were asked about advisement and its influence on their specialty choice: 68.5% reported being advised against choosing EM residency training. The most common sources of advisement away from EM were attendings/residents in non-EM specialties (73.3%), peers (50.0%), social media/message boards (47.5%), and EM attendings (37.5%). Medical school representatives in the Dean's office accounted for a small proportion of advisement away from EM (15.8%). Most participants in our survey (81.8%) reported that advising against entering EM did not change their application strategy. Of those who initially pursued a different specialty 5.7% ultimately entered EM in the SOAP, 5.0% applied to another specialty as a backup to EM, and 3.3% applied to EM as a backup specialty. Of those applicants who did not change application strategy despite negative advice about EM, the most commonly cited reasons were perceived fit with EM (73.7%), flexible lifestyle of EM (64.6%), lack of interest in other specialties (49.5%), and doubt in accuracy of workforce report (49.5%).

Very few participants said they would not advise a friend to apply to EM for the 2024 Match (2.3%). Most (75%) would advise a friend to choose EM. Most of those who indicated they would advise a friend against applying to EM would do so because of concerns about fit for the specialty (42.9%) and the job market (22.9%), with corporatization of medicine, APP expansion, and burnout also mentioned.

Most somewhat agreed or strongly agreed that their peers would be more interested in EM as a career if they were exposed to EM during a rotation in the third year or earlier (82.7%). Participants were asked what they thought would make EM more appealing to peers who were undecided

Table 2. Factors influencing selection of career in emergency medicine.

What factors influenced your choice of EM as a career?	Strongly positive (5)	Somewhat positive (4)	Neutral (3)	Somewhat negative (2)	Strongly negative (1)	Mean (95% CI)
4th-year EM clerkship	118	26	8	3	2	4.62 (4.50, 4.74)
Worked as scribe in ED	40	12	5	0	1	4.55 (4.35, 4.75)
3rd-year EM clerkship/elective	79	27	5	2	3	4.53 (4.37, 4.69)
Worked in EMS outside hospital	32	7	2	2	1	4.52 (4.24, 4.80)
Shadowing experience in ED	44	24	5	3	0	4.43 (4.25, 4.61)
Worked non-physician role in ED	24	10	5	1	0	4.43 (4.18, 4.68)
ED residents on shift	81	52	14	1	1	4.42 (4.30, 4.54)
Other	8	3	0	0	1	4.42 (3.79, 5.05)
Family/friend is emergency physician	33	27	10	1	0	4.30 (4.12, 4.48)
ED attending on shift	75	61	13	4	3	4.29 (4.15, 4.43)
Mentor/advisor	54	35	12	6	2	4.22 (4.04, 4.40)
Volunteer experience in ED	22	21	9	1	0	4.21 (4.00, 4.42)
EM experience in preclinical years	37	28	16	5	0	4.12 (3.92, 4.32)
EM related research	17	21	24	1	1	3.81 (3.59, 4.03)
Word of mouth/reputation	22	44	22	14	8	3.53 (3.31, 3.75)

CI, confidence interval; *EM*, emergency medicine; *ED*, emergency department; *EMS*, emergency medical services.

about a specialty but were considering EM. The most common responses included early exposure to EM (31.5%) and alleviating concerns about job security raised by the EM workforce report (30.2%). Other suggestions included addressing the expanded use of APPs in the ED (10.1%), improving the perception of EM among medical students and physicians (9.4%), and improving work-life balance and compensation (8.7% and 8.1%, respectively).

Table 3 shows how applicants ranked different factors when choosing EM as a career. The most important positive factors were variety of patient pathology (4.66 on a 1–5 scale), lifestyle/flexibility (4.63), high-acuity patient care (4.43), length of residency training (4.37), and family considerations (4.36). Participants were asked specifically if they believed that EM is a "lifestyle specialty," and 60.1% responded yes; 9.0% did not consider EM a lifestyle specialty, while 28.1% were neutral, and 2.8% were unsure. The factors negatively influencing a career choice in EM, defined as 95% CI less than 3.0, were corporate influence in EM (2.51, 2.33–2.69), ED crowding (2.52, 2.37–2.67), burnout (2.59, 2.44–2.74), and use of APPs in EM (2.63, 2.47–2.79). Average rating of concerns about EM experience during the COVID-19 pandemic (2.95) and workforce report/job security was negative (2.85); however, upper limit of 95% CI was positive, 3.12 and 3.03, respectively.

Applicants were asked to identify the most important reason contributing to a larger-than-normal number of unfilled positions in the EM Match. They identified concerns about job security and the future EM workforce as the primary concern (Table 4). Qualitative responses to the increase in unfilled spots in the EM Match predominantly reflected concerns regarding the EM workforce report and job security. Themes and representative quotations are included in Table 5.

DISCUSSION

Applicants in our survey were drawn to EM by clinical experiences in the ED during the third and fourth year and by interactions with ED residents and attending physicians during those experiences. Unfortunately, only a small proportion of applicants in our survey had required EM clinical experience during the third year of training. Developing best practice recommendations for early exposure to EM during medical school may be an area to target to increase interest in future applicants. Additionally, employment in an EM-related field (ie, EMS, scribe) prior to medical school was also a positive experience. Early identification of those students with prior EM-related employment may be an area for mentorship efforts by EM advisors.

Applicants continue to be drawn to the high-acuity patient care, diverse patient pathology, and the flexible lifestyle EM offers. These findings are in line with prior studies of EM applicant attitudes and the cornerstone of EM's appeal.[12–19,23] Additional factors that appeal to applicants are the variety of fellowship options available after EM residency, the length of residency training, compensation, and availability of jobs in their desired location. Family considerations are important to applicants and, coupled with the desire for a flexible lifestyle, signal a desire for work-life balance. Shift work in the ED has downsides such as sleep

Table 3. Importance of various aspects of emergency medicine to applicants in the 2023 Match.

How important were the following factors in your decision to apply to EM residency	Strongly positive (5)	Moderately positive (4)	Neutral (3)	Moderately negative (2)	Strongly negative (1)	Does not apply	Mean (95% CI)
Variety of pathology	132	24	16	1	0	5	4.66 (4.56, 4.76)
Lifestyle/flexibility	124	39	11	1	0	3	4.63 (4.54, 4.72)
High-acuity patient care	101	47	24	1	0	5	4.43 (4.32, 4.54)
Length of residency training	89	62	21	2	0	4	4.37 (4.26, 4.48)
Family considerations	95	52	22	5	0	4	4.36 (4.24, 4.48)
Compensation/salary	57	79	27	10	0	5	4.06 (3.93, 4.19)
Mentor/advisor influence	61	55	40	7	2	13	4.01 (3.87, 4.15)
Fellowship options	44	56	59	5	4	10	3.78 (3.64, 3.92)
Availability of jobs in desired location	41	67	40	19	4	7	3.71 (3.56, 3.86)
Competitiveness of EM match	30	47	83	6	3	9	3.56 (3.43, 3.69)
Student debt	18	54	70	11	3	22	3.47 (3.34, 3.61)
Career longevity	29	42	59	38	5	5	3.30 (3.14, 3.46)
COVID-19 experience in EM	20	24	69	39	17	9	2.95 (2.78, 3.12)
EM workforce report/job security	20	21	59	48	19	11	2.85 (2.68, 3.03)
APPs in EM	11	17	64	47	27	12	2.63 (2.47, 2.79)
Burnout in EM	13	12	57	75	17	4	2.59 (2.44, 2.74)
ED crowding	8	12	67	56	27	8	2.52 (2.37, 2.67)
Corporate influence in EM	16	14	48	50	39	11	2.51 (2.33, 2.69)

APPs, advanced practice practitioners; *CI*, confidence interval; *EM*, emergency medicine; *ED*, emergency department.

transitions associated with night shifts and working weekends and holidays. However, applicants were signaling those issues are still favorable to being on call or working in a clinic five days a week. Highlighting the factors that resonate with applicants is a good starting point when promoting the specialty.

Table 4. Single most important reason for unfilled emergency medicine (EM) residency positions in 2022 and 2023 Match, per EM applicants.

Response	N%
Workforce/job security	79 (53.0%)
COVID-19	28 (18.8%)
Number of residencies	20 (13.4%)
Burnout	17 (11.4%)
APP expansion	15 (10.1%)
Perception of emergency medicine	15 (10.1%)
Quality of life, change in practice environment (boarding, volumes, etc)	11 (7.4%)
Corporatization	8 (5.4%)
Other	6 (4.0%)
Programs' failure to adapt to changing applicant pool	2 (1.3%)

Note: Totals exceed 100%, as respondents could indicate more than one item; % indicates the percent of total respondents endorsing a choice.
APP, advanced practice practitioner; *EM*, emergency medicine.

With regard to factors pushing applicants away from EM, most applicants experienced badmouthing of EM and advising away from the specialty. In prior studies, over three-quarters of respondents reported experience with badmouthing of another specialty and one-quarter changed their specialty choice because of it.[24–26] When uncertain applicants are narrowing their specialty choices between a few serious options, contending with negativity about your career choice, both now and in the future, from friends or mentors in other specialties may be enough to sway someone away from EM.

The most common source of advice against EM in 2023 was not from peers, formal mentors, or Dean's offices but from attendings and residents in non-EM specialties. Experiencing negative advisement from a trusted mentor about one's desired specialty is likely impactful. In addition, applicants reported receiving negative pressure from their peers and social media. Most people involved in EM medical education suspected applicants were being advised away from EM. This was suggested by our data. Most assumed advisors from the Dean's office were advising students away from EM toward more prestigious specialties or those with safer match rates. But that was not the case in our survey, as

Table 5. Qualitative analysis themes and representative quotations regarding the 2022 and 2023 EM match.

Theme	Code	Guideline for use
Employment opportunities	**Workforce/job security**	**This code is used when participants discuss the workforce report, job security, employment opportunities, or difficulty finding jobs**
• *There is a myth going around that there are not enough jobs for EM physicians after residency. I know a lot of people that made this comment upon saying I was applying to EM* • *Covid, and that damn memo. Yall shot yourselves in the damn foot with that bonehead move* • *Workforce report hysteria* • *The infamous report predicting a coming labor surplus. The timing lines up and it tracks with what friends in med school were saying*		
	Number of residencies	**This code is used when participants discuss residency expansion**
• *Increased amount of residency program spots created by CMG hospitals* • *Too many residency programs* • *Surplus of "pop-up" programs leveraging resident labor with no intention of real training*		
	APP expansion	**This code is used when participants discuss competition with APPs for employment or increased use of APPs in EM**
• *Midlevel creep* • *increasing number of NPs/PAs filling in positions* • *PA/NP takeover* • *Increased NP/ PA replacing jobs and then MD license online for anything they do. Including signing their charts*		
Practice environment	**Burnout**	**This code is used when participants discuss burnout**
• *Concern over burnout* • *Fear of burnout* • *Emergency doctors burnt out*		
	COVID-19	**This code is used when participants discuss the impact of COVID-19**
• *Treatment during COVID-19* • *COVID-19 experiences, lack of patient care opportunities during COVID-19* • *High stress, especially during COVID-19* • *COVID-19 showed EM's true colors* • *COVID-19 experiences and fears of future health risks*		
	Corporatization	**This code is used when participants discuss corporatization of emergency medicine or private equity influence**
• *Corporate takeover, thus physicians lose power every day* • *Corporate practice of medicine* • *HCA programs!!!!! There are a ton of new, sketchy programs.* • *Increase in for-profit hospital slots available in Texas, Cali, and Florida*		
	Quality of life, change in practice environment (boarding, volume, etc.)	**This code is used when participants discuss negative practice factors**
• *Lack of perceived quality of life* • *Bad job prospects and ED culture has become toxic* • *Seeing patients in waiting rooms/bed holds* • *Culture of what EM has become. No one wants to choose to work in this over run environment especially when the job market is uncertain when there are specialties like dermatology and sub- specialties where you don't have to deal with the chaos and patient volumes we are now seeing in the ED. ER medicine is at an all-time low and never used to be this overwhelming pre-pandemic.*		
Applicant or match factors	**Programs' failure to adapt to changing applicant pool**	**This code is used when participants discuss residency programs' failure to assess competitiveness or select applicants efficiently**
• *Mismatch between programs' opinion of themselves/how they are perceived vs actual applicant perceptions of programs.* • *Programs being overly selective and not honestly introspecting regarding how applicants perceive their program*		

(*Continued on next page*)

Table 5. Continued.

Theme	Code	Guideline for use
	Perception of emergency medicine	**This code is used when participants discuss negative perceptions of emergency medicine among students or through social media or mentors**
	• *Lack of respect to emergency physicians and thought that we are not that smart* • *Perception from attendings of both EM and non-EM* • *Social media influence and immaturity on behalf of applicants* • *Decreased perceived competitiveness leading to lack of interest* • *Bad reputation among consultant specialties* • *Jack of all trades/EM incompetency stigma*	

APP, advanced practice practitioner; *CMG*, contract management group; *EM*, emergency medicine; *ED*, emergency department; *HCA*, Hospital Corporation of America; *NP*, nurse practitioner; *PA*, physician assistant.

advisors in the Dean's office ranked as the sixth most frequent source of advisement away from EM.

Additional factors pushing applicants away from EM were corporate influence in EM, ED crowding, burnout, the use of APPs in EM, the experience of emergency physicians during COVID-19, and concerns regarding job security stemming from the 2021 EM workforce report. Applicants are wary of entering a specialty dominated by corporations that place profits over patient care. Residencies at for-profit clinical sites had 1.3 times greater risk of not filling in 2023.[9] Applicants are showing an aversion to training at these sites. However, spots continue to fill during the time-limited SOAP as unmatched applicants are likely excited about the ability to secure any training position. Further understanding applicant concerns and the experiences of residents in for-profit programs is important and requires additional study. Likewise, understanding the experience of EM residents who enter training via the SOAP is valuable for future investigation.

Emergency department crowding not only negatively impacts quality of patient care; it also deters future emergency physicians from entering the field. Students on ED rotations see the challenges of finding space to re-evaluate patients, delays in workup, and prolonged care of patients boarding in the ED who are awaiting inpatient beds. Efforts to address boarding as well as the implementation of surge capacity plans may result in improving this factor as students consider specialty choice.

Furthermore, burnout generated the largest number of moderate or strongly negative responses. Emergency medicine is widely cited as the specialty with the highest rates of burnout.[27,28] Requirements to promote well-being and counter burnout exist in both undergraduate (Liaison Committee on Medical Education standard 12.3)[29] and graduate medical education (Accreditation Council for Graduate Medical Education Common Program Requirements for residency VI.C).[30] Prior qualitative research suggests faculty modeling may influence residents' career perspectives, indicating targeting faculty for education on well-being and burnout may yield substantial benefits for both current and prospective residents.[31]

Applicants, additionally, have concerns about the use of APPs in the ED. Many free-text responses cited "scope creep" of APPs as well as the negative impact on physician job availability as negative factors. Applicants signaled that they are paying attention to the topic of APP usage in the ED and it is an important issue to them. National leaders in EM are actively working to protect the scope of all practitioners in the ED and continue to emphasize the importance of physician-led patient care teams. Further dissemination of these advocacy efforts and the effects on our specialty would be beneficial for applicants.

Lastly, the workforce report has been frequently hypothesized as a major contributing factor to the rapid decline in EM residency applications over the last two years.[8] Applicants to EM in our survey confirmed this hypothesis, citing projections stemming from the report as the most important factor leading to the significant rise in unfilled EM residency positions in the 2022 and 2023 Matches. Subsequent studies have addressed workforce considerations such as physician attrition and geographic distribution.[32,33] Further investigation and clarity into the future EM workforce would aid applicants as they weigh their career decisions.

Reinforcing the positive aspects of EM while addressing the negative factors above will go a long way toward bolstering the EM applicant pool and future workforce. The 2023 EM Match was unprecedented with 554 unmatched positions. However, EM still matched 2,456 applicants, the fourth largest number in the 2023 Match.[3] Our survey yields insights into the positive aspects of EM that draw applicants to the specialty and identifies negative factors following the 2023 EM Match.

LIMITATIONS

Our survey may be impacted by selection bias as our distribution method did not guarantee that every residency applicant who considered applying to EM residency was included. For this reason, survey response rate was not calculated, and it is unknown to what extent our results are representative of all EM residency applicants in the 2022 and 2023 Match cycles. Additionally, recall bias may also contribute as responses from applicants who matched to EM in 2022 were included. As potential survey participants were identified through their membership in national EM resident and student organizations, this study may not be representative of individuals who considered EM early in their medical school career and ultimately did not pursue EM. The exact number of individuals who received the survey solicitation is not known, making it impossible to calculate a response rate. Our survey responses represent 7.7% of the total number of applicants to EM in 2023, although it is unlikely the survey reached all applicants in the pool. Future studies may benefit from a longitudinal approach soliciting EM interest-group participants in the first two years of medical school and following them through their respective Match years to improve response rate.

CONCLUSION

The specialty of emergency medicine experienced a sharp increase in unfilled positions in the 2022 and 2023 matches. Most applicants received advisement away from EM with the most common source being physicians in non-EM specialties. Applicants perceive corporate influence in EM, ED crowding, burnout, influence of advanced practice practitioners in EM, and workforce concerns as driving forces behind the EM Match results. Applicants cited clinical experiences in the ED and interactions with EM attendings and residents as positive factors. High-acuity patient care, diverse patient pathology, and flexible lifestyle were seen as positive characteristics of a career in EM.

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Combining Immersive Simulation with a Collaborative Procedural Training on Local Anesthetic Systemic Toxicity and Fascia Iliaca Compartment Block: A Pilot Study

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Introduction: Readiness to perform a wide variety of procedures or manage nearly any patient presentation remains an essential aspect of emergency medicine training and practice. Often, simulation is needed to supplement real-life exposure to provide comfort and knowledge, particularly with rarer pathology and procedures. As the scope of practice continues to grow, newer procedures, such as ultrasound (US)-guided nerve blocks (UGNB), are becoming integrated into resident training, building on previously established skills. The fascia iliaca compartment block (FICB) is performed on patients with specific femoral fractures and is a now a component of standard multimodal pain regimens, with US-guidance limiting adverse events. Given the need for high volumes of local anesthetic to perform the block it is imperative for clinicians to understand dosing as well as recognize and treat local anesthetic systemic toxicity (LAST). With sparse literature on sequential immersive and procedural simulation involving intertwined topics, this presents a unique opportunity for learners.

Methods: To study the perceived knowledge and comfort with FICB and LAST, a pilot study was developed with two separate but concurrent one-hour simulations completed encompassing one of each topic over one day. We surveyed 19 learners, consisting of residents ranging from postgraduate years 1–3, prior to and immediately following completion, regarding their perceptions. We used the Stuart-Maxwell test to compare survey data.

Results: More than half of participants (56%) had not received prior formal training on FICB. There was a positive trend in perceived confidence and knowledge with visualizing relevant anatomy (4.0 [2.0–6.0] vs 9.0 [7.5–10.0], $P = 0.10$), performing FICB (4.0 [1.0–5.0] vs 9.0 [7.0–10.0, $P = 0.08$]), and perceived ability to teach their peers (3.0 [1.0–5.0] vs 8.5 [7.0–10.0], $P = 0.20$). Perceived ability in diagnosing and managing LAST also increased following the simulation (5.0 [3.0–6.0] vs 6.0 [6.0–7.0], $P = 0.12$ and 3.0 [2.0–6.0] vs 6.0 [6.0–7.0], $P = 0.08$, respectively).

Conclusion: Learners' perceptions of this simulation experience echo the findings of previous studies in which simulation can be used to teach procedures and pathology; of note, however, we presented a novel experience with a combination of immersive and procedural simulation. [West J Emerg Med. 2025;26(2)271–278.]

INTRODUCTION

To enhance preparedness to care for uncommon patient presentations and procedures, simulation has often been used in graduate medical education (GME) to lay the foundation as well as to fine tune skills, including resuscitations.[1] Simulation has also been at the forefront of procedural skill acquisition and increasing learner's confidence at both the GME and undergraduate medical education levels, with a focus on both high-acuity and low-occurrence procedures.[2–4] Both in simulation and clinical practice, more procedures are being performed under ultrasound (US) guidance with trends toward increased safety and efficacy, most notably including placement of central venous lines.[5,6] With this increasing incorporation of US training in emergency medicine (EM) residency programs, the variety of procedures performed in an emergency department (ED) setting have also expanded.

Regional nerve blocks were previously completed via landmark only; however, there has been progression toward US-guidance due to reduced adverse events and greater first-attempt success rates.[7,8] Regional nerve blocks have increasingly fallen under the scope of EM practice, particularly with regard to US-guided nerve blocks (UGNB). Many patients are poor candidates for frequent or high doses of opioids as a primary pain management strategy in the ED.[9] One study found almost 25% of elderly patients suffered from delirium while hospitalized, with the majority of those receiving polypharmacy.[10] However, UGNB is a valuable tool for managing pain in hip fractures, regardless of patient ability to tolerate opioid and non-opioid analgesics. Nerve blocks are now recommended by the American College of Surgeons and the American Academy of Orthopaedic Surgeons as a standard component of a multimodal approach to pain management.[11,12] The American College of Emergency Physicians (ACEP) recently stated that UGNBs make up a core skill for emergency physicians, voicing broad support for its use and citing its versatility for a variety of procedures, from complex laceration repairs to orthopedic reductions/splinting.[7]

The fascia iliaca compartment block (FICB) can provide significant analgesia, particularly in populations that may have contraindications or comorbidities that preclude standard systemic intravenous and/or oral pain regimens including opioids, ketorolac, and other analgesic agents. The block, with its discovery in 1989 and eventual introduction in the EM literature in 2007, has been slow to be adopted despite its safety profile and efficacy.[13,14] The FICB can be used for femoral neck fractures in the pre-, peri-, and postoperative stages given the blockade of femoral nerve, local femoral cutaneous nerve, and variable coverage of the obturator nerve.[8,15] By incorporating US guidance, the compartment block is done lateral to the femoral triangle (femoral nerve, artery, and vein), thus minimizing the chance of intravascular injection.[13] A meta-analysis of FICB has also been shown to reduce morphine dosing requirement and may even negate the need for additional medications beyond the block.[16] In another study, 90% of patients had blockade with a significant reduction in the visual analogue scale from 7.5 to 2.94 at the 20-minute mark.[17] With such compelling data regarding its efficacy and the widespread availability of US in EDs, the FICB represents a powerful tool in pain control in the ED setting that is well within the scope of the emergency physician. Within our current practice, this could result in increased patient satisfaction and possibly free up more resources, including nursing, particularly if not requiring consistent treatment for breakthrough pain.

Local anesthetics are commonplace within the medical field and especially within the ED where they are a routine component of any clinician's medical practice.[18] However, complications exist, particularly when large quantities of anesthetic are used, or inadvertent intravascular injection occur, which may cause local anesthetic systemic toxicity (LAST). Elderly patients or those with organ dysfunction are at a particularly high risk.[19,20] Further complicating the syndrome, LAST has considerable variability in onset and symptomatology.[19] It can be detrimental through its effects on both the central nervous system (CNS) and cardiovascular systems, resulting in arrhythmias, seizures, cardiovascular collapse, and risk of cardiac arrest. Each anesthetic agent has its own maximum, weight-based dosing that may be augmented if formulated in combination with epinephrine.[19]

Previously, it was believed the agents would behave in a predictable, stepwise manner with precedent CNS symptoms appearing prior to cardiac dysrhythmias; however, the more potent agents have been found to have preceding and possibly concomitant cardiac and CNS toxicity.[20] The incidence of LAST is variable with one study reporting occurrence in up to 25 per 10,000 blockades and another specifying occurrence in 79 of 10,000 brachial plexus blockades.[20] Regardless of the true incidence, LAST occurrence has been shown to be reduced with US-guided regional anesthesia by up to 65%, although risk still exists.[21] Thus, training on recognition of the signs and symptoms, as well as treatment, is imperative for emergency physicians. Simulation of this procedure and its most dangerous complication allows learners an opportunity to gain experience with the condition without effects on patient outcomes. Following recognition of LAST, injection must be first discontinued and in severe cases may require administration of intralipid emulsion therapy (ILE). The American Heart Association also includes ILE in its guidelines for cardiac arrest secondary to LAST.[22]

Following ACEP guidelines and expanding on basics of well-known procedures, FICB may be a beneficial procedure for emergency physicians to master along with the consideration of the risks of LAST and its management. Simulation has been documented as being an effective teaching modality, offering a safe environment for

learners.[23,24] Ultrasound-based training has been previously shown to be beneficial with an improvement in confidence and procedural skills.[23] The literature is sparse on a combination of sequential immersive and procedural simulation techniques in medical education. While taking into consideration the variable presentations and severity of complications related to LAST, as well as the rising importance of regional nerve blocks in EM, a paired simulation experience can improve identification and treatment of the syndrome, as well as allow learners to enhance their skillset. Here we present a pilot study on EM residents' perceptions and confidence with diagnosing and managing LAST as well as procedural skills with FICB.

OBJECTIVES

Our objective in this study was to create an immersive simulation that teaches EM residents to recognize clinical signs and symptoms of LAST, develop an appropriate treatment algorithm, and manage potential outcomes including cardiac arrest. Secondary objectives included successful performance of US-guided FICB, troubleshooting complications, and determining proper local anesthetic dosing to prevent LAST. Ultimately, the goal was to develop a simulation-based curriculum to increase resident comfort and knowledge with the FICB while recognizing and managing its rare and more dangerous complications.

METHODS

We conducted a prospective pilot study, deemed exempt by the institutional review board, for both an immersive case and procedural simulation in the fall of 2023. A pre-simulation questionnaire was administered a month prior with a focus on residents' perceived comfort levels with various US-guided procedures, along with uncommon causes of cardiac arrest and their management. Another pre-questionnaire was administered just prior to the procedural FICB simulation regarding comfort and knowledge with the specific procedure.

Participants were EM residents ranging from postgraduate years (PGY) 1–3 at a Level I trauma center university hospital system. A convenience sample of 19 residents who were present for the conference day participated. All participants voluntarily agreed to participate in the activities with informed consent provided. As part of the residency curriculum, residents must complete a four-week rotation focusing on US skills and interpretation as PGY-1s as well as fulfill the Accreditation Council for Graduate Medical Education-required number of resuscitations, ultrasounds, and procedures. An additional four weeks of the PGY-1 year is devoted to toxicology with focus on awareness and management of toxicologic emergencies. However, as the session was completed in the first half of the year, not all PGY-1s had completed a toxicology and/or US rotation. Prior to the simulations, hands-on practice had only occurred on the individual level in the department clinically with numbers ascertained prior to the simulation. A pre-survey had been filled out one month prior to the simulations.

The LAST immersive simulation was performed first for each participant to avoid participant bias and anchoring. For the simulation, participants were randomly divided into groups of approximately three residents for a 30-minute novel immersive case simulation with subsequent structured debrief and post-survey. The simulation was developed in conjunction with EM simulation fellowship-trained faculty. This case involved ascertaining a history and physical, which included a recent FICB for a traumatic hip fracture. The case progressed with the patient showing clinical signs and symptoms of LAST, including seizure and subsequent cardiac arrest. Participants were tested on and expected to develop a differential diagnosis for the patient's presentation, identify LAST, and treat the patient with intralipid therapy as well as supportive care. The team was interdisciplinary with EM nurses and pharmacy residents also participating. Following the simulation during a debriefing session, diagnostic criteria and management of LAST were discussed using information provided by a board-certified toxicologist. Participants then filled out a post-survey evaluating their knowledge and comfort level regarding their recognition and management of LAST.

Following completion of the LAST immersive simulation, participants were transitioned to the FICB procedural simulation in a separate location to avoid communication with incoming participants. Each group consisted of approximately six residents to allow for adequate hands-on time. A pre-survey was administered with specific questions directed toward residents' perceived comfort and knowledge with the FICB procedure. A brief didactic lecture followed with focus on clinical indications for the procedure, US anatomy, procedural setup, and local anesthetic specifications and dosing. A reiteration of signs of LAST as well as management was included in the lecture as well. A standardized procedural checklist developed in conjunction with board-certified US faculty was used by all facilitators (Figure 1). Another handout for practicing calculating maximum doses was provided as a cognitive aid.

A standard setup of nerve block supplies was used (Figure 2). The procedural simulation used a fascia iliaca manikin (Valkyrie Simulators, Johnson Mills, WV) for practice visualizing anatomy with US, and a porcine-tissue model was used to practice hydrodissecting akin to performing the procedure in clinical practice (Figure 3). No manipulations were made to the porcine-tissue model including addition of mock nerve structures. Following completion of the procedural simulation, a post-survey was administered to the resident participants with specific questions pertaining to confidence and knowledge of procedural indications, relevant anatomy, and perceived

Planning for procedure	
	Confirm patient identity using two-patient identifiers
	Obtain informed consent
	Perform hand hygiene and don exam gloves
	Document physical exam prior to procedure including neurovascular exam
Preparing for procedure	
	Gather appropriate equipment
	Place patient in neutral position
	Calculate maximum dosing of anesthetic
Procedural Steps	
	Analyze anatomy with US including location of femoral artery
	Disinfect site
	Don PPE and drape field
	Draw up local anesthetic and normal saline if desired in syringe
	Connect spinal needle or PIV needle to connector tubing and syringe
	Cover linear array with sterile probe cover
	Insert with needle in-plane
	Hydrodissect fascia iliaca with partner pushing syringe
	Inject entire solution ensuring not to exceed maximum dose
	Remove needle
Performing appropriate aftercare	
	Dispose of all other non-sharp materials
	Remove PPE and perform hand hygiene
	Clean hands using alcohol-based hand sanitizer or soap and water

Figure 1. Learner checklist for fascia iliaca compartment block (FICB) procedure.
PPE, personal protective equipment; *PIV*, peripheral intravenous; *US*, ultrasound.

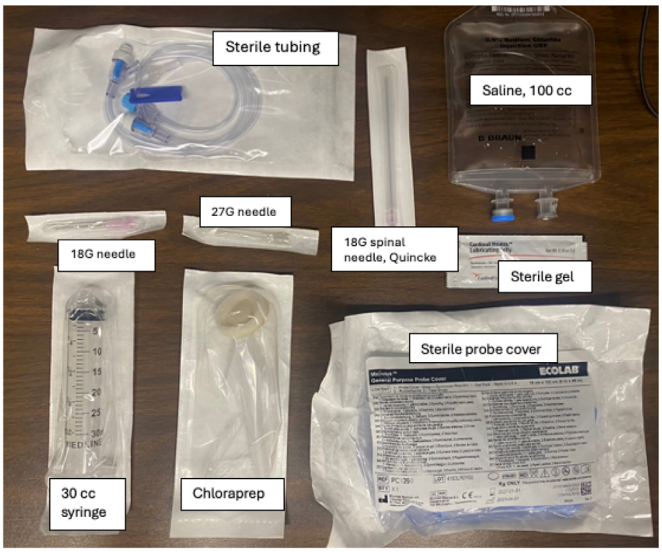

Figure 2. Supplies for fascia iliaca compartment block procedure.
G, gauge; *cc*, cubic centimeter.

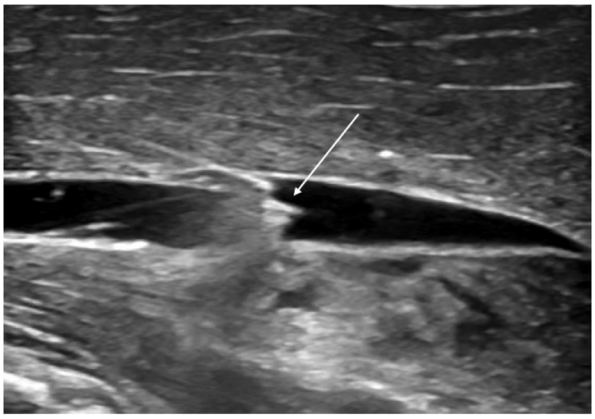

Figure 3. Simulation of hydrodissecting on porcine-tissue model (arrow indicating needle tip).

comfort in performing the procedure following hands-on teaching and guidance. Board-certified US faculty directed all hands-on teaching and instruction.

We compared pre- and post-training survey responses using a generalized Stuart-Maxwell test to evaluate the impact of the training on residents' knowledge and attitudes toward the procedure and LAST toxicity. Questionnaires included scale of 1–10 for FICB surveys and 1–7 for LAST surveys, with 1 corresponding to strongly disagree and the upper limits of 7 and 10 representing strongly agree, respectively. An alpha level of 0.05 was set for all statistical tests. We performed all analyses in SAS 9.4. (SAS Institute Inc, Cary, NC).[25]

Prior to implementation of both simulations, we performed walk-through sessions to anticipate and identify any logistical or systems issues. Nursing, pharmacy, and

Table 1. Group characteristics.

Pre-simulation group characteristics	LAST (n = 19)	FICB (n = 16)
PGY level		
PGY-1	4 (21.1%)	3 (18.8%)
PGY-2	7 (36.8%)	5 (31.3%)
PGY-3	8 (42.1%)	8 (50%)
Prior to workshop: number of previously performed FICB		
I have never heard of it		0
0		8 (50%)
1–3		5 (31.3%)
4–6		1 (6.3%)
>6 times		2 (12.5%)

PGY, postgraduate year; *LQ*, lower quartile; *UQ*, upper quartile; *FICB*, fascia iliaca compartment block; *LAST*, local anesthetic systemic toxicity.

simulation staff were also consulted for input regarding the session as well as implementation in the department. A board-certified toxicologist also provided input to ensure management was consistent with the standard of care.

RESULTS

A total of 19 EM residents ranging from PGY 1–3 participated in the LAST simulation, and 16 residents participated in the FICB procedural simulation. The distribution among training levels is described in Table 1 with a skew toward more PGY-3s (42.1% and 50%, respectively). Overall, 16 participants, or more than half (56%), had not received prior formal training on FICB. Half of the participants had previously performed a FICB, with the majority (31.3%) only performing 1–3 FICB prior to the session (Table 1). Following simulation, learners reported an improvement in confidence and knowledge with performing a FICB, with the pre-simulation improving from 4.0 (1.0–5.0) to 9.0 (7.0–10.0) post-simulation using the scale previously mentioned with 10 representing "strongly agree." There was also an increase in the perception of the utility of FICB in the ED. Learners felt more confident in using US to visualize the relevant anatomy (4.0 [2.0–6.0] vs 9.0 [7.5–10.0]) and general knowledge of UGNB (5.0 [2.0–7.0] vs 10.0 [8.0–10.0]). Residents felt more confident in their ability to teach their peers the procedure (3.0 [1.0–5.0] vs 8.5 [7.0–10.0]). A general positive trend in comfort and knowledge was noted in the FICB following simulation, although no results were statistically significant (Table 2).

Learners rated similar perception in comfort with diagnosing and managing uncommon conditions both prior to and following the LAST simulation. There was an increase in comfort in both diagnosing and managing LAST. Recognition of LAST increased from 5.0 (3.0–6.0) to 6.0 (6.0–7.0) from pre- to post-simulation, respectively, with 7.0 representing strong agreement with a statement. Perception regarding management followed a similar trend with 3.0 (2.0–6.0) pre-simulation to 6.0 (6.0–7.0) post-simulation (Table 2), although neither was found to be statistically significant.

DISCUSSION

Simulation is a key component of GME, for both immersive cases as well as practicing and mastering procedures, but there is limited research on combining both approaches to better mimic real-life practice and tie in connected topics. Simulation of the FICB, and its most serious adverse effect, LAST, offers a unique opportunity for resident simulation. With minimal resources and setup, it is possible for learners to experience the multitude of pathologic presentations and needed resuscitative measures of LAST. Although the main goal of both simulations was to assess perceptions in knowledge and confidence, the residents were also able to practice management of seizures, airway, and cardiac arrest while also fine-tuning US-guidance skills.

While our study was limited by underpowering, as is common in simulation-focused GME studies due to limited learner numbers, we found evidence of several important trends although they lacked statistical significance.[26] In the timing immediately following simulation, residents reported an increasing trend in confidence and self-perceived knowledge, with the trend being more profound for the FICB procedural simulation. These findings are in line with prior procedural simulation-based research, demonstrating a trend toward improved learner confidence and knowledge following the procedure.[27,28] Residents also noted increasing comfort with teaching peers the procedure. As resident perceptions were surveyed immediately following the simulation events, it is unclear whether those trends persisted beyond the day of simulation or were applied to subsequent clinical practice. Future investigations would benefit from follow-up at a scheduled interval and clinically focused outcome measures, such as procedural proficiency or the absence of adverse events.

Regarding the immersive simulation, no significant impact was seen in diagnosing and managing uncommon conditions or working in an interdisciplinary team, although there was a positive trend with residents' ability to diagnose and manage LAST. Previous studies have focused on the impact of interprofessional teams for immersive simulation and have noted a positive correlation with appreciation and general knowledge of other healthcare professions.[29] Despite resuscitation being a major component of EM training, this study may demonstrate a need for more detailed instruction regarding rarer causes of arrest.

Overall, perceptions of the simulation experience were also positive with learners indicating support of future

Table 2. Pre- and post-simulation reported experiences.

Mean reported pre- and post-simulation perceptions (FICB) (n = 16)	Median	LQ	UQ	*P*-value
Perceived knowledge of ultrasound-guided nerve blocks				
Pre-simulation	5.0	2.0	7.0	0.13
Post-simulation	10.0	8.0	10.0	
Perceived comfort level with performing FICB				
Pre-simulation	4.0	1.0	5.0	0.08
Post-simulation	9.0	7.0	10.0	
Perceived comfort visualizing fascia iliaca anatomy on US				
Pre-simulation	4.0	2.0	6.0	0.10
Post-simulation	9.0	7.5	10.0	
Perception of FICB utility in the ED				
Pre-simulation	8.0	7.0	10.0	0.13
Post-simulation	10.0	9.0	10.0	
Perceived comfort teaching procedure to peers				
Pre-simulation	3.0	1.0	5.0	0.20
Post-simulation	8.5	7.0	10.0	
Mean reported pre- and post-simulation perceptions (LAST) (N = 19)	**Median**	**LQ**	**UQ**	***P*-value**
Perceived confidence in diagnosing uncommon conditions				
Pre-simulation	5.0	4.0	6.0	0.79
Post-simulation	5.0	4.0	6.0	
Perceived confidence in managing uncommon conditions				
Pre-simulation	5.0	4.0	6.0	0.40
Post-simulation	5.0	4.0	6.0	
Perceived confidence in working in a multi-disciplinary team				
Pre-simulation	6.0	6.0	7.0	0.23
Post-simulation	6.0	5.0	7.0	
Perceived confidence in recognition of LAST				
Pre-simulation	5.0	3.0	6.0	0.12
Post-simulation	6.0	6.0	7.0	
Perceived confidence in management of LAST				
Pre-simulation	3.0	2.0	6.0	0.08
Post-simulation	6.0	6.0	7.0	

PGY, postgraduate year; *LQ*, lower quartile; *UQ*, upper quartile; *FICB*, fascia iliaca compartment block; *LAST*, local anesthetic systemic toxicity; *US*, ultrasound.

sessions for other EM residents and clinicians. Although not statistically significant and largely similar pre- and post-simulation, the combination of cases was well received by residents in survey comments. Combination cases may provide a chance for a deeper grasp of integrated topics as well as a unique opportunity for residents to practice in an immersive simulation environment. The limited time available for resident education makes this approach valuable, as both simulations cover multiple aspects of medical care.

LIMITATIONS

Limitations to the study include participants' self-reported confidence and knowledge after a single encounter and, thus, may have been subject to bias given its subjective nature. While there was a general trend toward improvement in perceptions of knowledge and skills following the simulation, this is also in reference to short-term recall with further studies needed to ascertain long-term retention of knowledge and procedural skills. Further studies would also be required to elucidate the effects of combination simulation as a

Table 3. Learner perceptions regarding simulation experience.

Post-simulation learner experience survey	Median	LQ	UQ
The goals of the simulation were clearly outlined prior to participation	10.0	9.0	10.0
Felt had enough supervision during simulation	10.0	9.0	10.0
Felt comfortable asking questions or for help during the simulation	10.0	9.0	10.0
Felt was given adequate feedback during simulation	10.0	9.0	10.0
Simulation complimented learning style	10.0	9.0	10.0
This workshop would be useful for future ED residents and clinicians	10.0	9.0	10.0

ED, emergency department; *LQ*, lower quartile; *UQ*, upper quartile.

learning opportunity. Neither were we able to measure translation to real-world practice, with unclear integration of FICB into the participants' future clinical practice. An expansion of the study with an extended timeline may show a decline in the knowledge and skills acquired in this simulation over time, as well as practice changes. Participation was another key limitation with a predominance of upper-level residents; and loss of participants may be attributed to scheduling difficulties particularly with off-service rotations.

Further limitations may exist if attempting to reproduce this experience at other sites; this simulation is based on faculty's own perceived skills and confidence in performing, and teaching, FICB, which may not be as strong at other sites. This simulation may not be worthwhile at other sites if FICB procedures cannot be implemented given accessibility to intralipid emulsion therapy in case of possible LAST. Although research has already shown the benefit of using FICB in EDs both in the United States and resource-limited areas, further studies should be performed on teaching modalities, particularly for those with historically more limited ultrasound teaching.[13] The homogenous responses in Table 3 may reflect further limitations to the study, which could reflect underlying bias.

CONCLUSION

Overall, this study continues to demonstrate the positive effect regarding the use of simulation in medical education, both with immersive and procedural simulations. Increasing exposure, even at an introductory level, of rarer pathology, including LAST, may aid in diagnosis and management. Residents' perception of the procedural simulation in this study, while limited to fascia iliaca compartment block procedure, also had a positive trend toward comprehension and skillset. Although limited in the number of participants, this study demonstrates that the use of combination immersive and procedural simulation may provide an exciting and worthwhile experience for learners, particularly with interconnected topics.

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Development of a Reliable, Valid Procedural Checklist for Assessment of Emergency Medicine Resident Performance of Emergency Cricothyrotomy

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Introduction: Emergency cricothyrotomy is a rare but potentially life-saving procedure performed by emergency physicians. A comprehensive, dichotomous procedural checklist for emergency cricothyrotomy for emergency medicine (EM) resident education does not exist.

Objectives: We aimed to develop a checklist containing the critical steps for performing an open emergency cricothyrotomy, to assess performance of EM residents performing an open emergency cricothyrotomy using the checklist on a simulator, and to evaluate the reliability and validity of the checklist for performing the procedure.

Curricular Design: We developed a preliminary checklist based on literature review and sent it to experts in EM and trauma surgery. A modified Delphi approach was used to revise the checklist and reach consensus on a final version of the checklist. To assess usability of the checklist, we assessed EM residents using a cricothyrotomy task trainer. Scores were determined by the number of correctly performed items. We calculated inter-rater reliability using the Cohen kappa coefficient. Validity was assessed using the Welch *t*-test to compare the performance of residents who had and had not performed an open emergency cricothyrotomy, and we used analysis of variance to compare performance of postgraduate year (PGY) cohorts.

Impact/Effectiveness: The final 27-item checklist was developed after three rounds of revisions. Inter-rater reliability was strong overall ($\kappa = 0.812$) with individual checklist items ranging from slight to nearly perfect agreement. A total of 56 residents participated, with an average score of 14.3 (52.9%). Performance varied significantly among PGY groups ($P < 0.001$). Residents who had performed an emergency cricothyrotomy previously performed significantly better than those who had not ($P = 0.005$). The developed checklist, which can be used in procedural training for open emergency cricothyrotomy, suggests that improved training approaches to teaching and assessing emergency cricothyrotomy are needed given the overall poor performance of this cohort. [West J Emerg Med. 2025;26(2)279–284.]

BACKGROUND

Emergency cricothyrotomy is a rare but potentially life-saving procedure that emergency physicians (EP) must be able to competently perform. It is performed when the EP is unable to oxygenate and ventilate a patient after rapid sequence intubation is initiated and, therefore, must pursue cricothyrotomy in a time-sensitive manner. Thus, it is essential for EPs to be able to perform the procedure correctly. Furthermore, the Accreditation Council for Graduate Medical Education includes cricothyrotomy as a "key procedure" for which residents "must demonstrate competence."[1] However, there are few opportunities to learn this procedure in the clinical environment, with one study demonstrating that only 22% of graduating emergency medicine (EM) residents had the opportunity to perform cricothyrotomy on a living patient.[2] Another study indicated that even experienced EPs felt that they lacked training in performing cricothyrotomy and that this procedural inexperience could directly affect the survival of a patient and lead to high emotional pressure.[3] Lastly, the critically important nature of the procedure makes learning on shift a patient safety issue.

The combination of competency-based approaches using checklist-based assessments and the simulation environment has demonstrated a long track record of improving resident performance on specific procedural skills.[4–8] While various instructional videos and checklists meant for different specialties are available, a standardized, reliable, valid, comprehensive, and dichotomous procedural checklist for assessment of performing emergency cricothyrotomy for EM resident education is lacking.[9–11] Historically, the study site program's method for teaching the open emergency cricothyrotomy occurred during the annual "rare procedures" simulation lab. These sessions involved non-standardized practice with a task trainer or sheep larynx that did not follow a competency-based training model.

OBJECTIVES

Recognizing this unmet need in EM procedural training for our learners, we set several objectives in this study. The primary objective was to develop a checklist containing the critical steps for performing an open emergency cricothyrotomy based on input from a multidisciplinary team of experts. The second objective was to evaluate the reliability and validity of the checklist for performing open emergency cricothyrotomy. Finally, the third objective was to use the checklist to assess a group of EM residents on their ability to perform the procedure on a simulator and compare performance by training year.

CURRICULAR DESIGN

Checklist Development

We performed a literature review in MEDLINE and the MedEd Portal to assess published literature for emergency cricothyrotomy procedure checklists and curriculums. Key phrases for literature searches included "emergency cricothyrotomy curriculum," "emergency cricothyrotomy checklist," "emergency cricothyrotomy procedure," "emergency cricothyrotomy simulation," "emergency cricothyrotomy resident," "emergency cricothyrotomy residency," "emergency cricothyrotomy education," and variations and combinations of the key words/phrases. Searches included all articles published until the search date of November 1, 2020. An EM procedural skills textbook and a surgical technique textbook were reviewed as well.[12,13] We also evaluated relevant articles from the bibliographies of the textbooks and included studies for inclusion.

We used the Stufflebeam framework for checklist development after the literature review was completed.[14] A preliminary dichotomous ("done" vs "incorrect/not done") checklist was developed based on this literature review. The initial checklist was sent to a panel of 13 experts comprised of emergency physicians and trauma surgeons of varying practice type (academic, community, military), geographic practice location (within the United States), and gender. Practice type included 10 academic, two community, and one military hospital; practice location included five internal and eight external; and breakdown by sex was five female and eight male. Experts were blinded to each other's identities and comments. We informed the expert panel of the curriculum's intended audience of EM residents with anticipated use for a competency-based curriculum. We used a modified Delphi approach to serially refine the checklist and reach consensus on a final checklist.[15,16] We then pilot-tested the checklist to ensure the items, wording, and formatting were ideally operationalized. Finally, the expert panel reviewed it for final approval.

Study Population

The study was performed at a single urban academic center with a four-year EM residency training program. Four residents were excluded from the study due to their participation in the checklist design and assessment process. All other EM residents were included in the education as part of the annual simulation curriculum; however, participation in the study was voluntary. The study was reviewed by the institutional review board (IRB) at Northwestern University, Feinberg School of Medicine and determined to be exempt. Written informed consent was obtained from participants using a consent form approved by the IRB.

Assessment

Assessments occurred in the simulation center using a simulation manikin (TraumaMan, Simlab, Seattle, WA) from August 31–September 28, 2021. Performance assessments were documented using an electronic version of the checklist in Qualtrics (Qualtrics, Seattle, WA), including a dichotomous "Yes" or "No" for completion of each step.

One in-person rater (DL) was situated adjacent to the simulation manikin with the ability to move about the simulation room to ensure ideal visualization. Audiovisual recording of the assessment included one camera overhead providing a direct overhead view and a second camera situated to provide a view from the side. Each participant assessment was recorded from start to completion of the checklist. The dual video feeds with audio were saved as a single side-by-side video recording. These recorded videos were reviewed by a second rater at a later time. We used an online random number picker (https://www.random.org/lists/) to select 30% of the participants for scoring by the second rater.[17] The second rater (AR) scored the randomly selected sample of video recordings using the same electronic assessment instrument in Qualtrics.

Data Analysis

The checklist was analyzed for inter-rater reliability and validity among a cohort of EM residents ranging from PGY1-4. Inter-rater reliability was calculated overall and for each checklist step using the Cohen kappa coefficient. We determined validity using the Welch *t*-test to compare the performance of participants who had and had not performed an emergency cricothyrotomy in clinical practice or simulation and also between consecutive PGY groups. Analysis of variance was used to compare performance among PGY cohorts.

IMPACT/EFFECTIVENESS

Results

The literature search produced a total of 394 articles. After review, 13 articles were deemed suitable to inform checklist development. An additional two articles were identified and included upon reviewing references of the included articles and the two textbooks. We developed a preliminary 33-item dichotomous checklist based on this literature review. Consensus was achieved after three rounds of revisions, resulting in the fourth version of the checklist being the final version. We then tested the final 27-item checklist among ourselves for usability. Only minor wording and formatting changes were made to ensure ideal operationalization of the checklist. The final checklist was approved by the expert panel after usability testing, and no additional revisions were suggested.

The table includes percentage correct of checklist items, inter-rater agreement, and Cohen kappa coefficients for each checklist item. Overall, inter-rater reliability was strong ($\kappa = 0.812$) with individual checklist items ranging from fair to nearly perfect agreement, with one item having slight agreement. A total of 56 residents participated, including 15 PGY-1, 14 PGY-2, 13 PGY-3, and 14 PGY-4 residents. While only one resident had performed an emergency cricothyrotomy on a live patient, 69.6% had previously performed an emergency cricothyrotomy in simulation. The average checklist score for the overall resident cohort was 14.3 (52.9%). Emergency medicine resident checklist performance varied by PGY class (Figure). Performance varied significantly amongst PGY groups ($P < 0.001$). The PGY-4s performed best with an average score of 16.7 (61.9%) of checklist items completed correctly. They performed better than PGY-3s, but not significantly (61.9% vs 59.5%, $P = 0.21$). The PGY-3s performed significantly better than PGY-2s (59.5% vs 48.9%, $P = 0.01$). The PGY-2 performance was better but not significantly different compared to PGY-1 performance (48.9% vs. 42.7%, $P = 0.13$). The residents who had previously performed an emergency cricothyrotomy on a live patient or in simulation performed significantly better than those who had not (56.8% vs. 44.2%, $P = 0.005$).

Discussion

Although we identified procedural narratives and checklists with varying degrees of specificity for our learner group at the time of our literature review, our search demonstrated a lack of a standardized, validated, reliable, and dichotomous procedural checklist for emergency cricothyrotomy for EM residents. This checklist adds to more recently published articles targeting attendings, students, and "novice" learners. This newly developed procedural checklist for emergency cricothyrotomy addresses this unmet need for EM resident procedural training.

The expert panel provided critical insight during the checklist development. Our initial checklist focused on the classic "hook and dilator," scalpel-based approach to emergency cricothyrotomy. However, we ultimately revised the checklist based on expert feedback to include the additional accepted approaches of "scalpel only" and "bougie-assisted" emergency cricothyrotomy. The inclusion of all three accepted approaches allowed for a more versatile checklist that is more generalizable to all resource settings and better reflects the variable real-world environment and urgency of the procedure. The inclusion of multiple techniques also suggests generalizability to other clinical environments, such as surgery and otolaryngology; however, this was not the intended audience at the time the checklist was developed. While there are several potential options for performing an emergency cricothyrotomy, including a needle/wire Seldinger technique, this checklist reflects the development with the primary construct of using a scalpel-based approach.

This study's strong overall inter-rater reliability using this checklist and one in-person rater and one remote-video rater reinforces previous studies using a similar technique.[18,19] Additionally, inter-rater reliability using this method was strong overall, which is consistent with prior checklist development studies with similar methods.[18,19] Most individual items had moderate to near-perfect inter-rater

Table. Percent correct, inter-rater agreement, and reliability for individual checklist-item scoring.

	Checklist item	Percent correct	Rater agreement	Kappa coefficient
1.	Gathers sterile supplies	48.2%	64.7%	0.370
2.	Gathers primary cricothyrotomy procedure supplies	66.1%	100%	1.000
3.	Gathers secondary/supplemental cricothyrotomy procedure supplies	82.1%	94.1%	0.821
4.	Gathers supplemental intubation supplies	0%	100%	n/a*
5.	Washes hands	17.9%	94.1%	0.638
6.	Sterilizes the neck	87.5%	94.1%	0.767
7.	Dons personal protective equipment	67.9%	100%	1.000
8.	Proceduralist positions on the patient's right side	89.3%	88.2%	0.605
9.	Identifies cricothyroid membrane (CTM)	482.%	52.9%	0.171
10.	Uses thumb and middle finger of non-dominant hand to stabilize airway	33.9%	88.2%	0.721
11.	Confirms incision site with palpation by index finger on the CTM using non-dominant hand while maintaining stabilization using thumb and middle finger of non-dominant hand	28.6%	88.2%	0.595
12.	Uses scalpel to make vertical skin incision ~2–4 cm in length over the CTM using dominant hand	57.1%	64.7%	0.320
13.	Dissects down to CTM	87.5%	88.2%	0.433
14.	Re-identifies CTM by palpation or visualization	76.8%	100%	1.000
15.	Makes ~1–2 cm (width of scalpel blade) horizontal incision through CTM with dominant hand and maintains scalpel blade in trachea	51.8%	76.5%	0.514
16.	Maintains patency of tract	12.5%	94.1%	n/a*
17.	Removes scalpel, only after tracheal hook, Trousseau dilator, bougie, or secondary scalpel handle is in place, maintaining patency of CTM	12.5%	94.1%	n/a*
18.	Proceduralist dilates CTM	3.6%	100%	1.000
19.	Inserts endotracheal tube or trach	91.1%	100%	1.000
20.	Inserts endotracheal tube or trach to correct depth	21.4%	88.2%	0.452
21.	Inflates the cuff with a 10-cc syringe	78.6%	88.9%	0.766
22.	Connects bag-valve-mask to endotracheal tube/trach and begins assisted ventilation	92.9%	94.1%	0.638
23.	Uses capnography to confirm tube location	89.3%	94.1%	0.638
24.	Listens for bilateral breath sounds	66.1%	94.1%	0.881
25.	Secures endotracheal tube/trach	64.3%	100%	1.000
26.	Orders chest radiograph	46.4%	100%	1.000
27.	Documents procedure	8.9%	100%	1.000

*Unable to calculate kappa coefficient due to one or both raters giving the same score to all scored participants.

reliability, overall demonstrating reliability of the checklist.[20] The items with the lowest kappa scores included "gathers sterile supplies" (item 1), "identifies cricothyroid membrane" (item 9), and "uses scalpel to make vertical skin incision ~2–4 cm in length over the cricothyroid membrane using dominant hand" (item 12). We suspect that this likely reflects the remote nature of the second rater, as mishearing a request for a single piece of equipment or inability to accurately visualize the membrane or exact length of incision on a recorded video would lead raters to score differently. This could have been improved with greater verbalization of all steps by the learner and primary rater or having a second in-person rater when able.

The residents who had performed an emergency cricothyrotomy previously performed significantly better than those who had not, demonstrating criterion validity for this checklist as there was correlation with this group's prior experience. Several studies with similar methods have also demonstrated congruent findings on checklist validity.[18,19] While not significant, more senior PGY residents performed better as well. This may have been due to increased clinical exposure with seeing an emergent cricothyrotomy performed or improved procedural experience with practice in the simulation environment. However, despite these potential exposures and previous experiences, this cohort only correctly completed just over half of the checklist items.

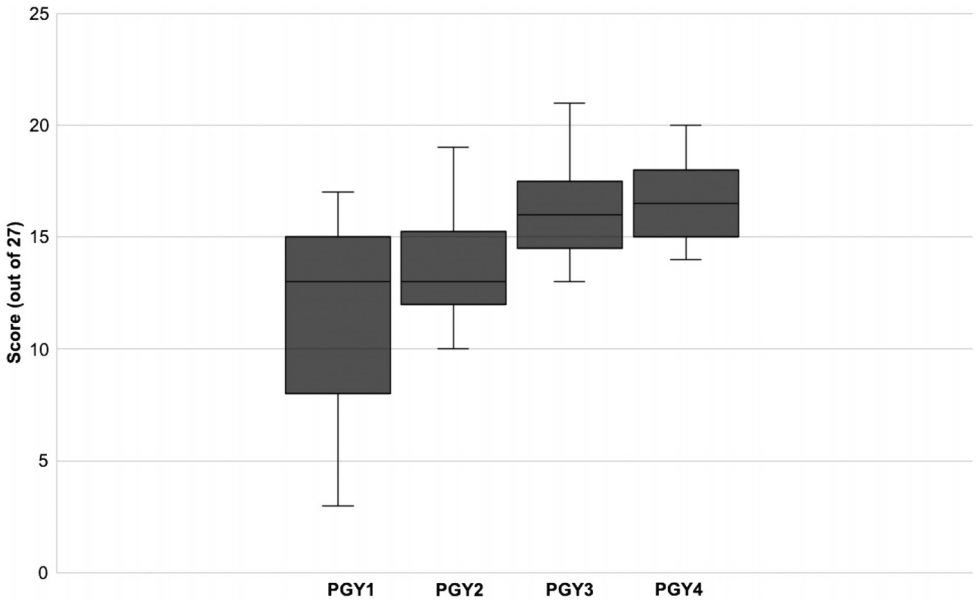

Figure. Emergency cricothyrotomy checklist performance by emergency medicine resident postgraduate year. Box limits represent the 25th and 75th percentiles with the median checklist score represented by the bar.
PGY, postgraduate year.

Additionally, certain items had particularly low completion rate, including "Gathers supplemental intubation supplies" (item 4) (0%); "Proceduralist dilates cricothyroid membrane" (item 18) (3.6%); and "Documents procedure" (item 27) (8.9%). While some of these completion rates may be attributable to the simulation environment, it is important to highlight that merely planning for an intubation would not necessarily ensure that all equipment necessary for a cricothyrotomy was also available. The overall performance of this resident group, with residents only completing roughly 50% of the checklist items, suggests that the current, non-standardized technique for teaching emergency cricothyrotomy in this cohort is lacking and that a competency-based approach using a well-developed procedural checklist may improve performance.

LIMITATIONS

This study has several limitations. First, the single-site nature of the study may not reflect resident performance at other institutions. Studying the checklist's use at other residency sites would help to understand its generalizability to other environments with different approaches to teaching open cricothyrotomy. Second, while we recruited an expert panel including EM and trauma surgery representatives with diversity in practice type, practice location, and gender, most of the experts practiced in an academic environment. Despite this, the steps to performing the procedure should not vary by practice environment and, therefore, we do not believe that this limits validity or generalizability of the checklist. Expert panel review including additional community and hybrid experts would help test this hypothesis.

Third, the checklist and testing were performed using a bloodless simulation task trainer, which may not ideally represent an actual patient encounter. However, the infrequent nature of the procedure, as evidenced by only one resident having performed an emergency cricothyrotomy during their training, necessitates a non-clinical environment training simulation. While emergency cricothyrotomy simulation experience has been documented using sheep larynx and 3D-printed models, our study was not performed using these models and instead used a commercially available training device. Therefore, we do not know the influence of different simulation methods on the study and checklist performance, and this remains an area for future study.

CONCLUSION

We designed a reliable, valid, dichotomous procedural checklist to assess EM residents' ability to perform emergency cricothyrotomy. The overall performance of the residents tested in this study suggests that the current method of teaching emergency cricothyrotomy for this group is insufficient. Given the need to develop procedural competency for this rare but potentially life-saving procedure, a curriculum such as simulation-based mastery learning should be developed to ensure mastery of this procedure for EM residents. The checklist developed in this study could serve as a foundation for such a curriculum.

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Virtual Interviews Correlate with Home and In-State Match Rates at One Emergency Medicine Program

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Introduction: Incorporating virtual interviews into residency recruitment may help diversify access to residency programs while reducing the cost involved with travel and lodging. Programs may be more likely to rank students they have met in person at an interview when compared to unknown virtual applicants. Our objective was to characterize home institution, in-state, and in-region match rates to emergency medicine (EM) residency programs for fourth-year medical students.

Methods: We used National Residency Matching Program data available to the program director to identify medical school and match location of fourth-year medical students who interviewed at a large EM residency program in the Midwest from 2018–2023. Students' medical schools and ultimately matched programs were mapped to Electronic Residency Application Service geographic regions; subgroup analyses evaluated allopathic and osteopathic medical students separately. We used chi-square tests to compare proportions of students matching to home, in-state, or in-region programs across years.

Results: There were 1,401 applicants with match information available. The percentage of students matching to a home institution remained stable over the course of the study. The percentage of students matching to an in-state institution increased over the first two years of virtual interviews rising from 23.2% in the 2020 match to 30.8% in-state matches for the 2022 match. Chi-square tests did not reveal any significant differences among groups for all applicants. Allopathic medical students demonstrated a significant increase in matches to home institutions. In-region matches stayed relatively stable over the study time frame regardless of subgroup.

Conclusion: Virtual interviews changed the landscape of residency interviews. Home institution and in-state matches may be more likely for applicants from allopathic schools who participated in a virtual interview as both programs and applicants are more familiar with each other; however, our study did not find convincing evidence of this possibility among all applicants. Additional study is needed to determine ongoing effects of the transition to virtual interviews. [West J Emerg Med. 2025;26(2)285–289.]

INTRODUCTION

Interviews are a critical element of the residency match process for both residency programs and medical students to ensure selection of high-quality applicants and training programs. Until the COVID-19 pandemic struck in early 2020, nearly all interviews were conducted in person requiring medical students to arrange travel to different program locations, a process known to be expensive and time-consuming.[1] With travel restrictions and social distancing concerns, the 2021 Match cycle marked the first use of virtual interviews for emergency medicine (EM) residency spots.

The transition to virtual interviews was marked with uncertainty from both students and programs. Students were uncertain as to how they would be able to assess programs while programs felt similarly about the ability to assess

students, particularly those who had not completed a rotation at their program. Program directors have also been noted to report difficulty assessing the fit of applicants despite the increased convenience of virtual interviews.[2] However, virtual interviews offer increased opportunities for students to complete additional interviews at lower cost, which has been noted in surgical specialties with a transition to virtual interviews.[3] Program directors also expressed concerns that programs would match more students from their home programs, reducing opportunities for programs to benefit from students with non-homogenous medical student training.[2] For fellowship applicants, similar concerns have been expressed; however, there was not found to be a significant increase in interviews completed by pediatric EM fellowship applications or a change in fellowship applicants matching within their preferred state.[4]

We evaluated whether the transition to virtual interviews at one large, Midwestern EM program correlated with increased numbers of students matching to their home programs. Additionally, we evaluated whether the transition to virtual interviews correlated with increased numbers of students matching to in-state or in-region program.

METHODS

Study Population

We obtained data from the National Resident Matching Program (NRMP) for ranked medical students from one Midwestern EM residency program for the years 2018–2023.

Data Collection and Analysis

All medical students who interviewed at one midwestern university from 2018–2023 had their home and matched programs recorded as part of routine NRMP recordkeeping. All data was stored on a secure server. This data was deidentified by the program director and coded to determine whether the interviewee matched with a program from any of the following: 1) the same institution as their medical school; 2) the same state as their medical school; and 3) the same region as their medical school. Regions were defined according to Electronic Residency Application Service (ERAS) geographic preference regions; these regions were designated beginning in 2022. Interviewees were able to signal a geographic preference according to these regions. Areas of disagreement regarding program affiliation were discussed between authors and resolved. Author AH performed the initial coding, and after review by author CM any discrepancies were resolved between affiliations using resources including the Accreditation Council for Graduate Medical Education and program websites to verify affiliations. We used chi-squared tests to assess differences between groups.[5] We conducted subgroup analyses to evaluate differences between applicants from allopathic (MD) and osteopathic schools (DO).

Outcome

The primary outcome of this study was percentage of students who matched to programs within their home institution, state, or region.

Ethics Statement

This study was reviewed and approved by the institutional review board. No funding was obtained for this study.

RESULTS

Over the six interview cycles included in the study period, 1,401 students contributed data to the NRMP and were subsequently coded to having matched at their home program or to programs within the same state or region. There was an increase in the number of interviews completed by the program over the six-year period with an average of 201 interviews completed in an in-person format prior to and during the 2020 pre-pandemic interview season. After the global COVID-19 pandemic, beginning in the 2021 recruitment season, there was an initial increase in the number of interviews offered as the format switched to virtual. Virtual interviews continued throughout the 2022 and 2023 interview seasons, but overall numbers of interviews decreased during this time frame (Table 1).

An increasing percentage of students matched to their home institution from 2020–2023, with the largest increase being observed over the 2020–2021 season corresponding with the transition to virtual interviews; however, this trend was not statistically significant. Notably, proportions of students matching to home institutions were similar in 2018 and 2023. An increasing number of students matched to in-state institutions from 2020 to 2021; further increases in the percentage of in-state matches were observed from 2021 to 2022 before stabilizing at approximately 30% of in-state matches in the final included year, close to 2018 levels. In-region matches remained roughly stable across the study period with slightly less than half of students matching to an institution in their home ERAS geographic region (Table 1). Chi-square tests did not reveal any significant differences between groups.

When evaluating the subgroup of applicants from allopathic schools, it appeared that an overall increased proportion of these applicants matched to their home institutions over the course of the six years of the study ($P < 0.01$). This increase was most notable in 2023 when 31.8% of these applicants matched to their home institutions, nearly double that of any prior year. There was also an increase in MD applicants matching to institutions within the same state as their medical school over the study period ($P = 0.01$). Regional institution matches for allopathic applicants remained stable over the study period. Osteopathic applicants did show an increase in proportion of them matching to in-state or in-region institutions; however, these trends were not statistically significant (Table 2).

Table 1. Applicant match location by year.

	Application year						
Matched to:	**2018 (n = 199)**	**2019 (n = 202)**	**2020 (n = 202)**	**2021 (n = 321)**	**2022 (n = 239)**	**2023 (n = 238)**	***P*-value**
Home institution	16.1%	12.9%	11.4%	14.0%	15.5%	16.4%	0.64
State institution	29.1%	27.6%	23.2%	26.4%	30.5%	29.4%	0.59
Regional institution	46.0%	45.7%	47.0%	44.4%	47.7%	47.5%	0.96

DISCUSSION

We found no statistically significant difference of match location among all applicants applying to one Midwestern EM residency program after the implementation of virtual interviews. Similar numbers of applicants matched to the same ERAS region as their medical school regardless of in-person or virtual- interview format. Applicants from allopathic schools did show an increased proportion matching at their home or state institutions after the implementation of virtual interviews, and this finding was statistically significant. An increasing number of osteopathic applicants matched to in-state institutions after the implementation of virtual interviews. This trend did not reach statistical significance but did approach significance.

Virtual interviews reduce cost to applicants and may allow applicants to complete interviews at additional programs. Correspondingly, the number of interviews conducted by the program increased in the first year of virtual interviews prior to stabilizing at a somewhat higher number than in the previous time frame with in-person interviews. Increased numbers of interviews offered meant increased time demands from faculty participating in those interviews and may have contributed to interview fatigue. Notably, one obstetrics/gynecology program did not find an increase in numbers of interviews offered to or completed by applicants.[6] Conversely, applicants having the ability to complete more interviews may allow for fewer financial disparities to perpetuate among students, as some students may have previously limited interviews due to cost concerns. An Association of American Medical Colleges survey showed that previous monetary costs for residency interviews ranged from $1,000 to $11,580 (median $4,000).[7] Using a virtual process may also benefit financially challenged students by eliminating the cost of flights and hotels, and other travel expenses previously necessary to complete the interview season. The transition to virtual interviews may have downstream effects on the diversity of the EM workforce if applicants are less likely to match outside their home or in-state programs.[8]

Higher percentages of allopathic students matching to in-home and in-state programs may indicate that programs and applicants alike preferentially rank each other due to familiarity, although given the uncertainties of the COVID-19 pandemic and restrictions on away rotations from 2021 onward, it is difficult to attribute this increase to one factor. It is well known that most students have a strong geographic preference to match near their home and that location is a significant driver of residency program choice.[9]

Table 2. Allopathic and osteopathic applicant match location by year.

	Application year						
Matched to:	**2018 (n = 176)**	**2019 (n = 183)**	**2020 (n = 184)**	**2021 (n = 268)**	**2022 (n = 213)**	**2023 (n = 198)**	***P*-value**
MD applicants							*P*-value
Home institution	18.2%	14.2%	12.0%	16.8%	17.4%	31.8%	<0.05
State institution	31.8%	29.5%	22.8%	26.5%	30.1%	40.4%	<0.05
Regional institution	47.2%	44.8%	47.8%	43.7%	47.4%	50.0%	0.81
	2018 (n = 22)	**2019 (n = 19)**	**2020 (n = 16)**	**2021 (n = 38)**	**2022 (n = 24)**	**2023 (n = 32)**	
DO applicants							
Home institution	0.0%	0.0%	6.3%	0.0%	0.0%	0.0%	0.13
State institution	9.1%	10.5%	31.3%	36.8%	37.5%	34.4%	0.08
Regional institution	36.4%	42.1%	43.8%	68.4%	54.2%	40.6%	0.12

MD, Doctor of Medicine; *DO*, Doctor of Osteopathic Medicine.

This trend has also been seen in orthopedic surgery programs with their transition to a virtual interview process[10]; however, this did not hold true for neurology and general surgery programs.[11,12] Students' geographic preferences in EM seem to have been amplified by the transition to virtual interviews, particularly among allopathic applicants. While virtual interviews are not the only change that occurred in the resident recruitment process during the 2021 and subsequent interview seasons, it is plausible that interview format is one of many factors influencing student interview behavior, although we did not find evidence of this behavior among all applicants in our study.

It was not possible to determine what effect other factors including travel restrictions, societal unrest, and other changes had on applicant behavior and their process of selecting application locations, interviews, and ultimately match location. Further, it is difficult to understand what effect the advent of program signaling had on both interviewee and interviewer behavior after its introduction in 2022, and this remains an active area of study. Understanding the stability of the in-region match rates is difficult to interpret but suggests that similar numbers of students are looking to leave their medical school region over time. The ERAS regions were also defined during this time frame, which may have altered students' perceptions of region. These geographic preferences are an area for ongoing study as programs evaluate residency matches to serve their communities and ensure mutually beneficial matches between programs and applicants.

LIMITATIONS

This study has multiple limitations. First, only one large, Midwestern EM residency program is represented. There are multiple other factors including the numerous social and societal changes that took place during the COVID-19 pandemic, as well as the introduction of preference signaling certainly impacted applicants' match preferences and interview behaviors in addition to the transition to a virtual interview model. We were unable to control for these factors or other changes to applicant behavior such as the potential desire to remain closer to home when travel was more constrained during the global pandemic or as a result of ongoing societal unrest. Of note, overall applicant behavior also changed across match years with a decrease in applications beginning in 2022 and increased proportions of osteopathic and international medical graduates.[13] Additionally, EM applicants continue to be advised to complete no more than one away rotation per interview cycle, which limits program and applicant exposure to each other. Further, while ERAS regions were used, this does not account for applicants who may have matched just across the border to another region, creating a false inflation of geographic distance.

CONCLUSION

Virtual interviews are now a fixture of the residency application process with EM programs requiring this process to participate in the match.[14] We did not find statistically significant differences in home institution or in-state match rates for all applicants; however, allopathic applicants did have an increase in proportion of students matching to their home institution. While our data does not suggest an overall impact of virtual interviews in match decisions made by applicants or programs, these trends warrant additional monitoring for ongoing impact, particularly among allopathic applicants where an increase in home and in-state matches was statistically significant. Further larger studies would be helpful to understand how transitioning to this model affects applicant match behavior. Additional studies would be beneficial to help programs further understand key areas of focus and ensure successful interview planning for EM programs.

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Two-year Results of an Emergency Department Night Shift Buy-out Program

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Introduction: Emergency physicians have the highest rates of burnout among our physician peers, with prior literature suggesting clinician schedules can play a significant role in burnout. We assessed our transition from a tenure- and age-based paradigm to an egalitarian, night shift buy-out program that allows schedule flexibility for physicians at all stages of their careers.

Methods: The night shift buy-out program was implemented in the emergency department (ED) of an academic, quaternary-care center that treats approximately 100,000 adult patients annually with 56 faculty emergency physicians. We sought to create a cost-neutral program, carefully balancing incentives between nocturnists and those wanting to reduce allotted night shifts. Ultimately, the program was designed to allow all faculty to buy out of any number of nights for $500 per night shift, with the funds generated used to increase nocturnist salaries. We analyzed two years of the program (July 2022–June 2024) to assess trends in night shift buy-outs, the primary outcome. We also conducted an all-faculty survey after the program's first year to gauge sentiments about the program.

Results: Over two years, 22 faculty (42%) fully bought out of nights; an additional 10 (15%) bought out of some nights. By year two, the program could grant all faculty their preferred night-shift allotment. Faculty who bought out fully had worked longer in EM on average, worked fewer clinical hours per year, were more likely to be associate/full professors, and were less likely to be women. Nocturnists had the highest mean clinical hours of the four groups, had the lowest average tenure, and were least likely to be associate/full professors. A total of 86% of faculty responded to the survey, to which more than 80% of those buying out reported that reducing the night-shift burden was either "very important" or "critical for continuing in this job."

Conclusion: Our academic ED transitioned from a tenure- and age-based, overnight shift paradigm to an egalitarian buy-out program that allows physicians flexibility at all career stages. This approach could improve career satisfaction and reduce burnout among emergency physicians. [West J Emerg Med. 2025;26(2)290–294.]

INTRODUCTION

Emergency physicians (EP) have the highest rates of burnout among our physician peers.[1] Maslach defines burnout as the triad of depersonalization, emotional exhaustion, and decreased sense of personal accomplishment.[2] While much effort has been directed toward finding meaningful solutions to counteract burnout in our field, the problem only appears to be worsening. In the

2022 Medscape Physician Burnout and Depression Report, there was a significant increase in burnout among EPs between 2021 and 2022, from 43% to 60%.[3]

Prior studies suggest that one factor affecting burnout in medicine is a physician's clinical schedule. Night shifts have been shown to negatively influence job satisfaction among EPs.[4] While "exhaustion" often refers to "emotional exhaustion" in the burnout literature, sleep deprivation has been identified as a contributing factor to decreased personal well-being, lower quality of care, and harmful health outcomes.[5–7] Sequential night shifts, in particular, have been associated with reduced cognitive performance in EPs, and shift work in general has been associated with a disruption in circadian rhythms.[8] While providing care around the clock is fundamental to the duty of emergency departments (ED), the 24/7 shifts also likely contribute to the high burnout rates among EPs.

Despite concerns about night shifts, some physicians elect to work only overnight. Reasons cited for choosing a nocturnist schedule include more independence, more time with family, higher salary, and scheduling flexibility.[9] Hiring dedicated nocturnists may allow some physicians to avoid undesirable night shifts while enabling others to opt into a primarily night-shift schedule. According to Maslach's theory of burnout, increasing employees' control over their work can decrease burnout; allowing physicians to opt in or out of nights may be a win-win for everyone's well-being.[2] In our academic ED, we transitioned from a tenure- and age-based nights paradigm to an egalitarian, night shift buy-out program that allows physicians flexibility at all career stages. Goals included budget neutrality, improving equity (by giving all faculty, irrespective of age, equal options), and increasing agency (by giving all faculty opportunity to adjust their schedule to match their own needs). This study assessed patterns in night shift buy-outs and EPs' sentiments about the program.

Population Health Research Capsule

What do we already know about this issue?
Emergency physicians (EP) have the highest rates of burnout among physicians, with prior literature suggesting clinician schedules can play a significant role.

What was the research question?
Does a night shift buy-out program improve physician career satisfaction and reduce burnout among emergency physicians?

What was the major finding of the study?
More than 80% of physicians buying out of night shifts reported this was either "very important" or "critical for continuing in this job."

How does this improve population health?
We transitioned from a tenure -and age-based overnight paradigm to an egalitarian buy-out program. This could improve career satisfaction and reduce burnout among EPs.

METHODS

Study Design and Setting

This retrospective, cohort, institutional review board-exempt study was conducted in an ED within an academic, quaternary-care center that sees approximately 100,000 adult patients annually. Our department includes both a pediatric section and an adult section; this study focuses on the staffing of the adult section. The adult attending group in the study ED comprises 56 faculty and 7–9 fellows per year. Only faculty were eligible for the overnight buy-out program; fellows did not have this option. There are 13 adult attending shifts per 24-hour period, three of which are overnight shifts. Historically in our department, attending night shifts were allocated based on academic rank, with an additional option to stop working nights altogether at age 60, regardless of academic status.

Night Shift Buy-out Program

We sought to create a new program where all faculty could buy out of night shifts. To facilitate this, we recognized the need to hire more nocturnists. Our goal was a cost-neutral program, requiring careful balancing of incentives. Therefore, several rules were established for the program.

All faculty members were eligible after one year of service, regardless of academic rank; over two years our program evolved into the system described below. To determine how many baseline night shifts EPs in our department owed, we used a prorated equation based on total clinical time, adjusted each year depending on the makeup of the attending roster and scheduling needs of the department. Most physicians in our department owed between 12–24 night shifts per year. Physicians were then offered the option of reducing their number of night shifts for the year in exchange for a salary reduction of a specific dollar amount ($500) per night shift. This number was chosen because it reflects the pay differential per shift for a nocturnist in our group. Physicians could buy out of any number of night shifts; they could decrease their nights by a single shift, buy out of all night shifts, or anything in between. Total annual clinical hours owed by these physicians did not change: bought-out night shifts were instead converted to days and evenings. The funds generated by bought-out nights were used to increase the salaries of nocturnists compared to non-nocturnist

attendings, keeping the program cost-neutral. Nocturnists could also pick the exact days they wished to work, providing total schedule control as an added incentive.

We did maintain an additional option for faculty over the age of 60. These faculty were given a choice regarding how they would like to decrease their nights: they could buy out as above, work more weekends instead of nights in a 1:1 proportion, or increase their total clinical hours in exchange for decreasing nights.

The EM night shift buy-out program was originally implemented on July 1, 2022. All faculty had to commit to their buy-out plan for one full year, with an option to modify their choices at the end of each year. While we are currently in year two at the time of writing, all buy-out decisions have already been made for the program's full second year.

Outcome Measures and Data Collection

We analyzed two years of program data to assess patterns in night buy-outs among the faculty, the primary outcome measure. We also evaluated the demographic characteristics of participating EPs separated into four groups: those who 1) had full buy-out from nights; 2) had partial buyout of nights; 3) had no buy-out of nights; and 4) were nocturnists. Demographics assessed included the following: years in EM, defined as years since medical school graduation; academic rank, stratified as clinical instructor or assistant professor vs associate or full professor; clinical hours worked, expressed as a percentage of a full-time clinical requirement in our ED; and sex, defined as male, female, or other. This data was assembled from our faculty hiring database as well as our department's scheduling software, with analyses performed in Excel (Microsoft Corporation, Redmond, WA).

We also performed a survey during the program's first year that included all EM faculty. This annual electronic survey typically assesses the well-being of our department. In the winter of 2022, we added the following question with multiple-choice, Likert scale answer choices for faculty who bought out of at least some night shifts: "How important is it for you to be able to decrease your night shift burden?" Answer choices included the following: not at all important; slightly important; moderately important; very important; and critical for continuing in this job. Given the small sample size, only descriptive statistics were performed.

RESULTS

Trends in Night Buy-outs

By the end of the program's first year, our department increased its nocturnist faculty roster from three to six attendings. In the first year, we could not allow attendings under the age of 60 to fully buy out of nights because of clinical coverage needs; those desiring full buy-out had their nights decreased by 75% rather than 100%. With three additional nocturnists hired, we could fully accommodate buy-out requests for year two. Over the two years, 22 faculty (42%) fully bought out of nights, while an additional 10 (15%) bought out of some night shifts. Seven of the 10 who chose a partial buy-out decreased their nights by 50%, while the other three bought out for fewer than 50% of their night shifts.

Demographics of Physicians Buying Out

Faculty who bought out fully had worked in EM for slightly longer on average, had lower total required clinical hours per year, were more likely to be associate or full professors, and were less likely to be women (See Table for total faculty group characteristics, as well as demographics by buy-out category). Nocturnists had the highest mean clinical hours of the four groups and the lowest average tenure and were least likely to be associate or full professors.

Faculty Feedback About the Program

Overall, 48 of 56 faculty (86%) responded to the survey at the end of year one. Of the 32 faculty who bought out at least some nights, 26 (81%) responded to the survey. More than 80% of those buying out reported that the ability to reduce the night shift burden was either "very important" or "critical for continuing in this job" (Figure).

DISCUSSION

Night shifts contribute to burnout for some EPs and can detract from academic productivity.[4] For others, working more night shifts can improve job satisfaction, mainly if doing so provides additional schedule control and compensation.[9] Many departments currently reduce night shifts for physicians over a certain age, and the American College of Emergency Physicians has recommended accommodations for physicians in their pre-retirement years.[10] More needs to be written about options for physicians to customize their overnight shifts at all stages of their careers. Our department created a program to allow any faculty member to buy out of night shifts, using the funds generated from buy-outs to incentivize nocturnist positions. Within two years of initiating the program, we allowed every faculty member with at least one year of service to buy out of their desired number of night shifts while hiring three additional nocturnists.

According to a national survey of academic EM leaders regarding policies around aging physicians, over half of the surveyed leaders reported decreasing or eliminating overnight shifts to accommodate aging physicians.[9] While this is undoubtedly an important option for supporting longevity in EM, it does not address the impact of night shifts on younger physicians who, some studies suggest, experience the highest rates of burnout within medicine.[11] During years when physicians may be raising young children while actively building their careers, increased schedule control might be beneficial for mitigating burnout.[12] In addition, there may be non-age related reasons for some EPs to be

Table. Demographic characteristics of faculty in each buy-out category.

	All faculty (N=56)	Full buy-out (n=22)	Partial buy-out (n=10)	No buy-out (n=18)	Nocturnist (n=6)
Female	30%	18%	40%	39%	33%
Mean clinical FTE	0.56	0.48	0.55	0.61	0.65
Mean years in EM	15	17	14	15	9
Associate or full professor	45%	68%	20%	44%	0%

FTE, full-time equivalent; *EM*, emergency medicine.

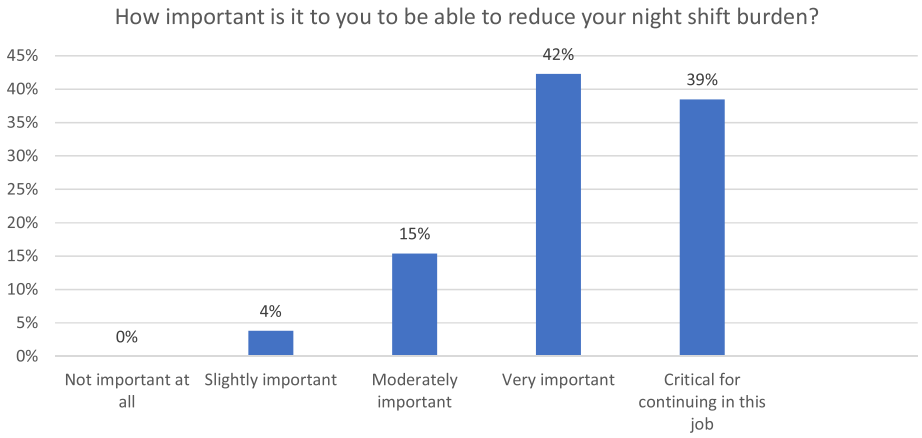

Figure. Responses from faculty (n=26) who used the buy-out program regarding the importance of buying out of night shifts as reported on our annual well-being survey.

disproportionately impacted by night shifts, including medical issues, mental health issues, or caregiver responsibilities, which can be hard to quantify.

A critical goal of the program was to promote equity across our faculty group. Programs that reduce night shifts based on age, academic rank or tenure may inadvertently propagate inequity, as physicians who are older, with longer tenure, or of higher rank may be more likely to be male and White than younger physicians.[13] Despite offering the same buy-out option for all faculty, we did observe that those who bought out of nights entirely were more likely to be male, longer-tenured, and of higher academic rank than our group average. It should be noted that male faculty did have higher average academic rank than female faculty, but this did not fully explain the gender difference; among only high-ranking faculty, men were also more likely to buy out of nights than women. These trends may be related to historical preferences in our department or to financial realities for physicians at various career stages or with different family structures, among other potential explanations. Future research might explore reasons for differences in schedule preference among different demographic groups in EM.

For those participating in our program, most faculty reported that the ability to reduce nights was at least "very important," with 39% indicating this was critical for continuing in their jobs. Prior research also suggests that simply giving people more control over their work can reduce burnout; there may be benefits of increased schedule choice for all faculty with a buy-out program, not just those who reduce night shifts.[2] With record burnout in EM threatening career longevity for many, providing increased schedule control may be one strategy for improving faculty retention. Future research should examine whether self-reported answers to surveys like ours ultimately predict burnout and career decisions.

LIMITATIONS

This study assessed our experience with a policy implemented for a single faculty group of physicians in one large ED. The trends discussed here may, therefore, be different from other departments. While this program could be adopted at other institutions, there may be unique considerations for implementation in other settings. We also observed the effects of the policy over a relatively short period and were only able to assess impact based on self-report; future work might examine longer intervals along with objective patterns of hiring and retention. We also did not specifically study the financial impacts of the program on our faculty. The personal impact of the loss of salary for attendings could be worth investigating in the future.

CONCLUSION

In our large academic ED, we successfully transitioned from a tenure- and age-based night shift paradigm to an egalitarian night shift buy-out program that allows flexibility for physicians at all stages of their careers. Given the favorable results of the program, we have continued to allow this optional overnight buy-out for our faculty. This approach has the potential to improve career satisfaction, promote equity, and reduce burnout among emergency physicians.

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Modeling Hourly Productivity of Advanced Practice Clinicians in the Emergency Department

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Introduction: Advance practice clinicians (APC) play significant roles in academic and community emergency departments (ED). In attendings and residents, prior research demonstrated that productivity is dynamic and changes throughout a shift in a predictable way. However, this has not been studied in APCs. The primary outcome of this study was to model productivity for APCs in community EDs to determine whether it changes during a shift similar to the way it does for attendings and residents.

Methods: This was a retrospective, observational analysis of 10-hour APC shifts at two suburban hospitals, worked by 14 total individuals. We examined the number of patients seen per hour of the shift by experienced APCs who see all acuity and staff all patients with an attending. We used a generalized estimating equation to construct the model of hour-by-hour productivity change.

Results: We analyzed 862 shifts over one year across two sites, with three shift start times. Site 1 10 AM–8 PM saw an average of 13.31 (95% confidence interval [CI] 13.02–13.63) patients per shift; Site 2 8 AM–6 PM saw an average of 12.64 (95% CI 12.32–13.06) patients per shift; Site 2 4 PM–2 AM saw an average of 12.53 (95% CI 12.04–12.82) patients per shift. Across all sites and shifts, hour 1 saw the highest number of patients. Each subsequent hour was associated with a small, statistically significant decrease over the previous hours. This was most pronounced in the shift's last two hours.

Conclusion: The productivity of APCs demonstrates a similar pattern of hourly declines observed in both resident and attending physicians. This corroborates prior findings that patients per hour is a dynamic variable, decreasing throughout a shift. This provides further external validity to prior research to include both APCs and community EDs. These departments must take this phenomenon into account, as it has scheduling and operational consequences. [West J Emerg Med. 2025;26(2)295–300.]

INTRODUCTION

Advanced practice clinicians (APC) play a significant role in the care provided in many academic and community emergency departments (ED). APCs are non-physician clinicians, such as nurse practitioners (NP) and physician assistants (PA), who see and evaluate patients under the supervision of, and in collaboration with, attending physicians. The use of APCs has increased in the past few decades, with the most recent National Hospital Ambulatory Medical Care Survey in 2020 estimating that 10.1% of ED visits involved an NP, and 13.4% of visits involved a PA.[1]

Previous literature on APCs in the ED is limited but has ranged from analyzing resource utilization to describing overall trends in how APCs are used and in which practice

settings.[2,3] One group found that APCs saw more patients per hour and generated more relative value units (RVU) per hour—both key markers of productivity—than a resident physician in a fast track setting, while generating fewer RVUs per patient.[4] This trend held up in a higher acuity setting in this same group.[5] However, with such a significant portion of ED visits involving an APC, there is still limited data on overall productivity.[6]

Among the metrics commonly used to measure clinical productivity, patients seen per hour is one of the most essential to ED operations planning. It often leads to important staffing decisions at all types of EDs, ranging from large academic EDs to small community ones.[7] While productivity is often thought of as a static quantity measured across a shift, in reality it is dynamic and changes throughout the course of a shift in a predictable way. This phenomenon has been demonstrated in emergency medicine (EM) attendings and residents, and it manifests as a stepwise decrease in productivity after the first few hours of a shift.[8,9] This behavior was similar in both of these groups and is consistent with the lived experience of working in an ED. When a physician shows up fresh to a shift, they have more bandwidth to see new patients. After a few hours, as each of those patients starts to have results return and require additional decisions, there is less time to see new patients.

Accounting for this phenomenon can have significant operational impacts. By understanding the true hourly capacity of the workforce, administrative leadership can ensure this best matches up with the hourly patient demand.[10] This has the potential to improve key operational metrics such as door-to-clinician time and the rate of patients that leave without being seen, a metric that is itself not static and is impacted by various departmental factors.[11] To date, however, this pattern has not been studied in APCs practicing in the ED. Our primary outcome in this study was to determine whether this pattern was similar for APCs working in a community ED, as this would provide further external validation of the previous model to the community setting and to a relatively new group of the workforce.

Population Health Research Capsule

What do we already know about this issue?
Patients seen per hour is a key productivity metric. For attendings and residents, it has been shown to be dynamic and changes throughout the course of a shift.

What was the research question?
Is this productivity pattern similar for advanced practice clinicians working in community EDs?

What was the major finding of the study?
Mean number of new patients seen decreased at each hour of the shift relative to the previous hour ($P < 0.01$).

How does this improve population health?
Understanding how many patients are seen at each hour of the day, based on clinician type and hour of shift, could inform staffing models and help throughput.

METHODS

We performed a retrospective, observational analysis of APC shifts at two suburban hospitals in the Northeastern United States from July 1, 2020–June 30, 2021. Site 1 saw an average daily volume of 54.46 patients with an Emergency Severity Index (ESI) score mix of 1.48% ESI 1; 30.00% ESI 2; 50.65% ESI 3; 17.28% ESI 4, and 0.58% ESI 5. Site 2 had an average daily volume of 79.71 patients with an ESI score mix of 1.01% ESI 1; 26.7% ESI 2; 49.6% ESI 3; 20.4% ESI 4; and 2.3% ESI 5.

For the attending shift schedule, site 1 had a shift schedule of 7 AM–4 PM, 2 PM–11 PM, and 10 PM–7 AM for the first six months of the study. For the second six months the schedule changed to 7 AM–2 PM, 12 PM–7 PM, 4 PM–11 PM, and 11 PM–7 AM to add more attending coverage. At site 2, the shifts were 7 AM–3 PM, 12 PM–9 PM, 3 PM–11 PM, and 10 PM–7 AM. The sign-out culture at both sites is that patients will have an established plan for disposition prior to transitioning to the new team.

At both sites, APC shifts are 10 hours long. At the first site, there is a single daily APC shift from 10 AM–8 PM. At the second site, there were two APC shifts during the study period, from 8 AM–6 PM and from 4 PM–2 AM. There were several days during which the first site had no APC coverage, and the second site had only a single shift. Five APCs worked the shifts at site 1, including a mix of both NPs and PAs, while 10 APCs worked the shifts at site 2, consisting solely of PAs. One of the PAs worked shifts at both sites during the study period. In total there were 14 APCs, 2 NPs and 12 PAs. The APCs saw all levels of patient acuity. These sites employ a shared-visit model, and all patients seen by an APC are presented to, and then evaluated by, an attending physician. The APCs continue to pick up new patients throughout the shift and are not limited in doing so by attending availability to staff. Over 70% of the APCs in the study had >5 years of clinical experience at the start of the study period.

We used a de-identified quality assurance database for this study, which is primarily used for operations planning. The database is automatically populated by the sites' electronic health record (EHR). Timestamps of patient arrivals, APC assignments, and patient dispositions are automatically

recorded by the EHR. The timestamp data is compiled along with additional aggregated and de-identified patient-level data, in accordance with HIPAA-SAFE HARBOR criteria, prior to data analysis. Only the patients seen by an APC were included for analysis, and registration anomalies had already been removed. This study was granted an exemption of informed consent, as part of a larger project usiing a de-identified administrative dataset of ED throughput for quality assurance purposes. The exemption was granted by the institutional review board affiliated with the clinical sites, which includes direct involvement by patient and community representatives in the oversight and approval of all research protocols.

The primary outcome was the number of new patients seen at each hour of a standard 10-hour APC shift. We used a generalized estimating equation to construct the model of APC productivity, with the individual shift as the grouping in light of the use of multiple hourly measurements from the same shift. A Poisson distribution with a log link was used, as the outcome variable (patients seen in an hour) reflects a positive count variable in a fixed time interval. We evaluated the model using an autoregressive covariance structure, with alternate covariance structures tested in sensitivity analyses. The hour of the shift and the shift time and location were used as covariates. We report final parsimonious models as determined by quasi-likelihood score. A two-sided *P*-value <.05 was considered statistically significant, with strict correction for multiple comparisons. For the purposes of model interpretability, we report the calculated model predictions, with the raw (exponential) model covariates in a supplemental appendix. Analysis was conducted in Python 3.11 using the Statsmodels and SciPy packages (Python Software Foundation, Wilmington, DE).

RESULTS

During the study period (July 1, 2020–June 30, 2021), we analyzed 862 shifts, of which 345 were at Site 1 (single coverage), and 517 were at Site 2 (two-shift coverage). All the worked shifts in this period were included in the study, and no aberrant timestamps were found in the database, meaning that the timestamp of APC assignment always aligned with the shift hours on the schedule. Not every APC shift was staffed during the study period, due to factors including quarantine, operational reassignments within the network, and staffing shortages from the COVID-19 pandemic.

Site characteristics are summarized in Table 1. At Site 1 with a single APC shift from 10 AM–8 PM, APCs saw a mean of 13.31 patients per shift (95% CI 13.02–13.63). At Site 2, APCs saw 12.64 (95% CI 12.32–13.06) patients during the 8 AM–6 PM shift, and 12.53 (95% CI 12.04–12.82) patients during the 4 PM–2 AM shift. While small, these differences were statistically significant ($P < 0.01$ for all pairwise comparisons).

Across all sites and shifts, the first hour of the shift demonstrated the highest number of patients seen (Site 1: 2.25 [95% CI 2.17–2.33], Site 2 8 AM–6 PM: 2.12 [95% CI 1.98–2.26], and Site 2 4 PM–2 AM: 2.10 [95% CI 1.95–2.26]). Each hour was associated with a small, but statistically significant decrease over the previous hours (Table 2). This decrease was most pronounced during the last two hours of the shift, leading to an average well below a single patient seen per hour during hours 9 (Site 1: 0.57 [95% CI 0.50–0.64], Site 2 8 AM–6 PM: 0.54 [95% CI 0.46–0.62], Site 2 4 PM–2 AM: 0.53 [95% CI 0.45–0.62]) and 10 (Site 1: 0.14 [95% CI 0.11–0.17], Site 2 8 AM–6 PM: 0.13 [95% CI 0.10–0.17], Site 2 4 PM–2 AM: 0.13 [95% CI 0.10–0.17]). This trend can be visualized in Figure. A sensitivity analysis did not reveal any significant difference in hourly volume of patients seen by APCs by day of week. Prior research at these hospitals has shown adequate hourly patient volumes suggesting there is not a shortage of patients to be seen.[9]

DISCUSSION

Our findings in this study suggest that APCs may demonstrate a similar pattern of hourly declines in productivity that has been observed in both resident and attending physicians.[8,9] This corroborates prior findings that suggest that patients seen per hour is a dynamic variable. An intuitive explanation of this finding follows from the fact that patient evaluations take place over multiple hours of a shift, and that seeing a new patient later in the shift requires the APC to balance the demands of seeing an additional patient

Table 1. Characteristics of the study participants and sites evaluated.

Characteristic	Site 1	Site 2
Approximate yearly visits	23,000	33,000
Shifts per day	1	2
Shifts evaluated	345	517
APCs working during the study period	5	10
Mean patients per shift	13.31 (95% CI 13.02–13.63) [10 AM–8 PM]	12.64 (95% CI 12.32–13.06) [8 AM–6 PM] 12.53 (95% CI 12.04–12.82) [4 PM–2 AM]

APCs, advance practice clinicians.

Table 2. Models of new patients seen per hour.

Site 1: 10 AM–8 PM shift		
Shift hour	**Mean new patients (95% CI)**	***P*-value**
1	2.25 (2.17–2.33)	< 0.01
2	1.96 (1.80–2.13)	< 0.01
3	1.80 (1.65–1.96)	< 0.01
4	1.66 (1.52–1.81)	< 0.01
5	1.42 (1.29–1.50)	< 0.01
6	1.33 (1.21–1.46)	< 0.01
7	1.26 (1.14–1.39)	< 0.01
8	0.98 (0.89–1.09)	< 0.01
9	0.57 (0.50–0.64)	< 0.01
10	0.14 (0.11–0.17)	< 0.01
Site 2: 8 AM–6 PM shift		
Shift hour	**Mean new patients (95% CI)**	***P*-value**
1	2.12 (1.98–2.26)	< 0.01
2	1.85 (1.65–2.07)	< 0.01
3	1.69 (1.5–1.91)	< 0.01
4	1.56 (1.38–1.76)	< 0.01
5	1.33 (1.18–1.50)	< 0.01
6	1.25 (1.10–1.42)	< 0.01
7	1.19 (1.04–1.35)	< 0.01
8	0.92 (0.81–1.06)	< 0.01
9	0.54 (0.46–0.62)	< 0.01
10	0.13 (0.10–0.17)	< 0.01
Site 2: 4 PM–2 AM shift		
Shift hour	**Mean new patients (95% CI)**	***P*-value**
1	2.10 (1.95–2.26)	< 0.01
2	1.83 (1.63–2.06)	< 0.01
3	1.68 (1.48–1.90)	< 0.01
4	1.55 (1.37–1.75)	< 0.01
5	1.32 (1.16–1.50)	< 0.01
6	1.24 (1.09–1.41)	< 0.01
7	1.18 (1.03–1.35)	< 0.01
8	0.92 (0.80–1.05)	< 0.01
9	0.53 (0.45–0.62)	< 0.01
10	0.13 (0.10–0.17)	< 0.01

CI, confidence interval.

with concurrently caring for existing patients. The APCs may see more patients earlier in the shift precisely because they have the greatest cognitive bandwidth at the start of a shift, with no active patients. As those patients start to generate results and require re-evaluation, interpretation of imaging

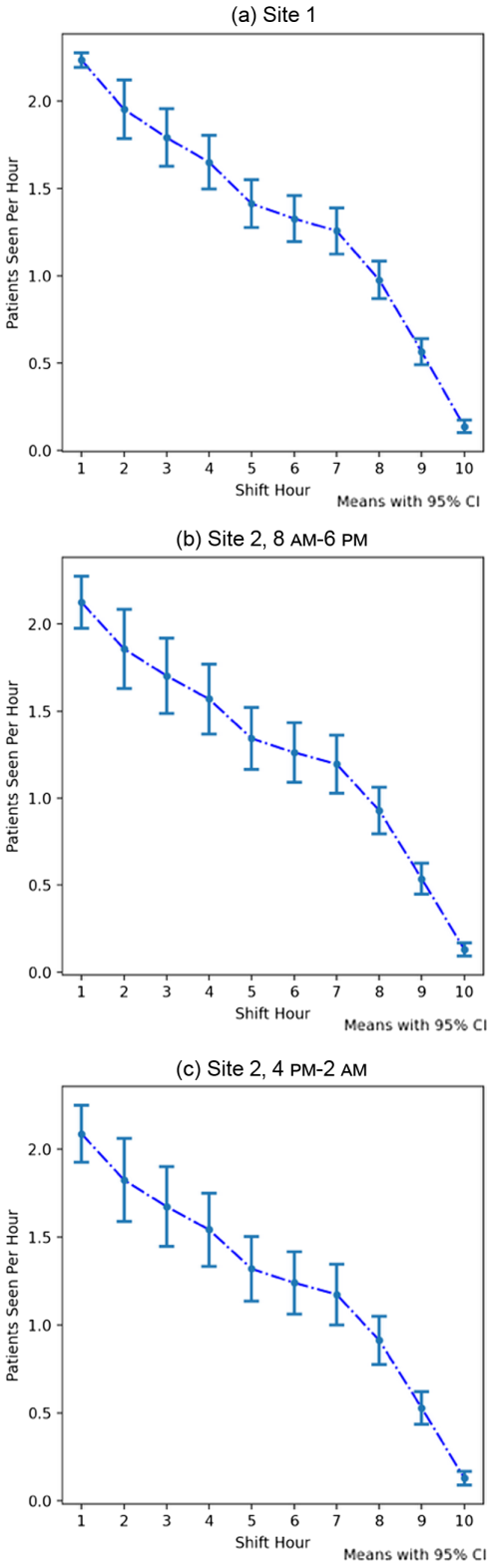

Figure. Mean number of patients seen per shift hour by advanced practice clinicians.
APC, advanced practice clinician.

or labs, or procedures that add to the cognitive load for an APC, they will see fewer new primary patients.

However, there are substantial differences in the patterns we have observed in APCs relative to patterns of physician productivity previously described in the emergency medicine operations literature.[8,9] Notably, while all of these groups demonstrate progressive declines in hourly productivity and see a higher proportion of patients in the first few hours of their shifts, the APCs in our study demonstrated both a smaller "peak" at the beginning of their shifts compared to those reported with attending physicians, and a more gradual decrease from hour-to-hour relative to resident physicians. The cause of this is likely multifactorial; however, in the prior studies for both attendings and residents, those groups were incentivized and graded on productivity; the APCs in our study did not have the same explicit tie to productivity.

This has important downstream consequences when creating staffing models. While shifts typically span 10 hours and there is an administrative expectation for equal capacity during all hours of coverage, the 9th and 10th hours of a shift do not provide much in the way of new patient evaluations. So, when hiring and staffing a department and trying to best align the number of hourly arrivals with the available staff (residents, attendings or APCs) the administration must take this pattern into account. Understanding how many patients are expected to be seen at a specific hour of the day, based on what staff are available and the hour of each person's shift, may help throughput.

LIMITATIONS

Our study does have many limitations. It was only done at two community hospitals in a similar geographic region. Because there were only three shift start times, there was less variability than prior studies performed on resident and attending physicians, which also had a greater variety of shift starting and ending times, including overnights. However, as long as there were adequate patients to be seen at each hour of the day—as seen in prior studies of attending independent productivity at these sites—this limitation should be mitigated. There were also two hours of overlap between shifts at the second site, which may have contributed to some productivity drop-off for the 8 AM–6 PM shift at site 2. Additionally, within this network APCs cared for all levels of patient acuity, and each visit required staffing and evaluation by an attending physician. This differs from other models where APCs can discharge lower acuity patients without an attending evaluation.

While the delay of waiting for an attending to see the patient may prolong some tasks and decisions, this group of APCs had a lot of experience and independence (>70% with over five years of experience) and continued to pick up new patients in the interim. Further, at the two study sites APCs were used to see patients primarily, and this may not be applicable to other ways they are used in departments, such as managing observation patients. Lastly, as this study was conducted at two small community sites there were only a few total APCs (14 total individuals) who primarily work only at a single site, and this group may not be representative of larger groups of APCs or those working in multiple hospital or urgent care settings.

CONCLUSION

Our findings suggest that the productivity of advanced practice clinicians may follow a pattern of decreasing over successive hours of a shift, similar to both attendings and residents. This study reinforces prior literature that demonstrates that patients per hour is a dynamic variable, which starts at its highest point and decreases significantly each subsequent hour. By verifying that this pattern is consistent in APCs, it broadens the productivity model of prior research. Community EDs, which are often staffed with APCs and have no resident coverage, may need to take this phenomenon into account as it has significant scheduling and operational consequences.

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Injuries and Outcomes of Ground-level Falls Among Older Patients: A Retrospective Cohort Study

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Study Objective: We sought to determine the overall rates of traumatic injuries and whether the rates of traumatic injuries and various clinical outcomes differed among older patients presenting to a tertiary-care emergency department (ED) after a ground-level fall (GLF) and who underwent whole-body computed tomography.

Methods: We conducted a retrospective cohort study of patients ≥65 years of age who presented to the ED with a GLF and received a whole-body CT from January 1–December 31, 2021. Age was stratified into age groups: 65–74; 75–84; and 85+. We presented a descriptive analysis of traumatic injuries, intensive care unit (ICU) admissions, and all-cause mortality rates. We used multivariable logistic regression to determine the association between increasing age, traumatic injuries, and clinical outcomes.

Results: Of 638 patients in the cohort, 120 (18.9%) sustained thoracic injuries and 80 (12.5%) sustained intracranial hemorrhages. Only five (0.8%) patients sustained an intra-abdominal injury, while 134 (21.0%) were admitted to the ICU, and 31 (4.8%) died during their index hospitalization. Head injuries (odds ratio [OR] 6.21, 95% CI 3.65–10.6, $P < 0.001$) and thoracic injuries (OR 5.25, 95% CI 3.30–8.36, $P < 0.001$) were associated with increased odds of ICU admission, whereas head injuries (OR 3.21, 95% CI 1.41–7.31, $P < 0.01$) and cervical injuries (OR 3.37, 95% CI 1.08–10.5, $P < 0.05$) were associated with increased odds of in-hospital, all-cause mortality. There were no statistically significant differences in the rates of injuries sustained between the respective age groups. There was no association between increasing age and ICU admissions or in-hospital, all-cause mortality rates.

Conclusion: Among patients aged ≥65 years of age who presented to the ED after a ground-level fall and underwent whole-body CT, thoracic injuries and intracranial hemorrhages were associated with increased odds of ICU admissions. We found no significant differences in injury rates or outcomes across age groups, indicating that age alone should not guide ICU admission decisions. These findings suggest that the use of whole-body CT in this population should be selective and guided by clinical judgment rather than applied universally. [West J Emerg Med. 2025;26(2)301–306.]

INTRODUCTION

Background

Falls are the leading cause of fatal and non-fatal injuries among the elderly. Up to 40% of men and women ≥65 years of age in the community fall each year.[1] Injuries related to falls among the elderly account for three million emergency department (ED) visits and 50 billion dollars of US healthcare spending annually.[2] Ground-level falls (GLF), defined as falls from a standing height, are particularly common among older patients. Age-related physiologic changes create significant fall-related morbidity and mortality in this patient cohort.[3]

Importance

Patients who present to the ED for trauma-related complaints are often evaluated with computed tomography (CT) for their accuracy and reliability in detecting injuries. The routine use of non-selective, whole-body (head to pelvis) CT is becoming an increasingly common diagnostic modality in these patients, particularly in those involved in high-energy mechanisms such as motor vehicle collisions, due to the more widespread availability of CT imaging and changing clinical practice patterns.[4] While whole-body CT is frequently used in high-energy trauma, its application in low-energy mechanisms like GLFs remains less clear and more variable. Several studies have shown conflicting evidence as to whether whole-body CT is warranted in trauma patients.[5,6] Given the low kinetic energy impact from GLFs, it is unclear whether the indiscriminate use of whole-body CT in GLFs can improve patients' outcomes by detecting clinically relevant injuries.

Goals of This Investigation

Our objectives of in this study were to determine the overall rates of traumatic injuries and clinical outcomes and whether the rates of traumatic injuries and clinical outcomes were associated with increasing age among patients ≥65 years of age presenting to a tertiary-care ED with a GLF and who underwent whole-body CT. We hypothesized that due to decreased physiological reserves and increased fragility, the incidence of traumatic injuries and adverse outcomes after a GLF among this selective population would increase with advancing age.

Population Health Research Capsule

What do we already know about this issue?
Falls are the leading cause of injury in older adults, yet optimal use of whole-body CT in low-energy mechanisms such as ground-level falls (GLF) is unclear.

What was the research question?
Do traumatic injury rates and clinical outcomes differ with age among older patients undergoing whole body CT for ground-level falls?

What was the major finding of the study?
Thoracic (OR 5.25, 95% CI 3.30–8.36) and head injuries (OR 6.21, 95% CI 3.65–10.6) after a ground-level fall were associated with ICU admissions. Only five (0.8%) patients sustained an intra-abdominal injury.

How does this improve population health?
Selective whole-body CT use in GLF patients can improve care efficiency by focusing on clinically significant injuries while reducing unnecessary imaging.

METHODS

Study Design and Setting

This study was approved by the Human Institutional Review Board. We conducted a retrospective cohort study of patients treated at this tertiary-care Level I trauma academic medical center with 90,000 annual ED visits. We adhered to the previously published methodological criteria for health record review studies.[7]

Study Population

We identified all patients ≥65 years of age who presented to the ED with a GLF and received a whole-body CT between January 1–December 31, 2021. At our institution, a whole-body CT is defined as a CT of the head, chest, abdomen and pelvis, cervical spine, thoracic spine, and lumbar spine; it includes intravenous contrast administration to evaluate for soft tissue injury of the thorax and abdomen. A GLF is defined as falling from a standing height, chair, wheelchair, or out of bed.

Measurements

Study variables collected included basic demographic characteristics (age and sex as identified by patient), antiplatelet or anticoagulant use, medical comorbidities, initial Glasgow Coma Scale (GCS) score, initial heart rate and systolic blood pressure, and traumatic injuries found on CT. Data was collected using a standardized data collection form through the electronic health record (Epic Systems, Verona, WI) by trained research assistants (RA) and a resident physician (WH). None of the trained RAs or the resident physician knew the study objectives. Data points collected included all acute traumatic injuries identified on the final CT imaging radiology reports. Co-author GS

performed a duplicate review of 10% of the health records for interobserver reliability assessment. We used the Cohen kappa to determine the inter-rater reliability of data abstraction.

Study Outcomes

Our primary study outcome measures included the rate of various acute traumatic injuries, admission to the intensive care unit (ICU), and all-cause, in-hospital mortality. Traumatic injuries included intracranial hemorrhages (ICH), thoracic injuries, intra-abdominal injuries, cervical spine fractures, thoracic spine fractures, and lumbar spine fractures. Intracranial hemorrhages were defined as any epidural, intraparenchymal, intraventricular, subarachnoid, or subdural hematomas or hemorrhage that were believed to be traumatic in etiology. We defined thoracic injuries as hemothoraces, pneumothoraces, pulmonary contusions, or rib fractures. Intra-abdominal injuries were defined as any solid organ or hollow viscous injuries. We excluded minor soft tissue injuries or hematomas, subacute or chronic traumatic injury findings, and non-traumatic findings on CT imaging. For our secondary outcome measures, we analyzed the association between age, traumatic injuries, and clinical outcomes, including ICU admissions and in-hospital, all-cause mortality. Age was stratified into age groups: 65–74; 75–84; and 85+.

Data Analysis

Descriptive statistics are presented as means ± standard deviations for continuous variables, and categorical variables are reported as percentages. Incidences of traumatic injuries, ICU admissions, and all-cause mortality are reported as proportions with accompanying 95% confidence intervals (CI). Differences between our age-specific comparison groups (65–74, 75–84, 85+) were examined using ANOVA for continuous variables and chi-squared and Fisher exact tests for categorical variables. Two-tailed values of $P < 0.05$ were considered statistically significant. We performed bivariate analysis to identify variables associated with clinical outcomes. Using the 65–74 cohort as the reference group, we used multivariable logistic regression to determine the association between age, traumatic injuries, and clinical outcomes controlling for medical comorbidities, antithrombotic use, and statistically significant traumatic injuries. Data analysis was performed using STATA/MP Version 17 (StataCorp, College Station, TX).

RESULTS

Baseline Patient Characteristics

A total of 638 patients met our inclusion criteria during the one-year period under study. The average age of the study population was 82.1 ± 9.0 years; 60.0 % were women, and 62.9% were on at least one antithrombotic agent, with 33.7% on an antiplatelet and 39.1% on an anticoagulant. The average number of comorbidities was 1.5 ± 1.3 (Table 1).

Table 1. Study population characteristics according to age.

	Age (yrs) 65–74 (n = 159)	75–84 (n = 213)	85+ (n = 266)	*P*-value
Age, years	70.1 ± 3.0	80.1 ± 2.7	90.7 ± 4.3	-
Sex (female), %	48.4	55.4	69.6	< 0.01
SBP	136 ± 27	144 ± 29	146 ± 29	< 0.01
HR	87 ± 22	85 ± 26	81 ± 20	0.02
GCS	14 ± 3	14 ± 2	14 ± 2	[1]
Comorbidities, %				
CHF	26.4	26.7	27.1	[1]
COPD	21.4	18.8	9.02	< 0.01
CVA/TIA	26.4	21.1	16.9	[1]
Dementia	14.5	21.1	29.3	< 0.01
Diabetes	31.5	35.7	18.8	< 0.01
MI	13.8	17.4	14.3	[1]
Osteoporosis	10.7	16.9	21.1	0.02
Antithrombotic, %				
Anticoagulant	39.0	43.7	35.7	[1]
Antiplatelet	32.7	36.2	32.7	[1]

[1]Not statistically significant.
CHF, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *CVA/TIA*, cerebrovascular accident/transient ischemic attack; *GCS*, Glasgow Coma Scale; *MI*, myocardial infarction; *HR*, heart rate; *SBP*, systolic blood pressure.

Main Results

Among the 638 patients who sustained a GLF, 120 patients (18.9%) sustained thoracic injuries, and 80 (12.5%) sustained ICH. Sixty (9.8%) patients sustained thoracic spine injuries, 51 (8.0%) s sustained lumbar spine injuries, and 34 (5.3%) patients sustained cervical spine injuries. Only five

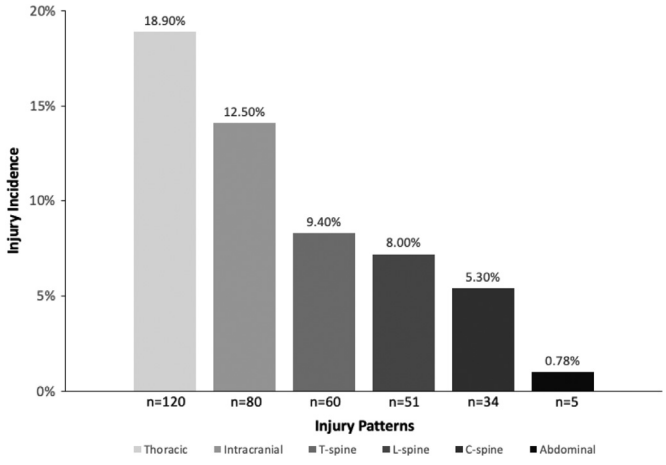

Figure. Incidence proportion among different injuries.

(0.8%) patients sustained an intra-abdominal injury (Figure). Of the five patients with intra-abdominal injuries, all five were found to have pertinent physical exam findings, initial unstable vital signs (systolic blood pressure <90 or heart rate 100), or abnormal GCS (<15). There were no statistically significant differences in the rates of various injuries sustained between the respective age groups (Table 2).

A total of 134 (21.0%) patients were admitted to the ICU, and 31 (4.8%) died during their index hospitalization. There were no statistically significant differences in the rates of clinical outcomes between the respective age groups. Using multivariable logistic regression models, we found no association between increasing age and ICU admissions or in-hospital, all-cause mortality rate (Table 3). In contrast to age, head injuries (odds ratio [OR] 6.15, 95% CI 3.62–10.5, $P < 0.001$) and thoracic injuries (OR 5.38, 95% CI 3.37–8.67, $P < 0.001$) were associated with increased odds of ICU admission, whereas head injuries (OR 3.21, 95% CI 1.41–7.31, $P < 0.01$) and cervical injuries (OR 3.37, 95% CI 1.08–10.5, $P < 0.05$) were associated with increased odds of in-hospital mortality.

Inter-rater Reliability

Among the 10% of the health records reviewed by a co-author, we found that our raters agreed on 88% of the information abstracted from the records, resulting in a Cohen kappa coefficient of 0.8.

DISCUSSION

In our study population, injuries sustained after a GLF were broadly consistent among all age groups. We found that a substantial minority of older patients who underwent whole-body CT at the discretion of the treating physicians after a GLF were found to have clinically significant injuries

Table 2. Traumatic injuries and emergency department dispositions stratified by patient age.

	65–74 (n = 159)	75–84 (n = 213)	85+ (n = 266)
Traumatic injuries, no. (%)			
Intracranial	16 (10.1%)	32 (15.0%)	32 (12.0%)
Thoracic	32 (20.1%)	40 (18.8%)	48 (18.1%)
Intra-abdominal	1 (0.63%)	0	4 (1.50%)
Cervical spine	10 (6.29%)	15 (7.04%)	9 (3.38%)
Thoracic spine	8 (5.03%)	24 (11.3%)	28 (10.5%)
Lumbar spine	11 (6.92%)	18 (8.45%)	22 (8.27%)
ED disposition, no. (%)			
ICU	38 (23.9%)	45 (21.1%)	51 (19.2%)
Death	2 (1.26%)	5 (2.35%)	3 (1.13%)

No statistical significance between all age groups.
ED, emergency department; *ICU*, intensive care unit.

Table 3. Association between increasing age and clinical outcomes.

	Count, no. (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
ICU admissions			
65–74	38 (23.9%)	1 [Reference]	1 [Reference]
75–84	45 (21.1%)	0.85 (0.52–1.40)	0.78 (0.45–1.35)
85+	51 (19.2%)	0.75 (0.47–1.22)	0.72 (0.42–1.22)
Mortality[1]			
65–74	3 (1.89%)	1 [Reference]	1 [Reference]
75–84	14 (6.57%)	3.65 (1.03–13.0)	3.46 (0.97–12.4)
85+	14 (5.26%)	2.89 (0.82–10.2)	2.83 (0.80–10.0)

[1]In-hospital, all-cause mortality.
For ICU admissions: adjusted for total comorbidities, head injuries, thoracic injuries.
For mortality: adjusted for total comorbidities, head injuries, cervical injuries.
OR, odds ratio; *CI*, confidence interval; *ICU*, intensive care unit.

that resulted in ICU admissions. Increasing age was not associated with an increased rate of ICU admission or death after a GLF. Thoracic injuries and ICH were associated with increased odds of ICU admission. Intracranial hemorrhages and cervical fractures were associated with increased odds of in-hospital mortality.

We found that over 30% of the injuries sustained were either ICH or thoracic injuries, both of which were associated with increased odds of ICU admissions in our study population. Intracranial hemorrhages and rib fractures among older patients are injuries that can result in high mortality rates,[8–10] thus requiring frequent monitoring and necessitating ICU level of care. Our findings reinforce the importance of using CT to identify these injuries in patients presenting with GLFs, particularly when there is clinical suspicion of those injuries.

Furthermore, our study did not show any significant association between increasing age and ICU admission and mortality. This contrasts with the results of a previous study, which showed a stepwise increment in the rate of cervical spine injuries and in-hospital mortality associated with increased age in GLF patients from an institutional trauma registry.[11] Patients recorded in a trauma registry will likely have sustained injuries requiring trauma team evaluation. In addition, we did not find any difference in the rates of various injuries after a GLF between the different age groups. Our study differs in that it included all patients who sustained significant injuries and those who did not. Furthermore, we included only patients who underwent whole-body CT at the discretion of the treating physicians after a GLF. Based on our findings, one should be cautious about using increased age as a risk factor alone to determine whether a patient warrants whole-body CT without considering other clinical factors.

Overall, our rates of different injuries are higher than reported in the literature. Our findings on the rate of ICH after a GLF was 12.5%, whereas the rates of ICH after a GLF reported in the literature have ranged from 3.5–7%.[12–15] A larger, nationally representative retrospective study found the rates of thoracic and lumbar spine injuries were 1.6% and 2.5%, compared to 9.4% and 8.0% in our study, respectively.[16] The discrepancy likely resulted from the fact that we included only patients who were selected by treating physicians to undergo whole-body CT in the ED. The treating physicians probably deem patients undergoing whole-body CT after trauma to have sustained a greater number of significant injuries during the initial evaluation.

We found that the rate of intra-abdominal injuries was low. This conclusion is broadly consistent with the literature.[11,17,18] Of the five patients found to have intra-abdominal injuries in our study, all five were found to have either unstable vital signs, abnormal GCS, or abnormal physical exams on initial evaluation. This finding is consistent with the literature where hemodynamically stable patients with normal physical exams are unlikely to have intra-abdominal injuries after a GLF.[18–20] Performing fewer abdominal CT scans in this population could have substantial cost savings without reducing diagnostic accuracy. Given the small number of patients who sustained intra-abdominal injuries in our study, we were not adequately powered to identify potential risk factors associated with intra-abdominal injuries after a GLF. Future prospective studies are needed to identify factors associated with intra-abdominal injuries and determine the cost-effectiveness of a selective imaging algorithm in low-risk GLF patients.

LIMITATIONS

Our study was retrospective and susceptible to biases. Non-differential misclassification can occur during the querying of health records, which will likely bias the results toward the null. However, 10% of the health records were reviewed by co-author GS to limit this bias. Furthermore, we demonstrated excellent inter-rater reliability. The study was also susceptible to selection bias, and was limited to patients who received a whole-body CT. At our institution, the decision to order a whole-body CT on a trauma patient depends on the treating physician's preference. Patients who received a whole-body CT are likely deemed by the treating physician to have sustained significant injuries. Therefore, our study likely overestimates injury incidence due to the selective nature of whole-body CT use. Moreover, we did not obtain information on older patients who sustained a GLF and did not receive a whole-body CT. Those two limitations likely resulted in our study overestimating the incidence proportion of injuries reported after a GLF. Furthermore, this study was based on a single institution at a tertiary-care Level I trauma center; thus, it cannot be generalized to other institutions. In addition, the nature of our query did not allow us to obtain Injury Severity Scores.

CONCLUSION

Among patients ≥65 years of age who presented to the ED after a ground-level fall and underwent whole-body CT, thoracic injuries and intracranial hemorrhages—while a minority of the injuries sustained—were associated with increased odds of ICU admissions. These findings highlight the importance of carefully assessing these injuries in older adults. Interestingly, we found no significant differences in injury rates or clinical outcomes across age groups, suggesting that age alone should not be the determining factor for ICU admission or mortality risk in this population. Given our findings, we propose that there may be value in reassessing trauma screening protocols, especially regarding the use of whole-body CT in patients who sustain a low-energy fall. Its use should be selective rather than applied universally. Multicenter prospective studies are needed to determine the broader utility and cost-effectiveness of whole-

body CT use among older patients who present to the ED after sustaining a ground-level fall.

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Relationship Between Social Risk Factors and Emergency Department Use: National Health Interview Survey 2016–2018

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Background: Evidence shows that social risks are highly prevalent in the patient population that presents to the emergency department (ED) for care; however, understanding the relationship between social risk factors and ED utilization at the population level remains unknown.

Methods: We used the National Health Interview Survey from the 2016–2018 sample adult files. The sample included 82,364 individuals, representing a population size of 238,888,238. The primary independent variables included six social risk factors: economic instability; lack of community; educational deficit; food insecurity; social isolation; and inadequate access to care. The outcome included ED use in the prior year. Covariates included age, race/ethnicity, insurance status, obesity, mental health (depression/anxiety), and comorbidities. We ran logistic regression models to test the relationship between the independent and dependent variables adjusting for covariates.

Results: In the study sample, 20% had at least one ED visit in the prior year. In the fully adjusted model, individuals reporting economic instability (odds ratio [OR] 1.33, 95% confidence interval [CI] 1.25-1.42), lack of community (OR 1.10, 95% CI 1.05-1.15), educational deficit (OR 1.12, 95% CI 1.06-1.18), food insecurity (OR 1.77, 95% CI 1.66-1.89), and social isolation (OR 1.32, 95% CI 1.26-1.39) had significantly higher odds of ED use. Inadequate access to care was significantly related to lower odds of ED use (OR 0.75, 95% CI 0.69-0.81).

Conclusions: Social risk factors are significantly associated with higher odds of ED use in the United States adult population. Interventions that integrate social and medical needs are greatly needed, as is understanding the role that preventive medicine may play in reducing avoidable ED visits. [West J Emerg Med. 2025;26(2)307–314.]

INTRODUCTION

Emergency department (ED) use in the United States remains high, with the most recent national estimates showing 18% of US adults had at least one visit in the prior 12 months.[1–3] Cost of ED utilization has remained over $76 billion per year,[4] with an estimated $30 billion spent on preventable hospitalizations.[4] Although the primary role of an ED is providing medical services to high-acuity or

life-threatening conditions, overuse and misuse of the ED in the US remains a major concern for population health, with increased attention being given to the role of unmet social needs underlying ED utilization.[5,6]

It has been well-established that an individual's social and physical environment plays a role in health outcomes and is becoming increasingly important for understanding access to health services.[7–11] Evidence shows that social risk factors, the adverse social conditions such as economic instability, food and housing instability, and limited access to transportation, are highly prevalent among patients who present to the ED.[6,12–19] For example, lower socioeconomic status and poverty are associated with increased ED and emergency service utilization rates,[16–18] with evidence showing that those presenting to the ED are more likely to be low income[19] and insured through Medicaid.[20] At the national level, food insecurity is independently associated with a 47% higher ED utilization rate.[14] Similarly, individuals with housing insecurity have a two-fold increased risk of ED use,[15] with a high risk for experiencing homelessness a year following an ED visit.[21] Evidence also shows that transportation barriers are high among those who present to the ED.[22]

As any increase in ED utilization represents a corresponding increase in associated costs, there is an urgent need to understand the underlying social drivers of ED utilization to appropriately develop targeted interventions to account for social risk burden and to decrease ED utilization and improve population health. While existing data shows that individual social risk factors are linked to increased ED utilization, little has been done to understand the prevalence of multiple social risk factors and their association with ED utilization at a national level. The purpose of this study, therefore, is to examine the relationship between multiple social risk factors (economic instability, lack of community, limited educational attainment, food insecurity, social isolation, and limited access to care) and ED utilization in a nationally representative sample of US adults.

Population Health Research Capsule

What do we already know about this issue?
Social risk factors play a role in access to healthcare. Prevalence of multiple social risk factors and their association with ED use at a national level remains unclear.

What was the research question?
What is the relationship between multiple social risk factors and ED use in a nationally representative sample of US adults?

What was the major finding of the study?
Economic instability, lack of community, educational deficit, food insecurity, and isolation increased ($P < 0.001$) ED use.

How does this improve population health?
These results provide targets for intervention development and clinical screening programs to reduce unnecessary ED use and healthcare costs.

METHODS

Data Source

We used the National Health Interview Survey (NHIS), person, adult, and family person files. The NHIS gathers information from people across the US. Information gathered includes disease and conditions information as well as healthcare information.[23]

Measures

The primary independent variables include the social risk factor domains initially described by Wray et al in 2022.[24] These domains were treated as binary: having a positive response to any item in a domain was considered a '1' while having no positive responses as '0.' (Missing was defined as missing all items in a domain.) The prompts and criteria for each domain are listed in Table 2. The outcome was binary and defined as having any visits to the ED in the prior year (0 visits vs ≥1 visits). We also included the following covariates: age; race/ethnicity; insurance status; obesity; mental health (depression/anxiety); and comorbidities (hypertension, coronary heart disease, heart attack, stroke, asthma, ulcer, cancer, emphysema/chronic obstructive pulmonary disease, kidney disease, diabetes, liver disease, arthritis, migraine, and chronic pain).

Analyses

We compared sample demographics, reported as percentages and means, using chi-square and analysis of variance statistics. Logistic regression models were used to assess the unadjusted independent association between ED use as a binary variable and each of the six social risk domains, followed by domain-adjusted models (ie, simultaneously controlling for all six social risks). Then, we used the fully adjusted logistic regression models to evaluate the independent association between ED use as a binary variable and each of the six social risk domains, adjusting for covariates, including age, race/ethnicity, insurance status, obesity, mental health, and comorbidities. Covariates were selected for inclusion in the model based on prior evidence on the relevance of these variables as well as based on $P = <0.25$ in bivariate analyses. We performed statistical analysis with R v 4.0.3 (R Foundation for Statistical Computing, Vienna,

Austria). To account for the complex survey design and produce population level estimates, weighting was done using the svydesign function in R. Statistical significance was set at $P = < 0.05$.

RESULTS

The study sample was comprised of 82,364 individuals in the 2016–2018 period, which represents 238,888,238 adults in the US population. This time frame was selected for its robust set of social risk factors available in the dataset. Table 1 shows demographic characteristics of our study population. Almost 20% reported using the ED one or more times. Middle-aged adults (ages 40-64) accounted for about 42% of this sample, with young adults (ages 18-39) representing 38%. Older adults (65+) account for approximately 20% of the study sample. The majority (64.8%) identified as non-Hispanic White, with Hispanic accounting for the second-highest group (16.1%), followed by non-Hispanic Blacks at 12%, and non-Hispanic other at 7.2%. About 9% of the adults were uninsured. Approximately 42% had 1-2 comorbidities and 23.2% had three or more, with chronic pain (34%) and hypertension (31%) representing the two most common comorbidities.

Table 2 shows characteristics of social risk domains in our study population. A total of 73.5% reported economic instability, 40.5% reported lack of community, 23.5% reported food insecurity, 27.2% reported social isolation, and 13.1% reported inadequate access to care.

Table 3 displays unadjusted, domain-adjusted (controlling for only social risks), and fully adjusted models (controlling of social risks, comorbidities, and all other covariates outlined in the table). All social risk factors (economic instability, lack of community, educational deficit, food insecurity, social isolation, and inadequate access to care) were significantly associated with higher odds of ED visits in the unadjusted models, with food insecurity, economic instability, and social isolation among those with higher odds ratios (OR) (OR 2.46, 95% confidence interval [CI] 2.32-2.59; OR 2.10, 95% CI 1.99-2.22; and OR 2.02, 95% CI 1.94-2.11, respectively). In the fully adjusted models, economic instability (OR 1.33, 95% CI 1.25-1.42), lack of community (OR 1.10, 95% CI 1.05-1.15), educational deficit (OR 1.12, 95% CI 1.06-1.18), food insecurity (OR 1.77, 95% CI 1.66-1.89), and social isolation (OR 1.32, 95% CI 1.26-1.39) were associated with higher odds of ED utilization. However, inadequate access to care was negatively associated with ED use in both adjusted models (fully adjusted: OR 0.75, 95% CI 0.69-0.81).

DISCUSSION

Overall, ~20% of US adults had at least one ED visit, and social risk factors were highly prevalent in the study sample with 74% having economic instability, 41% reporting lack of community, 37% reporting educational deficits, 27%

Table 1. Characteristics of adults, National Health Interview Survey, 2016–2018.

	Total sample (N = 238,888,238) (n = 82,364)
ED visits (binary)	
0	80.2%
1+	19.8%
Age	
18–39	38.0%
40–49	16.3%
50–64	25.6%
65–74	12.0%
75+	8.1%
Sex	
Male	48.3%
Female	51.7%
Race/ethnicity	
Non-Hispanic White	64.8%
Non-Hispanic Black	12.0%
Non-Hispanic other	7.2%
Hispanic	16.1%
Health insurance	90.6%
Obesity	30.8%
Mental health issue	2.7%
Comorbidities	
Hypertension	31.1%
Coronary heart disease	4.5%
Heart attack	3.1%
Stroke	3.1%
Asthma	13.6%
Ulcer	6.1%
Cancer	9.4%
Emphysema/COPD	3.7%
Kidney disease	2.1%
Diabetes	9.9%
Liver disease	1.9%
Arthritis	23.8%
Migraine	15.2%
Chronic pain	34.3%
Comorbidity count	
0	34.3%
1-2	41.8%
3-4	17.5%
5+	5.7%

COPD, chronic obstructive pulmonary disease; *ED*, emergency department.

Table 2. Characteristics of social determinants of health domains in adults, National Health Interview Survey, 2016–2018.

	Total sample (N = 238,888,238) (n = 82,364)
Economic instability	73.5%
Welfare assistance	1.2%
Income from state/county welfare	0.8%
Unemployed	37.5%
Ever applied for Social Security Disability insurance	7.7%
Subsidized rent	3.2%
Worry about maintaining current standard of living	36.1%
Worry about enough money for retirement	44.2%
Worry about paying normal monthly bills	26.5%
Worry about inability to pay rent, mortgage, or housing costs	21.0%
Worry about making minimum payment on credit cards	11.7%
Lack of community	40.5%
People in your neighborhood do not help each other out	16.6%
There are no people you can count on in your neighborhood	17.5%
People in your neighborhood cannot be trusted	16.1%
Do not live in a close-knit neighborhood	35.6%
Educational deficit	37.3%
No college or graduate degree	36.3%
English not well spoken	5.4%
Food insecurity	23.5%
Lose weight because not enough money for food	2.0%
Cut size of meals or skip meals in the past month	5.4%
Eat less than you should because not enough money for food	5.6%
Ever hungry but did not eat because no money for food	3.4%
Ever receive food stamps/SNAP in past year	12.1%
Worried that food would run out	12.6%
Food did not last until you could buy more	10.8%
Did not eat balanced meals due to costs	9.9%
Received benefits or food subsidies from WIC program	4.3%
Social isolation	27.2%
Lives alone	18.0%
Difficult to participate in social activities	8.4%
Difficulty going to events	9.9%
Delayed getting medical care due to lack of transportation	2.0%
Inadequate access to care	13.1%
Lacks regular place to go to when sick or need health advice	13.1%

SNAP, Supplemental Nutrition Assistance Program; *WIC*, Women, Infants and Children Program.

reporting social isolation, 24% reporting food insecurity, and 13% reporting inadequate access to care. In addition, fully adjusted models showed that economic instability, lack of community, educational deficits, food insecurity, and social isolation were independently associated with increased odds of ED visits, while inadequate access to care was significantly associated with lower odds of ED visits. This is one of the first studies to our knowledge that has assessed the relationship between multiple domains of social risk factors and ED utilization in a nationally representative US adult population.

Our findings are consistent with existing literature on the association of social risks with ED utilization. For example, studies by Estrella[25] and Dean[26] show food insecurity is significantly associated with increased ED use and ED expenditure even after adjustment for potential confounders.[25,26] Seim[16] has shown that economic instability and community factors, through neighborhood poverty, are positively associated with 9-1-1 ambulance utilization, a surrogate for ED utilization.[16] In another study, Ku[27] provides evidence that frequent users of the ED may be disproportionately homeless.[27] Similarly, available literature highlights the relationship between social isolation and ED use. In an observational study of older patients, Mosen[26] found that those who experience social isolation were more likely to have at least one ED visit than those who rarely or never experienced social isolation.[28]

The current findings show lack of access to care is negatively associated with ED use. Available evidence on the association between access to health and ED use is mixed.[29] Evidence suggests that greater access to care can translate into greater receipt of preventative care and being more cognizant of diseases and health, resulting in increased use across ED and primary care visits.[30] Conversely, lack of access can result in lower use of the ED, as the current findings show. On the

Table 3. Logistic regression for binary emergency department visits.

	Total sample		
	Unadjusted	**Domain adjusted**	**Fully adjusted**
Economic instability	2.10 (1.99, 2.22)***	1.61 (1.52, 1.71)***	1.33 (1.25, 1.42)***
Lack of community	1.33 (1.28, 1.39)***	1.17 (1.12, 1.23)***	1.10 (1.05, 1.15)***
Educational deficit	1.42 (1.36, 1.49)***	1.12 (1.07, 1.17)***	1.12 (1.06, 1.18)***
Food insecurity	2.46 (2.32, 2.59)***	2.10 (1.98, 2.23)***	1.77 (1.66, 1.89)***
Social isolation	2.02 (1.94, 2.11)***	1.76 (1.68, 1.84)***	1.32 (1.26, 1.39)***
Inadequate access to care	0.68 (0.63, 0.73)***	0.62 (0.57, 0.67)***	0.75 (0.69, 0.81)***
Age			
18–39 (ref)	-	-	-
40–49	-	-	0.72 (0.66, 0.77)***
50–64	-	-	0.58 (0.54, 0.63)***
65–74	-	-	0.58 (0.53, 0.63)***
75+	-	-	0.78 (0.71, 0.86)***
Sex (male)	-	-	0.85 (0.81, 0.89)***
Race/ethnicity			
Hispanic (ref)	-	-	-
Non-Hispanic White	-	-	1.10 (1.01, 1.20)*
Non-Hispanic Black	-	-	1.36 (1.23, 1.50)***
Non-Hispanic other	-	-	0.87 (0.77, 0.99)*
Health insurance (uninsured)	-	-	0.98 (0.89, 1.09)
Obesity	-	-	1.09 (1.03, 1.15)**
Mental health issue	-	-	1.31 (1.15, 1.49)***
Hypertension	-	-	1.32 (1.24, 1.40)***
Coronary heart disease	-	-	1.33 (1.19, 1.48)***
Heart attack	-	-	1.44 (1.27, 1.64)***
Stroke	-	-	1.73 (1.54, 1.93)***
Asthma	-	-	1.28 (1.20, 1.37)***
Ulcer	-	-	1.41 (1.29, 1.54)***
Cancer	-	-	1.26 (1.16, 1.35)***
Emphysema/COPD	-	-	1.55 (1.40, 1.72)***
Kidney disease	-	-	1.81 (1.59, 2.07)***
Diabetes	-	-	1.24 (1.15, 1.34)***
Liver disease	-	-	1.78 (1.51, 2.10)***
Arthritis	-	-	1.23 (1.16, 1.31)***
Migraine	-	-	1.54 (1.45, 1.64)***
Chronic pain	-	-	1.23 (1.16, 1.30)***

*$P = < 0.05$, **$P = < 0.01$, ***$P = < 0.001$.
COPD, chronic obstructive pulmonary disease; *ED*, emergency department.

contrary, some evidence shows that an increase in access to outpatient care is associated with a decrease in ED use.[29] Given the mixed findings, there remains an urgent need for further evidence on how the presence or lack of access impacts ED utilization across populations.

Overall, this study provides new evidence for understanding the relationship between social risk factors and ED use for adults at the national level with implications across research, practice, and policy. Specifically, available evidence shows ED visit rates are higher for patients in lower-

income and socially vulnerable communities, highlighting the need for specific initiatives aimed at understanding the drivers of their increased ED use, and the need to pay close attention to social risks and effective ways to address them.[10] Federal efforts to reduce ED overuse currently focus on improving primary care;[10] however, initiatives that have looked to increase the availability of low-cost options for the patients seeking these services, typically of low acuity, have yielded little in terms of reducing costs.[31,32] While our study underscores the linkage of individual social risks with ED utilization, it also highlights a greater opportunity to reduce costs by addressing social risks. Further research can elucidate whether addressing each of these social risks will translate into decreased ED use and cost.

Although various professional organizations recommend that health systems and clinicians incorporate social determinants of health and social risk screening into care models,[10,11] a vast majority of healthcare systems and hospitals (ie, 70%) do not have dedicated funds to address social needs, with many health systems lacking community-level social needs data to inform investment.[33,34] Even when a social risk is identified, emergency clinicians may not be aware of local resources or find it hard to best address it.[25] Doran and colleagues developed a screening tool for ED patients to identify the risk of becoming homeless to refer for services and support for homelessness prevention[9]; tools such as these, using models for referral services,[35] are greatly needed to assess across the spectrum of social risk factors known to impact health and lead to additional ED utilization.[9] While our study adds to the evidence on the role of social risks on ED utilization, there is need for research investigating how each risk is driving ED use, what initiatives can be taken by communities and policymakers to reduce such risks, and how EDs can better accommodate the patients who are experiencing these risks, both to reduce costs and ED burden, and also to improve their health outcomes.

Physicians can look to social emergency medicine (EM), an emerging field within EM, as a path forward to account for the intersection between emergency care and social determinants of health.[36] Social EM emphasizes a more holistic care model in the ED to better serve the populations who frequently visit the ED and receive care without adequate understanding by clinicians of the social forces at play. Our findings support the importance of this evolving field as a promising platform in mitigating the social risk burden on a broader scale and reducing ED utilization, especially among socially vulnerable populations.[37]

LIMITATIONS

There are some limitations that must be considered while interpretating our study findings. Although our study is based on a nationally representative sample, it excluded institutionalized individuals; therefore, the finding may not generalize to that segment of the US population. Secondly, to maintain a robust set of social risk factors, the dataset included NHIS data prior to the 2019 revision. For this reason, this study does not capture additional social risk factors that may have developed as a result of the COVID-19 pandemic. In addition, while our models controlled for relevant confounding variables, we did not have data on all possible confounders, which may have biased our estimates. Also, since the responses to all survey questions are based on self-report, they are subject to recall bias. Finally, given that the study is cross-sectional, we cannot speak to causality.

CONCLUSION

This study of a nationally representative sample of adults indicates that social risk factors are significantly associated with ED utilization. Specifically, economic instability, lack of community, educational deficit, food insecurity, and social isolation are associated with higher odds of ED use, whereas inadequate access to care is associated with lower ED use in fully adjusted models. Further research is needed to better understand potential pathways and mechanisms that underlie these associations. Interventions that can effectively address social risks have a potential to reduce unnecessary ED utilization and reduce healthcare costs. Emphasis should be placed on building infrastructure for screening and prevention programs for handoffs and referrals.

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Associations of Individual and Neighborhood Factors with Disparities in COVID-19 Incidence and Outcomes

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Introduction: The disproportionate impact of coronavirus 2019 (COVID-19) on Black and Hispanic communities has been widely reported. Many studies have used neighborhood racial/ethnic composition to study such disparities, but less is known about the interplay between individual race/ethnicity and neighborhood racial composition. Therefore, our goal in this study was to assess the relative contributions of individual and neighborhood risk to disparities in COVID-19 incidence and outcomes.

Methods: We performed a cross-sectional study of patients with emergency department (ED) and inpatient visits to an academic health system (12 hospitals; February 1–July 15, 2020). The primary independent variable was race/ethnicity; covariates included individual age, sex, comorbidity, insurance and neighborhood density, poverty, racial/ethnic composition, education and occupation. The primary outcome was severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) positivity; secondary outcomes included admission and death after COVID-19. We used generalized estimating equations to assess whether race/ethnicity remained significantly associated with COVID-19 after adjustment for individual and neighborhood factors.

Results: There were 144,982 patients; 5,633 (4%) were SARS-CoV-2 positive. Of those, 2,961 (53%) were admitted and 601(11%) died. Diagnosis of COVID-19, admission, and death were more common among non-Hispanic Black, Hispanic, Spanish-speaking patients, and those with public insurance. In the base model (adjusting for race/ethnicity, age, sex, and comorbidities), race/ethnicity was strongly associated with COVID-19 (non-Hispanic Black odds ratio [OR] 4.64 [95% confidence interval (CI) 4.18–5.14], and Hispanic OR 6.99 [CI 6.21–7.86]), which was slightly attenuated but remained significant after adjustment for neighborhood factors. Among patients with COVID-19, there was no significant association between race/ethnicity and hospital admission, other than for patients with unknown race.

Conclusion: This data demonstrates a persistent association between race/ethnicity and COVID-19 incidence, with Black and Hispanic patients at significantly higher risk, which was not explained by measured individual or neighborhood factors. This suggests that using existing neighborhood factors in studies examining health equity may be insufficient, and more work is needed to quantify and address structural factors and social determinants of health to improve equity. [West J Emerg Med. 2025;26(2)315–325.]

INTRODUCTION

The disproportionate impact of coronavirus 2019 (COVID-19) on Black and Hispanic communities has been extensive.[1–9] Along with the association with individual race and ethnicity, multiple studies have shown associations between neighborhood demographics and COVID-19 incidence and outcomes. Areas with higher proportions of Black and Hispanic residents have higher COVID-19 incidence and fatality rates.[10–13] Although a number of other neighborhood variables have been associated with increased rates of COVID-19, including poverty, insurance coverage,[13] unemployment, essential service employment,[14] and neighborhood education levels,[11] the association with neighborhood demographic composition may be stronger than that with neighborhood socioeconomic status (SES).[15] Importantly, the association between community-level social determinants of health, such as neighborhood poverty and COVID-19 rates, does not seem to be explained by differential testing rates.[14]

The connection between social determinants of health, unequal exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and race/ethnicity is a reflection of structural racism[16]—the "discriminatory policies, practices, and systems that reinforce an unequal distribution of power and resources in social institutions."[17] Non-White patients have increased representation in service-industry or low-income jobs, increased financial insecurity, more frequent residence in shared or congregate housing,[18] and a resulting increased risk of exposure to COVID-19. In addition, structural racism also affects patients' lived experience in the community and healthcare settings, and specifically their ability to access care.[19] Our previous work using data from a large academic health system has demonstrated co-location (overlap) of neighborhood factors, such as percentage of the population that was Hispanic, non-Hispanic Black, without health insurance or living in poverty, and COVID-19 cases.[13] However, recent research has demonstrated that relying on neighborhood-level social risk factors alone may over-attribute findings to the neighborhood-level factor.[20] Therefore, our goal in this study was to assess the relative contributions of individual and neighborhood risk to those disparities in a dataset where we could assess individual demographics, insurance status (as a proxy for individual SES), and comorbidities.

Population Health Research Capsule

What do we already know about this issue?
The disproportionate impact of COVID-19 on Black and Hispanic communities has been widely reported.

What was the research question?
We sought to assess the relative contributions of individual and neighborhood risk to disparities in COVID-19 incidence and outcomes.

What was the major finding of the study?
Race/ethnicity was associated with COVID-19 and remained significant after adjustment for neighborhood factors.

How does this improve population health?
This data suggests that using existing neighborhood factors in studies examining health equity may be insufficient.

METHODS

Study Design and Population

We performed a cross-sectional study of all emergency department (ED) and inpatient visits from February 1–July 15, 2020 within a large academic health system of 12 hospitals, including two academic medical centers, in New England. Data were abstracted from the electronic health record (EHR). Visits were eligible for inclusion if they were either (1) the first encounter (ED visit or admission) to any health system facility during the study period where the patient was SARS-CoV-2 positive or (2) the first visit if the patient was never SARS-CoV-2 positive. Patients were eligible if they were a Massachusetts state resident based on recorded address. We excluded patients if their address was a PO box or if they were undomiciled or not able to be geocoded via Epic or ArcGIS (Environmental Systems Research Institute, Inc, Redlands, CA) (for a total of 2,233 or 2% of participants; see eFigure1). Each patient was included only once.

Ethics approval

All methods were carried out in accordance with institutional guidelines; in particular, the study was deemed exempt from informed consent requirements by the Mass General Brigham Institutional Review Board. Because of this, the datasets generated and analyzed during the current study are not publicly available due to patient privacy concerns and data confidentiality rules.

Variable Definitions

The primary predictor variable was race/ethnicity. For a subset of 2,494 patients in the health system, Hispanic/Latino was included as a race. Patients were considered to be Hispanic if their race was Hispanic/ Latino, if their ethnicity was Hispanic/Latino regardless of race, or if their ethnicity was "Brazilian," "Dominican," "Honduran," "Puerto Rican," "Salvadoran," "Guatemalan," "Columbian," or "Mexican, Mexican American, Chicano," regardless of race.

Patients were otherwise categorized based on reported race and categorized as non-Hispanic White, non-Hispanic Black, Asian, other, missing, or unknown.

Sex was defined as male or female; data on eight patients whose sex assignment at birth was not known was coded as "missing." Similarly, data on 22 patients whose reported age was >107 years was also recorded as "missing" as it was presumed to represent an error in the EHR. Given the limited data on individual social determinants of health in the EHR, we chose to use insurance status and language as factors that are associated with access and utilization of care generally[21,22] and, specifically, for COVID-19.[13,23] Insurance status was defined as public, private or other (see Appendix), and preferred language abstracted from the EHR was English, Spanish, Portuguese, Creole-Haitian, Arabic, other, or missing/unknown (null, declined, unavailable).

We ascertained comorbidities by calculation of the Charlson Comorbidity Index (CCI) calculated from International Classification of Diseases, 10th Rev, Clinical Modification codes in the problem list,[24,25] and by direct identification of obesity, pulmonary disease, chronic kidney disease, diabetes mellitus, and hypertension in the problem list (see Appendix). Comorbidities were chosen based on previously published associations[2,26,27] and institutional guidance regarding risk factors for poor outcomes from COVID-19.

Neighborhood factors to assess social determinants of health were drawn from the 2015–2019 American Community Survey five-year estimates[28] and included neighborhood poverty,[13] educational attainment, service occupation,[29] and population density[30] as well as proportion Hispanic/Latino, non-Hispanic Black, non-Hispanic Asian, bachelor's degree or higher, and working in service occupation analyzed at the census tract level. We derived quintiles for neighborhood factors for analysis using all census tracts in the state of Massachusetts rather than those included in the sample.

Outcomes

The primary outcome was SARS-CoV-2 positivity (COVID-19 positivity), defined as polymerase chain reaction test result of positive or admission/discharge status documented as "COVID-19 Positive" or "Patient Expired (COVID-19)." Secondary outcomes were hospital admission after SARS-CoV-2 positivity (admission after COVID-19), defined as admission during first encounter where SARS-CoV-2 positive or within 14 days of the first encounter; or death after SARS-CoV-2 positivity (death after COVID-19), defined as death at any time during the study period after the first encounter where the SARS-CoV-2 test result was positive. Outcomes were ascertained from the EHR.

Statistical Analysis

We performed all statistical analyses with Stata SE 15.1 (StataCorp, College Station, TX), with $P < 0.05$ considered statistically significant. Continuous variables are displayed as mean (SD). Categorical variables are displayed as numbers (percentage) of participants within each group. Participants with missing data were excluded from models. We calculated descriptive statistics for patients and neighborhood characteristics in the sample overall and by COVID-19 outcomes.

Association between race/ethnicity and individual-level risk factors

We used multivariable logistic regression models to assess the association between comorbidities and individual risk factors and race/ethnicity. Given that we hypothesized that comorbidities were likely on the causal pathway between race/ethnicity and increased COVID-19 burden of disease, we also assessed the individual comorbidities as mediators of the association between race/ethnicity and COVID-19 incidence and outcomes. We used the Baron and Kenny methodology to assess for mediation.[31] First, we confirmed a significant association between race/ethnicity and each outcome (COVID-19 positivity, admission, and death) and between race/ethnicity and each mediator. Next, we included each mediator in a model with race/ethnicity and the outcome. We assessed for any major change in estimates, in particular a change in magnitude, direction, or statistical significance. Complete mediation would be indicated by the association between race/ethnicity and the outcome becoming non-significant once the mediator was included.

Accounting for neighborhood-level factors

Once we had determined that there were no significant mediation effects, we assessed neighborhood factors for multicollinearity using variance inflation factors (VIF) in a linear regression model. A VIF greater than 10 was considered indication of potential multicollinearity. We used generalized estimating equations to assess whether race/ethnicity remained significantly associated with COVID-19 positivity after adjustment for neighborhood factors and insurance status. We used a logit link, binomial distribution, and working independence correlation structure to estimate odds ratios separately for each outcome (COVID-19 positivity, admission, and death) with robust standard errors and clustering at the neighborhood level. For each outcome, a base model was created that included age, sex, and CCI. We chose to use the CCI as a summary measure of overall comorbidity status. We then generated models including each neighborhood factor individually and a fully adjusted model.

Sensitivity analyses

We conducted sensitivity analyses stratified by comorbidity and including insurance status in the base model. The analysis stratified by comorbidities was designed to address the concern that the distribution of comorbidities

in our population would be unequal by race[32,33] and, therefore, adjusting for comorbidities might diminish the overall impact of structural racism and disadvantage. The inclusion of insurance was designed to assess the impact of including a proxy measure of individual SES in the model.

RESULTS

There were 144,982 patients with ED visits or hospital admissions during the study period of whom 5,633 (4%) were COVID-19 positive (Table 1). Of those, 2,961 (53%) were admitted and 601 (11%) died. Although non-Hispanic Black

Table 1. Patient characteristics overall and by COVID-19 outcomes.

Patient characteristic	Overall	COVID-19 positive	Among COVID-19 positive	
			Admitted	Died
Overall, N (%)	144,982 (100)	5,633 (4)	2,961 (53)	601 (11)
Race/ethnicity, n (%)				
Non-Hispanic White	90,605 (62)	1,979 (35)	1,310 (44)	377 (63)
Non-Hispanic Black	12,824 (9)	894 (16)	489 (17)	90 (15)
Hispanic/Latino	19,115 (13)	1,667 (30)	692 (23)	63 (10)
Asian	5,496 (4)	192 (3)	102 (3)	13 (2)
Other	7,539 (5)	541 (10)	226 (8)	29 (5)
Missing or unknown	9,403 (6)	360 (6)	142 (5)	29 (5)
Age, mean (SD), years	44.6 (24.5)	54.3 (20.5)	63.0 (18.9)	75.7 (13.9)
Missing	22	0	0	0
Sex, n (%)				
Female	79,550 (55)	2,717 (48)	1,388 (47)	253 (42)
Male	65,424 (45)	2,916 (52)	1,573 (53)	348 (58)
Comorbidities, n (%)				
Charlson comorbidity index, mean (SD)	0.9 (1.6)	1.0 (1.7)	1.4 (1.9)	2.4 (2.4)
Obesity	15,473 (13)	827 (17)	492 (17)	84 (14)
Pulmonary disease	36,042 (31)	2,113 (43)	1,487 (50)	386 (65)
Chronic kidney disease	8,263 (7)	612 (13)	503 (17)	189 (32)
Diabetes mellitus	14,230 (12)	1,211 (25)	910 (31)	216 (36)
Hypertension	37,306 (32)	2,076 (42)	1,502 (51)	390 (65)
Missing comorbidities	27,389	738	8	4
Insurance, n (%)				
Private only	78,939 (55)	2,183 (39)	1,085 (37)	179 (30)
Public only	36,384 (25)	2,232 (39)	1,188 (40)	223 (37)
Other or multiple	27,489 (19)	1,174 (21)	673 (23)	199 (33)
Any public insurance, n (%)	60,515 (42)	3,054 (55)	1,787 (61)	418 (70)
Missing	2,170	44	15	0
Language preference, n (%)				
English	124,541 (86)	3,348 (59)	1,896 (64)	443 (74)
Spanish	12,879 (9)	1,695 (30)	737 (25)	74 (12)
Portuguese	991 (1)	50 (1)	18 (1)	4 (1)
Haitian Creole	543 (0)	124 (2)	89 (3)	24 (4)
Arabic	458 (0)	13 (0)	9 (0)	42 (7)
Other	3,563 (2)	242 (4)	154 (5)	14 (2)
Missing or unknown	2,007 (1)	161 (3)	58 (2)	443 (74)

COVID-19, coronavirus 2019.

patients were 9% of the overall cohort, they represented 16% of the COVID-19 positive patients, 17% of the admitted patients, and 15% of the patients who died after testing positive for COVID-19.

Similarly, Hispanic patients were 13% of the overall cohort, 30% of the COVID-19 positive patients, 23% of the admitted patients and 10% of the patients who died with COVID-19. Patients who were listed as having a language preference of Spanish were 9% of the overall cohort but 30% of the COVID-19 positive patients, 25% of the admitted patients, and 12% of those who died with COVID-19. Although 36,384 patients (25%) in the overall population had only public insurance, 39% of the COVID-19 positive, 40% of the patients admitted after COVID-19, and 37% of the patients who died after COVID-19 had only public insurance. When insurance was examined as those who had any public insurance (60,515, 42%), there were higher percentages of patients with public insurance who were COVID-19 positive (55%), admitted after COVID-19 (61%), or died after COVID-19 (70%) than in the overall cohort.

Regarding neighborhood characteristics (Table 2), there was a greater representation of patients from neighborhoods in the highest quintile of poverty, percentage Hispanic population, percentage non-Hispanic Black population and percentage service occupation, and lowest quintile of non-Hispanic White population and educational attainment within the COVID-19 outcome groups (tested positive, admitted, died).

Collinearity

For the outcome of COVID-19 positivity, we detected multicollinearity when including patient race/ethnicity and all neighborhood race/ethnicity variables; excluding variable for quintiles of non-Hispanic White population resolved the collinearity issues. For the outcomes of admission within 14 days of first COVID-19 positive presentation and death any time after first COVID -19 positive presentation (among COVID-19 positive patients), multicollinearity was detected between race/ethnicity variables and service occupation. Removing the variables for quintiles of non-Hispanic White population and service occupation resolved the collinearity.

Individual Comorbidity and Risk Factors: Association and Mediation

There were significant associations between race/ethnicity and each comorbidity, with the exception of non-Hispanic Black and hypertension (HTN) (eTable 1). In the unadjusted model for COVID-19 positivity (Table 3), race/ethnicity was a significant predictor of COVID-19 positivity (non-Hispanic Black odds ratio [OR] 3.36 [3.09–3.64] and Hispanic OR 4.28 [4.00–4.58]). The association with race/ethnicity remained significant even after adjustment for each individual comorbidity and risk factor (Table 3). There was potential partial mediation by language preference (Table 3), as the OR was substantially decreased but still statistically significant after adjustment for language preference.

In the unadjusted model for admission among the patients with COVID-19, non-Hispanic Black and Hispanic patients had lower odds of being admitted (OR 0.62 [0.52–0.72] and 0.36 [0.32–0.41], respectively), and the directionality and significance of the association was not altered by adjustment for any of the individual comorbidities or risk factors (eTables 2 and 3); a similar pattern was seen for deaths after COVID-19 (eTables 4 and 5). Together, this data suggests that the individual comorbidities and social risk factors are not significant mediators of the association between race/ethnicity and COVID-19 incidence and outcomes.

Full Model: Race/Ethnicity, Individual and Neighborhood Factors, and COVID-19

Once there was less concern for comorbidities serving as a mediator of the association, we created a base model that included age, sex, and the CCI to examine how the associations between race/ethnicity and COVID-19 outcomes would change with the inclusion of neighborhood factors. In the base model (Table 4), race/ethnicity was strongly associated with COVID-19 positivity (non-Hispanic Black, OR 4.64 [4.18–5.14], Hispanic, OR 6.99 [6.21–7.86], which was slightly attenuated but remained significant after adjustment for neighborhood factors (non-Hispanic Black, OR 3.27 [2.90–3.69], Hispanic, OR 4.10 [3.66–4.60]]). Trends for other racial/ethnic groups are displayed in Table 4. Among patients with COVID-19, there was no significant association between race/ethnicity and hospital admission, other than that patients with missing or unknown race were less likely to be admitted, and that association remained consistent after adjustment for neighborhood factors. For the outcome of death after COVID-19, Hispanic (OR 0.62 [0.46–0.83]) and Asian (0.46 [0.25–0.86]) patients had lower odds of dying as compared to non-Hispanic White patients in the base model, and that association persisted after adjustment for neighborhood factors (Hispanic OR 0.61 [0.44–0.85], Asian OR 0.47 [0.25–0.91]) (Table 4).

We further examined the association between race/ethnicity and COVID-19 outcomes in models stratified by comorbidity (eTables 6–10). For patients with and without obesity, race/ethnicity remained significantly associated with COVID-19 positivity in both the base and fully adjusted models, although the association was smaller in the obese patients for those who were Black or Hispanic and larger for those who were Asian. Similar trends were seen for pulmonary disease, although with smaller changes. For patients with chronic kidney disease, diabetes and HTN, the association with race/ethnicity was weaker in patients with the condition than those without, although it remained significant in all models.

As a sensitivity analysis, we modeled the association between race/ethnicity and COVID-19 including not only

Table 2. Neighborhood characteristics overall and by COVID-19 outcomes.

Neighborhood characteristic	Overall	COVID-19 positive	Among COVID-19 positive	
			Admitted	Died
Density, mean (SD), population per square mile	10,032 (11984)	16,121 (13,592)	15,062 (13529)	12,402 (11711)
Families living below poverty, n (%)				
Lowest quintile (0–1.5%)	28,375 (20)	634 (11)	382 (13)	83 (14)
2 (1.6–3.4%)	29,941 (21)	655 (12)	391 (13)	95 (16)
3 (3.5–6.3%)	26,173 (18)	712 (13)	400 (14)	80 (13)
4 (6.4–13.5%)	32,572 (22)	1,736 (31)	902 (31)	191 (32)
Highest quintile (13.6–65.2%)	27,849 (19)	1,890 (34)	882 (30)	152 (25)
Missing	72	6	4	0
Hispanic/Latino population, n (%)				
Lowest quintile (0–2.2%)	21,932 (15)	363 (6)	211 (7)	63 (10)
2 (2.3–4.5%)	27,409 (19)	584 (10)	379 (13)	99 (16)
3 (4.6–8.3%)	28,998 (20)	698 (12)	430 (15)	82 (14)
4 (8.4–19.1%)	27,399 (19)	962 (17)	498 (17)	110 (18)
Highest quintile (19.2–100%)	39,202 (27)	3,024 (54)	1,443 (49)	247 (41)
Non-Hispanic Black population, n (%)				
Lowest quintile (0–0.6%)	21,829 (15)	474 (8)	292 (10)	62 (10)
2 (0.7–2.0%)	24,281 (17)	506 (9)	282 (10)	73 (12)
3 (2.1–4.2%)	34,356 (24)	1,363 (24)	816 (28)	180 (30)
4 (4.3–9.2%)	27,814 (19)	970 (17)	511 (17)	98 (16)
Highest quintile (9.3–82.9%)	36,660 (25)	2,318 (41)	1,060 (36)	188 (31)
Non-Hispanic Asian population, n (%)				
Lowest quintile (0–0.7%)	20,830 (14)	556 (10)	296 (10)	71 (12)
2 (0.8–2.2%)	22,773 (16)	786 (14)	422 (14)	106 (18)
3 (2.3–4.9%)	30,938 (21)	1,194 (21)	602 (20)	110 (18)
4 (5.0–10.9%)	37,281 (26)	1,869 (33)	972 (33)	171 (28)
Highest quintile (11.0–59.2%)	33,118 (23)	1,226 (22)	669 (23)	143 (24)
Non-Hispanic White population, n (%)				
Lowest quintile (0–50.2%)	38,229 (26)	2,977 (53)	1,384 (47)	227 (38)
2 (50.3–72.3%)	28,958 (20)	1,098 (20)	606 (20)	129 (21)
3 (72.4–83.7%)	31,217 (22)	742 (13)	464 (16)	105 (17)
4 (83.8–91.4%)	28,150 (19)	574 (10)	366 (12)	98 (16)
Highest quintile (91.5–100%)	18,386 (13)	240 (4)	141 (5)	42 (7)
Bachelor's degree or higher level of education, n (%)				
Lowest quintile (0–22.3%)	24,773 (17)	1,926 (34)	878 (30)	136 (23)
2 (22.4–34.4%)	21,154 (15)	1,097 (19)	578 (20)	106 (18)
3 (34.5–46.5%)	27,471 (19)	756 (13)	406 (14)	101 (17)
4 (46.6–63.9%)	34,611 (24)	949 (17)	525 (18)	125 (21)
Highest quintile (64.0–95.6%)	36,930 (25)	903 (16)	574 (19)	133 (22)
Persons in service occupations, n (%)				
Lowest quintile (0–10.8%)	33,289 (23)	817 (15)	509 (17)	112 (19)
2 (10.9–14.8%)	31,728 (22)	723 (13)	430 (15)	111 (18)

(*Continued on next page*)

Table 2. Continued.

Neighborhood characteristic	Overall	COVID-19 positive	Among COVID-19 positive	
			Admitted	Died
3 (14.9–18.9%)	23,812 (16)	565 (10)	316 (11)	80 (13)
4 (19.0–25.2%)	23,950 (17)	1,028 (18)	508 (17)	116 (19)
Highest quintile (25.3–69.2%)	32,161 (22)	2,498 (44)	1,198 (40)	182 (30)

COVID-19, coronavirus 2019.

age, sex, and the CCI, but also insurance status as a marker of individual SES. Again, race remained strongly associated with COVID-19 positivity; only missing race was associated with admission for COVID-19, and Hispanic and Asian race/ethnicity were associated with lower odds of death after COVID-19 (Table 5).

DISCUSSION

In this cross-sectional study of health system data from the initial stages of the COVID-19 pandemic, non-Hispanic Black, Hispanic, and Asian race/ethnicity were significantly associated with increased COVID-19 positivity, and the association remained significant after adjustment for both individual risk factors (age, sex, comorbidity, insurance) and neighborhood risk factors (density, poverty, racial/ethnic composition, educational attainment, occupation). These results demonstrate a persistent association with race/ethnicity after adjustment for potential explanatory factors (eg, comorbidities). Importantly, we did not find that comorbidities or individual insurance status (as a marker of SES) were

Table 3. Association of race/ethnicity and COVID-19 positivity[a], unadjusted and adjusted for each comorbidity and individual risk factor.

	Race/ethnicity (primary exposure), OR (95% CI)[b]					
	Non-Hispanic White	Non-Hispanic Black	Hispanic/ Latino	Asian	Other	Missing or unknown
Unadjusted model	1.00 (referent)	3.36 (3.09–3.64)	4.28 (4.00–4.58)	1.62 (1.39–1.88)	3.46 (3.14–3.82)	1.78 (1.59–2.00)
Adjusted for each comorbidity						
CCI	1.00 (referent)	3.61 (3.31–3.93)	4.57 (4.25–4.92)	1.89 (1.61–2.22)	4.01 (3.60–4.47)	1.83 (1.61–2.08)
Obesity	1.00 (referent)	3.50 (3.21–3.81)	4.26 (3.96–4.58)	1.83 (1.56–2.15)	3.74 (3.36–4.16)	1.71 (1.50–1.94)
Pulmonary disease	1.00 (referent)	3.65 (3.34–3.97)	4.47 (4.16–4.81)	1.96 (1.67–2.30)	3.95 (3.55–4.40)	1.99 (1.75–2.26)
Chronic kidney disease	1.00 (referent)	3.49 (3.21–3.81)	4.51 (4.19–4.85)	1.88 (1.60–2.21)	3.98 (3.57–4.44)	1.79 (1.58–2.04)
Diabetes mellitus	1.00 (referent)	3.33 (3.05–3.63)	4.23 (3.93–4.55)	1.84 (1.57–2.16)	3.90 (3.50–4.35)	1.83 (1.61–2.08)
Hypertension	1.00 (referent)	3.57 (3.28–3.90)	4.80 (4.46–5.17)	2.02 (1.72–2.37)	4.33 (3.88–4.83)	2.06 (1.81–2.34)
Adjusted for each individual risk factor						
Insurance type	1.00 (referent)	3.33 (3.06–3.62)	3.99 (3.72–4.29)	1.79 (1.53–2.08)	3.43 (3.11–3.80)	1.88 (1.67–2.11)
Any public Insurance	1.00 (referent)	3.33 (3.07–3.61)	4.04 (3.77–4.32)	1.72 (1.47–2.00)	3.44 (3.11–3.79)	1.83 (1.63–2.05)
Language preference	1.00 (referent)	2.97 (2.73–3.23)	1.78 (1.62–1.96)	1.33 (1.14–1.56)	1.98 (1.78–2.21)	1.22 (1.08–1.38)

[a]COVID-19 positivity was defined as PCR test result of positive or admission/discharge status documented as "COVID-19 Positive" or "Patient Expired (COVID-19)."

[b]Presented are odds ratios (95% CI) for the outcome (COVID-19 positivity) for each race/ethnicity group compared to non-Hispanic Whites (referent, first column), with the unadjusted values in the first row and after adjustment for the variables separately in following rows.

CCI, Charlson Comorbidity Index; *COVID-19*, coronavirus 2019.

Table 4. Odds ratios[a] for the association between race/ethnicity and COVID-19 outcomes.

	COVID-19 positivity (N = 117,589; cluster n = 1,447)		Admission after COVID-19 (n = 4,895; cluster n = 848)		Death after COVID-19 (n = 4,895; cluster n = 848)	
	Base model	Fully adjusted[b]	Base model	Fully adjusted[c]	Base model	Fully adjusted[c]
Race/ethnicity						
Non-Hispanic White	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)
Non-Hispanic Black	4.64 (4.18–5.14)	3.27 (2.90–3.69)	1.06 (0.87–1.30)	1.23 (0.99–1.54)	0.91 (0.69–1.20)	0.89 (0.66–1.21)
Hispanic/Latino	6.99 (6.21–7.86)	4.10 (3.66–4.60)	1.03 (0.87–1.22)	1.05 (0.86–1.29)	0.62 (0.46–0.83)	0.61 (0.44–0.85)
Asian	2.52 (2.08–3.04)	2.00 (1.66–2.41)	0.91 (0.66–1.25)	0.92 (0.65–1.30)	0.46 (0.25–0.86)	0.47 (0.25–0.91)
Other	5.94 (5.15–6.86)	3.80 (3.34–4.32)	0.88 (0.69–1.13)	0.88 (0.68–1.14)	0.80 (0.53–1.22)	0.79 (0.51–1.22)
Missing or unknown	3.66 (3.12–4.30)	3.18 (2.73–3.69)	0.60 (0.44–0.80)	0.62 (0.46–0.84)	0.75 (0.46–1.20)	0.74 (0.45–1.23)

[a]Estimated using generalized estimating equations (binomial distribution, logit link, working independence correlation structure) with robust standard errors and clustering at the neighborhood level. All models (base and fully adjusted) include race/ethnicity, age, sex, and the Charlson Comorbidity Index.
[b]Includes all neighborhood factors (density, poverty, Hispanic/Latino, Non-Hispanic Black, Non-Hispanic Asian, Bachelor's degree or higher level of education and service occupation). Non-Hispanic White population within the census tract (neighborhood level variable) was excluded due to multicollinearity.
[c]Includes all neighborhood factors (density, poverty, Hispanic/Latino, Non-Hispanic Black, Non-Hispanic Asian, Bachelor's degree or higher education level). Non-Hispanic White population within the census tract (neighborhood level variable) and service occupation excluded due to multicollinearity.
COVID-19, coronavirus 2019.

meaningful mediators of the association between race/ethnicity and COVID-19 incidence or outcomes, meaning that we did not see evidence that they were on the causal pathway for this association. Additionally, the association was not fully explained by measured neighborhood risk.

From these results we draw two major conclusions. Firstly, recognizing that the residual association with measured race/ethnicity represents structural racism rather than biological variation and that there is no standard measurement for structural racism in administrative datasets, this data emphasizes the need for improved measurement of individual-level social determinants of health and the impact of structural racism. Similar to prior reports, we found stronger associations between race/ethnicity and COVID-19 positivity, again suggesting that higher rates in Black and Hispanic populations are driven by exposure,[4] and that the mortality trends are more complex.[6,7] This data builds upon prior reports that show a consistent impact of race and ethnicity that appears to be modified or mediated by social determinants of health.[26,30,34,35] Similarly, a recent study demonstrated limited ability of insurance to correctly classify SES, as defined by education and income.[36] Additional work is needed to define and reliably measure individual sociodemographic factors associated with disease vulnerability and use them to define areas for potential intervention.

The second major conclusion of our study urges caution in the use of neighborhood socioeconomic factors alone to examine disparities. Neighborhood factors represent the ecological exposure and not the individual experience, and this study demonstrates the complex interplay between these individual and neighborhood factors. For example, a study examining hospitalized patients with COVID-19 in Michigan found that those from socially vulnerable neighborhoods were more likely to present with severe disease, even after adjustment for age, sex, and comorbidities, but that neighborhood vulnerability was not associated with mortality.[37] Overall, this data emphasizes the importance of measuring the factors (eg, individual housing insecurity, crowding, and essential occupations that could not be completed remotely) that reflect structural racism, and may serve as potential mediators in the association between race/ethnicity and COVID-19, rather than relying on neighborhood-level measurements alone. Future directions for this research could include using improved measurements of individual-level social determinants of health in future investigations in other conditions and interventions to reduce the disproportionate burden of disease.

Table 5. Odds ratios[a] for the association between race/ethnicity and COVID-19 outcomes, including adjustment for insurance status.

	COVID-19 positivity (N = 116,631; cluster n = 1,447)		Admission after COVID-19 (n = 4,895; cluster n = 848)		Death after COVID-19 (n = 4,895; cluster n = 848)	
	Base model	Fully adjusted[b]	Base model	Fully adjusted[c]	Base model	Fully adjusted[c]
Race/ethnicity						
Non-Hispanic White	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)	1.00 (referent)
Non-Hispanic Black	4.22 (3.79–4.70)	3.16 (2.80–3.56)	1.06 (0.86–1.30)	1.25 (0.99–1.57)	0.89 (0.67–1.17)	0.88 (0.65–1.19)
Hispanic/Latino	5.97 (5.26–6.79)	3.83 (3.41–4.31)	0.98 (0.83–1.17)	1.02 (0.84–1.26)	0.60 (0.45–0.81)	0.60 (0.43–0.83)
Asian	2.44 (2.02–2.95)	1.97 (1.62–2.38)	0.90 (0.65–1.25)	0.93 (0.65–1.31)	0.47 (0.25–0.88)	0.49 (0.26–0.94)
Other	5.41 (4.67–6.29)	3.67 (3.22–4.19)	0.85 (0.66–1.10)	0.86 (0.66–1.13)	0.79 (0.52–1.21)	0.78 (0.51–1.21)
Missing or unknown	3.57 (3.04–4.19)	3.15 (2.71–3.66)	0.57 (0.43–0.77)	0.61 (0.45–0.82)	0.74 (0.46–1.18)	0.74 (0.45–1.22)

[a]Estimated using generalized estimating equations (binomial distribution, logit link, working independence correlation structure) with robust standard errors and clustering at the neighborhood level. All models (base and fully adjusted) include race/ethnicity, age, sex, the Charlson Comorbidity Index, and insurance status.
[b]Includes all neighborhood factors (density, poverty, Hispanic/Latino, Non-Hispanic Black, Non-Hispanic Asian, Bachelor's degree or higher education level and service occupation). Non-Hispanic White population within the census tract (neighborhood level variable) was excluded due to multicollinearity.
[c]Includes all neighborhood factors (density, poverty, Hispanic/Latino, Non-Hispanic Black, Non-Hispanic Asian, Bachelor's degree or higher education level). Non-Hispanic White population within the census tract (neighborhood level variable) and service occupation excluded due to multicollinearity.
COVID-19, coronavirus 2019.

LIMITATIONS

Limitations of this study include that the data was drawn from a single health system and, therefore, may minimize hospital-level differences and disparities in care[38] and may not fully capture the underlying population. This is particularly important because data from our city has shown differences in the racial/ethnic makeup of patient populations by hospital.[39,40] However, the health system includes the hospital that has cared for the highest number of admitted COVID-19 patients in the area,[41,42] and our prior work showed that our health system data identified similar clusters to the state data within our catchment area.[13] Early in the pandemic there were disparities in testing access,[43,44] although other studies in Massachusetts have found disparities that were not fully explained by testing access differences.[14] Additionally, not all comorbidities may have been coded in the problem list, particularly for patients who were new to our health system, potentially limiting our ability to ascertain them. We used insurance status as a proxy for individual SES because we do not have full data on social determinants of health for all patients in the cohort.

It is challenging to determine whether the measured differences in admission and death were due to unmeasured differences in illness severity or comorbidities, represented ascertainment bias due to use of EHR data, or were a manifestation of implicit bias. Increased mortality has been reported in Hispanic populations,[8,9] which was not demonstrated in our data, potentially reflecting unmeasured confounding from differences in the Hispanic population in our cohort (eg, healthy immigrant effect).[45] Because we were interested in neighborhood effects, we were not able to include patients without an address, and there may be a different relationship between social risk and COVID-19 incidence and outcomes in an undomiciled population that we were unable to examine. Finally, with the ability of patients to access vaccination, and the evolution of new COVID-19 variants, the disparities in COVID-19 continue to evolve.

CONCLUSION

The data shows a persistent association between non-Hispanic Black, Hispanic, and Asian race/ethnicity and higher COVID-19 incidence that is not explained by included individual or neighborhood factors. The results emphasize the importance of improving the measurement of structural factors and social determinants of health and careful attention to the use of individual-level and neighborhood-

level risk factors in studies to enable interventions to improve the equity of pandemic response.

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Food and Housing Insecurity, Resource Allocation, and Follow-up in a Pediatric Emergency Department

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Introduction: Food and housing insecurity in childhood is troublingly widespread. Emergency departments (ED) are well positioned to identify and support food- and housing-insecure children and their families. However, there is no consensus regarding the most efficient screening tools or most effective interventions for ED use.

Objective: In this cross-sectional study we aimed to investigate the implementation of a food/ housing insecurity screening tool and resource referral uptake in a pediatric ED.

Methods: During the study period (March 1–December 9, 2021), there were 67,297 ED visits at the study institution, which is a freestanding children's hospital. Caregivers of patients presenting to the ED were approached for participation in the study; 1,908 families participated (2.8% of all ED visits during the study period) and were screened for food and housing insecurity. Caregiver surveys included demographic, food and housing insecurity, caregiver/patient health status, and healthcare utilization questions. Caregivers who screened positive for food and/or housing insecurity received printed materials with food and/or housing resources. We analyzed data using descriptive statistics, one-way analysis of variance, and the Pearson chi-squared test.

Results: A total of 1,908 caregivers were surveyed: 416 (21.8%) screened positive for food and/or housing insecurity. Of those who screened positive, 147/416 completed follow-up surveys. On follow-up, 44 (30.0%) no longer screened positive for food and/or housing insecurity, while 15 (10.2%) reported using at least one resource referral. The most frequently reported referral utilization barrier was loss or reported non-receipt of the referral.

Conclusion: This study demonstrates high food- and housing-insecurity rates among families presenting to a pediatric ED, emphasizing the urgency and necessity of screening and intervening in this environment. The food and housing insecurity change between baseline and follow-up reported here and the overall low resource uptake highlights challenges with ED-based screening and intervention efficacy. [West J Emerg Med. 2025;26(2)326–337.]

INTRODUCTION

One in six of all children in the United States (US) are food insecure, while one in 18 under the age of six are unhoused.[1] In 2017, over 1.5 million children enrolled in public schools were unhoused.[2,3] Beyond a statistical representation of societal shortcomings of meeting the basic needs of children, these figures are distressing as food and housing insecurity has repeatedly been shown to be associated with adverse mental, physical, and developmental health outcomes.[1,4–12] Food and housing insecurity disproportionately burdens underserved communities of color, particularly those in which more than 20% of residents live in poverty, and downstream health disparities are common.[13]

Since 2015 the American Academy of Pediatrics has advocated for the screening of food insecurity during well-child visits, and this approach has now expanded to a variety of healthcare settings.[14] The emergency department (ED) is particularly well positioned to assess for health-related social needs (HRSN) and to potentially intervene. Over 15% of all US children visit the ED each year, many with barriers to routine preventive care, and food/housing insecurity has been shown to be associated with increased ED use.[15–18] Several studies have demonstrated the feasibility of various screening methods and resource referral for food and housing insecurity in the ED.[19–25] However, there is no current consensus regarding the most effective techniques for reliable, widespread screening in the ED or recommendations for optimizing caregiver resource utilization. In this study we aimed to investigate the implementation of a food and housing insecurity screening tool and resource referral uptake in a pediatric ED.

Population Health Research Capsule

What do we already know about this issue?
Food and housing insecurity interventions are increasing in the pediatric emergency department (ED) yet lack a standard approach to optimizing resource utilization.

What was the research question?
What are barriers to uptake of food and housing insecurity community-resource referrals in a pediatric ED?

What was the major finding of the study?
On follow-up, only 10% of participating families reported using at least one resource referral.

How does this improve population health?
This study identifies multiple barriers to community resource use and follow-up among families participating in a passive referral approach in a pediatric ED.

METHODS

This cross-sectional study included patients presenting to the ED of a freestanding children's hospital with a Level II trauma center between March 1–December 9, 2021. This institution, located in a suburban community in the Southwestern US, has an annual ED census of approximately 100,000 visits per year; 67,297 visits occurred during the study period. In the study county, approximately 24% of households report a household income of under $50,000/year, 25% report $50,000–100,000, 31% report $100,000–$200,000, and 19% report over $200,000. An estimated 11% of children live below the poverty line.[26] This study was approved by the study institution's institutional review board (IRB# 200326).

Using a convenience sample of adult caregivers of patients <18, trained research assistants (RA) approached prospective participants during triage, described the study, invited them to participate, and obtained verbal consent from those who agreed. The RAs approached eligible patient caregivers during the hours of 8 AM – 5 PM Monday through Friday during the study period. The RAs administered surveys via REDCap (Research Electronic Data Capture hosted at UC Irvine Emergency Department) on electronic tablets, in which participants directly entered their responses. Surveys were available in English and Spanish. The baseline survey included an expanded demographics section followed by 16 questions regarding food insecurity, access to food, housing insecurity, neighborhood safety, caregiver self-reported health, caregiver-reported patient health, and healthcare utilization (Supplementary Materials Appendix A). We also garnered caregiver self-reported race/ethnicity as well as insurance status from patient registration data. Surveys were developed by RA, VC, and JD, authors with expertise in public health.

We assessed and defined food insecurity based on two previously validated screening questions: "Within the past 12 months, I worried whether my food would run out before I got money to buy more"; and "Within the past 12 months, the food I bought just didn't last and I didn't have money to get more."[27] Affirmative responses to either or both questions was considered a positive screen. We assessed housing instability on an affirmative response either to 1) "In the past 12 months, have you had trouble paying your rent/ mortgage/ utility bills," or 2) a response of "Stay at a friend's home" or "I do not live in stable housing" to the survey question "In the past 12 months, have you been living in stable housing that you . . ." This definition is consistent with prior studies, although historically housing instability has been defined by various criteria in federal bodies and

scientific literature, rendering it more difficult to consistently measure than food insecurity.[4]

All caregivers who completed the survey received curated printed materials with current local food and/or housing resources. The RAs provided these resources immediately after the participants completed the survey. Direct communication between research personnel and community resources about individual-level need (eg, warm hand-offs) were not part of the study methods. The study institution's social work team worked with authors RA and VC to develop documents containing an extensive list of vetted local community resources. Additionally, those who screened positive for food or housing insecurity were contacted by RAs three weeks and six weeks after the index ED visit to conduct follow-up surveys. The RAs conducted follow-up surveys via telephone and attempted to contact families up to three times. Follow-up surveys included questions regarding use of provided resources, barriers to use, and food/housing insecurity in the prior three weeks (Supplementary Materials Appendix B). Follow-up status (food insecure, housing insecure, or both food and housing insecure) was recorded based on final responses (ie, at three weeks if caregivers didn't respond to the six-week survey or six weeks if they responded to both surveys).

Statistical Analysis

Data was screened and cleaned prior to analyses by PKP. Descriptive statistics were used to analyze demographic, healthcare utilization, and clinical characteristics. We analyzed patient age and ED length of stay (both continuous variables) using the Fisher *t*-test or Welch one-way analysis of variance. All other variables (categorical) were analyzed using the Pearson chi-squared test with Monte Carlo simulation and standardized residuals (z) to interpret significant associations.

RESULTS

A total of 2,144 adult caregivers participated in the survey. Initial food/housing insecurity status was indeterminate for 236 patients as their caregivers did not respond to the food/housing questions described above and, thus, this group was excluded from data analysis. Of the remaining 1,908 respondents (2.8% of total ED visits during the study period), a total of 416 (21.8%) screened positive for food and/or housing insecurity. Additionally, 164 caregivers (8.6%) screened positive for food and housing insecurity, 95 (4.98%) for solely food insecurity, and 157 (8.2%) for solely housing insecurity.

Initial Survey

Demographics

The mean age for all patients whose caregiver completed a survey was 6.68 ± 5.26 years. On average, patients with food or housing insecurity (7.42 ± 5.40 years), food and housing insecurity (7.95 ± 5.44 years) were older than those without (6.41 ± 5.18 years; $P < 0.001$). Slightly more than half of all patients were male (52.8%); there was no significant difference with respect to sex among patients with and without food and/or housing insecurity; $P = 0.43$. Among those surveyed, 64.1% were Hispanic, 20.4% White non-Hispanic, 7.3% Asian, and 2.5% Black. Just over 75% of caregivers who screened positive for food or housing security were Hispanic, 11.5% were White non-Hispanic, 4.4% were Asian, and 2.0% were Black. Caregivers who were both food and housing secure were more likely to report White non-Hispanic race and ethnicity ($z = 2.9$, $P < 0.001$). Over two-thirds, 67.5%, of patients had public health insurance; caregivers who were food and/or housing insecure were more likely to have public health insurance than private health insurance ($z = 4.22$, $z = 4.41$, $P < 0.001$). Complete demographics stratified by total population, and those with and without food and/or housing insecurity are included in Table 1.

Neighborhood safety

Of all caregivers surveyed, 72.9% reported always feeling safe in their neighborhood and 76.2% reported never being concerned about the patient's safety in their neighborhood. Caregivers screening positive for both food and housing insecurity were less likely to report always feeling safe in their neighborhood ($z = -4.5$) and more likely to report sometimes being concerned about the patient's safety in their neighborhood ($z = -4.5$, $z = 7.1$, $P < 0.001$).

Health status and healthcare utilization

Only 35.3% of caregivers rated the patient's health as excellent, while even fewer, 25.1%, rated their own health as excellent. Those screening positive for housing and/or food insecurity were less likely to rate the patient's health as excellent ($z = -3.1$, $z = -3.2$, $P < 0.001$) as well as their own health as excellent or very good ($z = -2.8$, $z = -3.4$, $P < 0.001$). Caregivers who screened positive for both housing and food insecurity were more likely to report that at some time a physician told them the patient was obese ($z = 3.22$), had anxiety ($z = 3.82$), or had emotional challenges ($z = 3.80$, $P < 0.001$).

In our study, 68.3% of caregivers reported the patient had not visited the ED in the previous year, 19.6% reported a single visit, and 12.1% reported two or more visits during the same time frame. Caregivers screening positive for both food and housing insecurity were more likely to report visiting the ED at least once ($z = 3.0$, $P < 0.001$).

ED visit characteristics

The majority (65.1%) of patients were triaged to Emergency Severity Index (ESI) level 3 and discharged home from the index ED visit (80.9%), while the mean length of stay in the ED was 4.5 ± 3.19 hours. There was no significant

Table 1. Initial survey: demographics and clinical characteristics as stratified by food and housing insecurity status.

Characteristics	Total population (N = 1,908)	Baseline status (N = 1,908)			*P*-value
		Food or housing insecure (n = 252)	Both food and housing insecure (n = 164)	Both food and housing secure (n = 1,492)	
Demographic					
Patient age, mean years (SD)	6.68 (5.26)	7.42 (5.40)	7.95 (5.44)	6.41 (5.18)	<0.001
Patient male sex, n (%)	1,008 (52.8%)	124 (49.2%)	90 (54.9%)	794 (53.2%)	0.43
Patient ethnicity and race					<0.001
White, non-Hispanic, n (%)	389 (20.4%)	29 (11.5%)	19 (11.6%)	341 (22.9%)	
Hispanic, n (%)	1,223 (64.1%)	191 (75.8%)	128 (78.0%)	904 (60.6%)	
Black, n (%)	47 (2.5%)	5 (2.0%)	4 (2.4%)	38 (2.5%)	
Asian, n (%)	139 (7.3%)	11 (4.4%)	4 (2.4%)	124 (8.3%)	
Other (multiethnic, multiracial, etc), n (%)	110 (5.8%)	16 (6.3%)	9 (5.5%)	85 (5.7%)	
Missing, n (%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Patient health insurance					<0.001
Public, n (%)	1,287 (67.5%)	225 (89.3%)	157 (95.7%)	905 (60.7%)	
Private, n (%)	597 (31.3%)	26 (10.3%)	6 (3.7%)	565 (37.9%)	
Military, n (%)	20 (1.0%)	0 (0.0%)	0 (0.0%)	20 (1.3%)	
Self-pay, n (%)	4 (0.2%)	1 (0.4%)	1 (0.6%)	2 (0.1%)	
Language spoken at home					<0.001
English, n (%)	1,380 (72.3%)	150 (59.3%)	95 (57.9%)	1,135 (76.1%)	
Spanish, n (%)	451 (23.6%)	94 (37.3%)	64 (39.0%)	293 (19.6%)	
Vietnamese, n (%)	25 (1.3%)	4 (1.6%)	2 (1.2%)	19 (1.3%)	
Other, n (%)	52 (2.7%)	4 (1.6%)	3 (1.8%)	45 (3.0%)	
Household income					<0.001
<$20,000, n (%)	325 (17.0%)	80 (31.7%)	58 (35.4%)	187 (12.5%)	
$20,000 – $39,999, n (%)	427 (22.4%)	73 (29.0%)	57 (34.8%)	297 (19.9%)	
$40,000 – $59,999, n (%)	253 (13.3%)	38 (15.1%)	20 (12.2%)	195 (13.1%)	
$60,000 – $79,999, n (%)	131 (6.9%)	14 (5.5%)	2 (1.2%)	115 (7.7%)	
$80,000 – $99,999, n (%)	77 (4.0%)	4 (1.6%)	3 (1.8%)	70 (4.7%)	
≥$100,000, n (%)	357 (18.7%)	7 (2.8%)	1 (0.6%)	349 (23.4%)	
Missing or prefer not to answer, n (%)	338 (17.7%)	36 (14.3%)	23 (14.0%)	279 (18.7%)	
Respondent's highest education level					<0.001
Less than high school, n (%)	68 (3.6%)	16 (6.3%)	7 (4.3%)	45 (3.0%)	
Some high school, n (%)	162 (8.5%)	42 (16.7%)	31 (18.9%)	89 (6.0%)	
High school diploma or GED, n (%)	499 (26.3%)	71 (28.2%)	54 (32.9%)	374 (25.1%)	
Some college, n (%)	594 (31.1%)	77 (30.5%)	48 (29.3%)	469 (31.4%)	
College degree, n (%)	542 (28.4%)	37 (14.7%)	21 (12.8%)	484 (32.4%)	
Missing or prefer not to answer, n (%)	43 (2.3%)	9 (3.6%)	3 (1.8%)	31 (2.1%)	
Number of times moved during past 12 months					<0.001
0, n (%)	1,294 (67.8%)	141 (56%)	88 (53.6%)	1,065 (71.4%)	
1, n (%)	274 (14.4%)	55 (21.8%)	39 (23.8%)	180 (12.1%)	

(*Continued on next page*)

Table 1. Continued.

Characteristics	Total population (N = 1,908)	Baseline status (N = 1,908)			*P*-value
		Food or housing insecure (n = 252)	Both food and housing insecure (n = 164)	Both food and housing secure (n = 1,492)	
2, n (%)	50 (2.6%)	20 (7.9%)	11 (6.7%)	19 (1.3%)	
≥3, n (%)	20 (1.0%)	7 (2.8%)	8 (4.9%)	5 (0.3%)	
Missing or prefer not to answer, n (%)	270 (14.2%)	29 (11.5%)	18 (11.0%)	223 (14.9%)	
Respondent's perception of neighborhood safety: "Do you feel safe in your neighborhood?"					<0.001
Always, n (%)	1,391 (72.9%)	150 (59.5%)	69 (42.1%)	1,172 (78.6%)	
Usually, n (%)	377 (19.8%)	68 (27.0%)	53 (32.3%)	256 (17.2%)	
Sometimes, n (%)	85 (4.5%)	24 (9.5%)	32 (19.5%)	29 (1.9%)	
Never, n (%)	22 (1.2%)	3 (1.2%)	5 (3.0%)	14 (0.9%)	
Missing, n (%)	33 (1.7%)	7 (2.8%)	5 (3.0%)	21 (1.4%)	
Respondent's concern for patient's safety in neighborhood: "Are you concerned about your child's safety in your neighborhood?"					<0.001
Always, n (%)	81 (4.2%)	16 (6.3%)	9 (5.5%)	56 (3.7%)	
Usually, n (%)	49 (2.6%)	9 (3.6%)	8 (4.9%)	32 (2.1%)	
Sometimes, n (%)	273 (14.3%)	57 (22.6%)	57 (34.8%)	159 (10.7%)	
Never, n (%)	1,453 (76.2%)	157 (62.3%)	82 (50.0%)	1,214 (81.4%)	
Missing, n (%)	52 (2.7%)	13 (5.2%)	8 (4.9%)	31 (2.1%)	
Respondent's perception of patient health					<0.001
Excellent, n (%)	674 (35.3%)	60 (23.8%)	34 (20.7%)	580 (38.9%)	
Very good, n (%)	654 (34.3%)	97 (38.5%)	50 (30.5%)	507 (34.0%)	
Good, n (%)	442 (23.2%)	68 (27.0%)	55 (33.5%)	319 (21.4%)	
Fair, n (%)	110 (5.8%)	24 (9.5%)	22 (13.4%)	64 (4.3%)	
Poor, n (%)	22 (1.2%)	2 (0.8%)	3 (1.8%)	17 (1.1%)	
Missing, n (%)	6 (0.3%)	1 (0.4%)	0 (0.0%)	5 (0.3%)	
Respondent's perception of own health					<0.001
Excellent, n (%)	479 (25.1%)	41 (16.3%)	26 (15.9%)	412 (27.6%)	
Very good, n (%)	676 (35.4%)	79 (31.3%)	32 (19.5%)	565 (37.9%)	
Good, n (%)	594 (31.1%)	91 (36.1%)	64 (39.0%)	439 (29.4%)	
Fair, n (%)	148 (7.8%)	39 (15.5%)	37 (22.6%)	72 (4.8%)	
Poor, n (%)	10 (0.5%)	2 (0.8%)	5 (3.0%)	3 (0.2%)	
Missing, n (%)	1 (0.1%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	
Clinical					
Emergency severity index					0.05*
Level 5, n (%)	33 (1.7%)	0 (0.0%)	5 (3.0%)	28 (1.9%)	
Level 4, n (%)	351 (18.4%)	50 (19.8%)	34 (20.7%)	267 (17.9%)	
Level 3, n (%)	1,243 (65.1%)	172 (68.3%)	109 (66.5%)	962 (64.5%)	

(*Continued on next page*)

Table 1. Continued.

Characteristics	Total population (N = 1,908)	Baseline status (N = 1,908)			*P*-value
		Food or housing insecure (n = 252)	Both food and housing insecure (n = 164)	Both food and housing secure (n = 1,492)	
Level 2, n (%)	281 (14.7%)	30 (11.9%)	16 (9.8%)	235 (15.8%)	
ED disposition					0.27
Discharged, n (%)	1,544 (80.9%)	206 (81.7%)	138 (84.1%)	1,200 (80.4%)	
Admitted, n (%)	354 (18.6%)	43 (17.1%)	24 (14.6%)	287 (19.2%)	
Transferred, n (%)	9 (0.5%)	3 (1.1%)	2 (1.2%)	4 (0.3%)	
Left against medical advice, n (%)	1 (0.1%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	
ED length of stay, mean hours (SD)	4.52 (3.19)	4.92 (2.80)	4.82 (2.87)	4.85 (3.45)	0.95
Number of ED visits during past 12 months					<0.001
0, n (%)	1,304 (68.3%)	160 (63.5%)	94 (57.3%)	1,050 (70.4%)	
1, n (%)	374 (19.6%)	49 (19.4%)	49 (29.9%)	276 (18.5%)	
2 or more, n (%)	230 (12.1%)	43 (17.1%)	21 (12.8%)	166 (11.1%)	
A doctor has stated that patient has (check all that apply):	1,479 (77.5%)	171 (67.9%)	103 (62.8%)	1,205 (80.7%)	
None of those listed					
Asthma, n (%)	224 (11.7%)	39 (15.5%)	19 (11.6%)	166 (11.1%)	0.05*
Missing, n (%)	31 (1.6%)	17 (6.7%)	14 (8.5%)	0 (0.0%)	
Obesity, n (%)	61 (3.2%)	9 (3.6%)	12 (7.3%)	40 (2.7%)	0.003
Missing, n (%)	34 (1.8%)	20 (7.9%)	14 (8.5%)	0 (0.0%)	
Diabetes, n (%)	25 (1.3%)	4 (1.6%)	2 (1.2%)	19 (1.3%)	0.93
Missing, n (%)	34 (1.8%)	20 (7.9%)	14 (8.5%)	0 (0.0%)	
Anxiety, n (%)	94 (4.9%)	13 (5.2%)	18 (11.0%)	63 (4.2%)	<0.001
Missing, n (%)	35 (1.8%)	21 (8.3%)	14 (8.5%)	0 (0.0%)	
Emotional challenges, n (%)	87 (4.6%)	14 (5.6%)	17 (10.4%)	56 (3.8%)	<0.001
Missing, n (%)	35 (1.8%)	21 (4.4%)	14 (8.5%)	0 (0.0%)	
Behavioral difficulties, n (%)	50 (2.6%)	11 (4.4%)	9 (5.5%)	30 (2.0%)	0.002*
Missing, n (%)	36 (1.9%)	21 (8.3%)	15 (9.1%)	0 (0.0%)	

**Note:* Despite this significant *P*-value, none of the *z*'s were ≥2.58; Type 1 error possible.
ED, emergency department; *GED*, General Educational Development.

difference in ED disposition or length of stay among caregivers reporting food and/or housing insecurity compared to those who were food and housing secure.

Moves in the preceding year

Baseline survey results indicated that 20 caregivers (1.0% of the sample) reported moving three or more times in the previous 12 months. Of those, none screened positive for solely food insecurity, 35% screened positive for solely housing insecurity, 40% screened positive for both food and housing insecurity, and 25% did not screen positive for food or housing insecurity.

Follow-up

Of the 416 families screening positive for food or housing insecurity, contact was successfully made with 147 (35.3%) caregivers at three weeks, and of those, 70 (47.6%) responded to surveys at six weeks post-ED visit.

Food/housing insecurity status

Of the 147 caregivers who participated in follow-up, 25 were solely food insecure at the index ED visit. Of those, seven (28%) continued to report food insecurity at the time of follow-up, two (8%) reported solely housing instability without food insecurity, three (12%) reported both food and

housing insecurity, and 12 (48%) no longer screened positive for either food or housing insecurity. Of the 60 caregivers who screened positive for solely housing insecurity at the index ED visit and participated in follow-up, 19 (31.7%) continued to report housing insecurity at the time of follow-up, three (5%) reported new food insecurity only, 11 (18.3%) reported both food and housing insecurity, and 26 (43%) no longer screened positive for either food or housing insecurity.

Of the 62 caregivers who screened positive for both food and housing insecurity at the index ED visit and participated in follow-up, 31 (50%) continued to report both food and housing insecurity, 15 (24.2%) reported food insecurity only, 10 (16.1%) reported housing insecurity only, and six (9.7%) no longer screened positive for food or housing insecurity. Follow-up status was unknown due to missing data for two families. (One reported food insecurity, and the other reported housing instability at the index ED visit.)

Transitions from positive food and/or housing insecurity screening to negative screening

Of the 147 caregivers who reported food and/or housing insecurity at the index ED visit and participated in follow-up, 44 (29.9%) no longer screened positive for either food or housing insecurity at follow-up. Families of those initially screening positive who subsequently did not screen positive appeared generally similar with respect to demographics, neighborhood safety, health status/healthcare utilization, and ED visit characteristics (Table 2). Younger patient age was associated with a transition from a positive to negative screen ($P = 0.02$). Table 2 includes comparisons of all collected variables for these two groups. Given the relatively low number of families that followed up and reported resource use, it was not possible to determine whether there was any association between referral use and transition from positive to negative screens.

Reported barriers to resource use

Of the 147 caregivers who participated in follow-up, only 15 (10.2%) reported using at least one of the resource referrals. The most frequently reported barrier for those reporting a barrier to resource use was losing or not receiving the referral (41.7%). Other common reasons included not having time (15.2%) and resources not fitting their needs (10.6%). The Figure demonstrates caregiver-reported barriers to referral use.

Demographics of those with and without follow-up

Patients whose caregivers participated in follow-up had largely similar demographics to those who did not, except for language spoken at home. Spanish-speaking caregivers were less well represented among those with follow-up ($z = -3.06$, $P < 0.001$). Supplementary Table 1 demonstrates demographics, neighborhood safety, health status, healthcare utilization, and ED visit characteristics of those with and without follow-up.

DISCUSSION

This study demonstrated high levels of social need in patients presenting to a pediatric ED. Over one in five patients screened positive for food and/or housing insecurity. The reported rate of food insecurity found in this study does appear somewhat lower than the national average as well as compared to previous studies investigating food insecurity in the pediatric ED, although overall numbers vary widely based on data source.[1,22,23,25,27] We did find higher food insecurity rates than that of the surrounding county in the study year.[28] Still, our study design was limited by convenience sampling and a 2.8% response rate of participants in the ED, limiting the generalizability of our findings. Other pediatric ED-based studies demonstrate similar challenges, with low response rate (3.6%)[29] and health-related social need-positive screening rate (16%).[30] It is important to note that even if families screen positive for social risk, a substantial proportion may still decline assistance.[31] Similarly, social needs navigation follow-up has been shown to be challenging in the ED setting, with low participation rate (7%)[32] and persistence of social need (56%) despite participation in navigation services.[19]

In our study, follow-up survey data revealed an overall reduction in the reported rates of food and housing insecurity, yet community resource referral uptake was low. This likely reflects the complexity and burden of patient social circumstances and a multitude of environmental factors. Among those who were food insecure at baseline, almost half no longer screened positive for food or housing insecurity, and among those who were housing unstable at baseline, over 40% no longer screened positive for food or housing insecurity. Those with food and housing insecurity at baseline demonstrated the least reduction in social need, with just under 10% no longer screening positive for either food or housing insecurity at follow-up. However, despite these apparent positive shifts, it is difficult to ascertain whether these developments were associated with ED interventions. Indeed, it seems unlikely given that the majority of caregivers with whom we followed up did not endorse resource use.

It is beyond the scope of this study to discern the etiology of this trend. It is possible that caregivers under-reported resource use, that completion of the survey itself may have precipitated a change, random chance, or a range of other explanations including an interplay of social determinants of health. Interestingly, Kanak et al demonstrated somewhat similar findings using an intervention available on tablet and personal smartphone (the HelpSteps app), reporting that only 23% of caregivers described using the tool.[19] Only 14% contacted at least one referral agency, yet 44% reported their primary need either completely or somewhat resolved.[19] As

Table 2. Follow-up survey: demographics and clinical characteristics as stratified by food/housing insecurity status.

Characteristics	Follow-up status*		
	Both food and housing secure (n = 44)	Food and/or housing insecure (n = 101)	*P*-value
Demographic			
Patient age, mean years (SD)	5.87 (5.14)	8.22 (5.37)	0.02
Patient male sex, n (%)	27 (61.4%)	48 (47.5%)	0.15
Patient ethnicity and race			0.68
Hispanic, n (%)	30 (68.2%)	80 (79.2%)	
Non-Hispanic White, n (%)	8 (18.2%)	11 (10.9%)	
Black, n (%)	1 (2.3%)	2 (2.0%)	
Asian, n (%)	3 (6.8%)	4 (4.0%)	
Other, n (%)	2 (4.6%)	4 (4.0%)	
Patient health insurance			0.02**
Public, n (%)	37 (84.1%)	97 (96.0%)	
Private, n (%)	7 (15.9%)	4 (4.0%)	
Language spoken at home			0.72
English, n (%)	31 (70.5%)	77 (76.2%)	
Spanish, n (%)	11 (25.0%)	21 (20.8%)	
Other, n (%)	2 (4.6%)	3 (3.0%)	
Household income			0.01**
<$20,000, n (%)	12 (27.3%)	36 (35.6%)	
$20,000 – $39,999, n (%)	13 (29.6%)	40 (39.6%)	
$40,000 – $59,999, n (%)	7 (15.9%)	12 (11.9%)	
$60,000 – $79,999, n (%)	6 (13.6%)	4 (4.0%)	
$80,000 – $99,999, n (%)	2 (4.6%)	0 (0%)	
≥$100,000, n (%)	2 (4.6%)	0 (0%)	
Missing, n (%)	2 (4.6%)	9 (8.9%)	
Respondent's highest education level			0.47
Less than high school, n (%)	2 (4.6%)	6 (5.9%)	
Some high school, n (%)	7 (15.9%)	17 (16.8%)	
High school diploma or GED, n (%)	10 (22.7%)	32 (31.7%)	
Some college, n (%)	14 (31.8%)	33 (32.7%)	
College degree, n (%)	11 (25.0%)	12 (11.9%)	
Missing, n (%)	0 (0%)	1 (1.0%)	
Number of times moved during past 12 months			0.76
0, n (%)	26 (59.1%)	59 (58.4%)	
1, n (%)	11 (25.0%)	25 (24.8%)	
2, n (%)	2 (4.6%)	5 (5.0%)	
≥3, n (%)	1 (2.3%)	7 (6.9%)	
Missing, n (%)	4 (9.1%)	5 (5.0%)	
Respondent's perception of neighborhood safety, n (%)			0.79
Always	26 (59.1%)	55 (54.5%)	
Usually	12 (27.3%)	34 (33.7%)	
Sometimes	3 (6.8%)	9 (8.9%)	

(*Continued on next page*)

Table 2. Continued.

Characteristics	Follow-up status*		*P*-value
	Both food and housing secure (n = 44)	Food and/or housing insecure (n = 101)	
Never	0 (0.0%)	1 (1.0%)	
Missing, n (%)	3 (6.8%)	2 (2.0%)	
Respondent's concern for patient's safety in neighborhood, n (%)			0.47
Always	3 (6.8%)	6 (5.9%)	
Usually	3 (6.8%)	5 (5.0%)	
Sometimes	8 (18.2%)	31 (30.7%)	
Never	27 (61.4%)	52 (51.5%)	
Missing, n (%)	3 (6.8%)	7 (6.9%)	
Respondent's perception of patient health, mean (SD)			0.34
Excellent	8 (18.2%)	23 (22.8%)	
Very good	18 (40.9%)	39 (38.6%)	
Fair	11 (25%)	32 (31.7%)	
Poor	7 (15.9%)	7 (6.9%)	
Missing, n (%)	0 (0.0%)	0 (0.0%)	
	0 (0.0%)	0 (0.0%)	
Respondent's perception of own health, mean (SD)			0.76
Excellent, n (%)	6 (13.6%)	13 (12.9%)	
Very good, n (%)	13 (29.5%)	31 (30.7%)	
Good, n (%)	19 (43.2%)	41 (40.6%)	
Fair, n (%)	6 (13.6%)	12 (11.9%)	
Poor, n (%)	0 (0.0%)	4 (4.0%)	
Missing, n (%)	0 (0.0%)	0 (0.0%)	
Clinical			
Emergency severity index			0.76
Level 5, n (%)	1 (2.3%)	1 (1.0%)	
Level 4, n (%)	5 (11.4%)	18 (17.8%)	
Level 3, n (%)	32 (72.7%)	70 (69.3%)	
Level 2, n (%)	6 (13.6%)	12 (11.9%)	
ED disposition			1.00
Discharged, n (%)	37 (84.1%)	84 (83.2%)	
Admitted, n (%)	6 (13.6%)	15 (14.9%)	
Transferred, n (%)	1 (2.3%)	2 (2.0%)	
ED length of stay, mean hours (SD)	5.50 (3.57)	4.58 (2.33)	0.13
Number of ED visits during past 12 months, n (%)			<0.001**
0, n (%)	25 (56.8%)	60 (59.4%)	
1, n (%)	3 (6.8%)	28 (2.8%)	
2 or more, n (%)	16 (36.4%)	13 (12.9%)	
A doctor has stated that patient has: none of those listed, n (%)	29 (65.9%)	69 (68.3%)	0.99
Asthma, n (%)	9 (20.5%)	12 (11.9%)	0.20
Obesity, n (%)	3 (6.8%)	7 (6.9%)	1.00

(*Continued on next page*)

Table 2. Continued.

Characteristics	Follow-up status*		*P*-value
	Both food and housing secure (n = 44)	Food and/or housing insecure (n = 101)	
Diabetes, n (%)	1 (2.3%)	0 (0%)	0.30
Anxiety, n (%)	4 (9.1%)	11 (10.9%)	1.00
Emotional challenges, n (%)	3 (6.8%)	13 (12.9%)	0.39
Behavioral difficulties, n (%)	3 (6.8%)	7 (6.9%)	1.00

*Follow-up status unknown due to missing data for two families (one food insecure and one housing insecure at baseline).
**Despite this significant *P*-value, none of the *z*'s were ≥2.58; Type 1 error possible.
ED, emergency department; *GED*, General Educational Development.

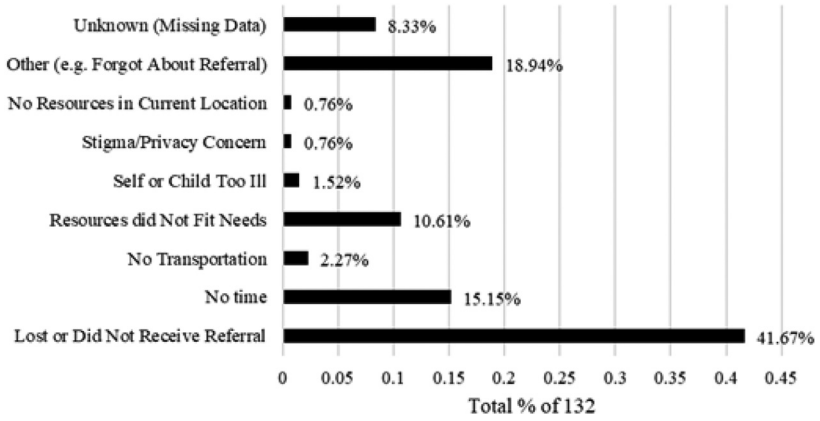

Figure. Reported barriers to referral use.

in the current study, Kanak et al found housing needs to be more persistent than food insecurity as well.[19] Liberman et al also examined social needs interventions in the pediatric ED with trained navigators and noted much greater use of resources (45.6% of those who followed up reported contacting at least one resource); however, it was difficult to determine whether these were housing- and food-related resources as these represented only 21% and 20%, respectively, of referral resources provided.[21]

In the current study, the most common barrier to resource use reported by caregivers was that they either lost or did not receive the referral. While this initially appears somewhat discouraging it also may potentially prove the simplest obstacle to address in future work. It may be helpful to provide electronic forms of resources in addition to written copies, as suggested by caregivers in other pediatric ED-based studies.[21,29] It is remarkable that among caregivers in a study by Cullen et al who screened positive for food insecurity and opted to receive a direct phone call from a food resource agency, only 35.9% were able to be reached, and of those, 31% were no longer interested in food-resource referrals.[23] It is possible that future research may also elicit appropriate methods of needs reassessment and timing for such reassessment. Increased engagement and collaboration with the community, both with those in need and with those providing resources (ie, food banks), may pave the way for improved screening design and resource information deployment, as well as more successful and increased use of interventions.

The current study reinforces associations demonstrated throughout the literature between food/housing insecurity and caregiver/patient physical and mental health.[1,4–12] This serves to underscore the importance of attempting to address food and housing insecurity at every opportunity. The association of neighborhood safety and food and housing insecurity, while not unexpected, likely additionally compounds the chronic illnesses such as anxiety, obesity, and asthma also found in the current study to be associated with food and housing insecurity. Notable demographic associations with food and/or housing insecurity included older age; age also appeared to be associated with the transition from positive to negative screens for food and/or housing. Gonzalez et al also found increasing age and public health insurance to be associated with food insecurity; however, unlike in the current study they did not find associations between food insecurity and chronic health conditions.[25]

The association of age and social need is likely multifactorial and may include variables such as reduced

resources available for families with older children, and increased monetary requirements of older children possibly represent more deeply entrenched social need. Interestingly, despite previous literature demonstrating an association between food insecurity and increased healthcare utilization such as ED visits, the current study found somewhat equivocal data.[15,17] One ED visit within the past year was more likely to be associated with food and housing insecurity; however, two or more was not. Additionally, the transition from positive to negative screens was also associated with a slightly increased mean number of ED visits within the prior year. It is difficult to hypothesize what may be driving these seemingly discordant results; however, it is possible that it is the unequal interplay of multiple variables; for example, younger children who are also more likely to transition from positive to negative screens are more likely to visit the ED overall.

LIMITATIONS

There were several limitations inherent to the design of this study, including the use of convenience sampling with data collectors present only during the day and early evening. This sampling technique may not have captured those with particularly challenging social circumstances, underestimating the true rates of food and housing insecurity, while increasing the likelihood of sample bias and presence of confounding factors. Additionally, this study relied upon self-report for identification of food/housing insecurity as well as resource use; therefore, reporting bias may have impacted our results. Although we attempted to design the study in such a way to reduce potential discomfort as much as possible, financial means and social need in general remain sensitive topics, and concerns regarding privacy and stigma may have contributed further to reporter bias. This is especially pertinent as follow-up surveys were conducted over the phone while initial surveys were completed on electronic tablets, possibly contributing to fluctuations in the reporting of food and/or housing insecurity.

Families were contacted by study research personnel, and this mechanism may be less effective than established closed-loop referral mechanisms in which the community-based social service itself is linked directly with the healthcare institution. The follow-up period of three to six weeks may also be somewhat limited, and it is possible that resource use, especially for more complex needs such as housing, may not effect change within this short period. It is also worth considering, for example, that while food banks are essential social resources to address hunger, they are a temporary solution, and do not increase the ability of a caregiver to purchase adequate food. Difficulties in contacting families for follow-up also presented a significant limitation and restricted our ability to evaluate study interventions. During the study period, researchers at the same institution were also conducting a study examining adverse childhood experiences; as part of this concurrent study, social workers may have been consulted for some of these families, potentially altering resource referral distribution for those families. Lastly, because this study took place during the COVID-19 pandemic the resultant increased social needs and rapidly changing economic landscape likely affected our results, possibly reducing the generalizability of this work.

CONCLUSION

This study suggests that screening and intervention among two common social determinants of health— food and housing insecurity—may be feasible in a pediatric ED setting. At the same time, it illustrates that achieving widespread participation among families may be a significant challenge. Although a significant proportion of caregivers reported a change in food and housing insecurity on follow-up, it is difficult to ascertain what may have contributed to this finding, especially given the limited response rate and reported resource use. Further social needs-intervention research in the pediatric ED setting should be designed to capture larger response rates (including an assessment of social need disclosure in day and overnight periods), while assessing the performance of closed-loop referral and follow-up mechanisms for those families who indicate a desire for assistance.

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Gender Disparities and Burnout Among Emergency Physicians: A Systematic Review by the World Academic Council of Emergency Medicine–Female Leadership Academy for Medical Excellence

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Background: The Female Leadership Academy for Medical Excellence, members of the World Academic Council of Emergency Medicine, conducted this systematic review, which explores gender disparities in burnout among emergency physicians (EP) using the Maslach Burnout Inventory-Human Services Survey (MBI-HSS). Burnout is a critical issue in healthcare, particularly in emergency medicine where high stress and demanding work environments prevail.

Methods: Following PRISMA guidelines, we searched PubMed and Epistemonikos for studies using MBI-HSS to measure burnout in EPs. Inclusion criteria encompassed peer-reviewed, English-language articles reporting burnout by sex. Data extraction focused on proportions of burnout and its subcomponents, mean scores, and odds ratios, with quality assessed using Joanna Briggs Institute criteria.

Results: We included 18 studies spanning 26,939 EPs from 10 countries. While overall burnout rates did not significantly differ between the sexes, the proportion of female EPs with high emotional exhaustion (EE) (69%) and low sense of personal accomplishment (PA) (45%) were significantly higher compared to males with high EE in 57% and low PA in 29%, respectively ($P < 0.001$ for both). Proportion with high depersonalization (DP) score was 44% in both male and female EPs. Mean scores revealed females experiencing higher mean EE (26.8 ± 15.7) scores vs males (25.4 ± 15.9) $P < 0.001$. Males had mean DP scores (8.6 ± 8.0) and mean PA scores (26.6 ± 12.7) compared to females with lower mean DP scores (7.4 ± 7.2) and higher PA scores (27.7 ± 11.9), respectively $P < 0.001$ for both. Odds ratios indicated varying risks, predominantly higher EE odds among females, varying from 0.72 to 2.3.

Conclusion: This review underscores gender-specific manifestations of burnout among emergency physicians, with females more susceptible to emotional exhaustion and lower sense of personal accomplishment. Standardized reporting methods are crucial for future meta-analyses to refine gender-specific interventions combating burnout in emergency medicine. Targeted strategies addressing distinct manifestations of burnout are imperative to support the well-being and retention of EPs, fostering sustainable healthcare delivery. [West J Emerg Med. 2025;26(2)338–346.]

INTRODUCTION

The term "burnout," introduced by Freudenberger in 1974, refers to job-related dissatisfaction primarily caused by work-related stress.[1] The most widely validated tool for measuring burnout among physicians is the Maslach Burnout Inventory-Human Services Survey (MBI-HSS) 22-item tool.[2] The MBI-HSS measures burnout in three subcomponents: emotional exhaustion (EE); depersonalization (DP); and personal accomplishment (PA).[2] Burnout is suggested by a high score in EE and DP, and a low score on PA.[2]

There is a palpable gender gap in academic emergency medicine (EM) where female emergency physicians (EP) are less likely to hold major leadership positions, more likely to spend a greater percentage of time in clinical and teaching activities, publish less in peer-reviewed journals, and are less likely to achieve senior academic ranks in their medical schools.[3] Even after adjusting for factors such as race, region, rank, years of experience, clinical hours, core faculty status, administrative roles, board certification, and fellowship training, the mean (±SD) salary of women was found to be $19,418 (±$3,736) less than that of men ($P < 0.001$).[4] This gender disparity can negatively impact the retention of female EPs and predispose them to higher burnout.

Although there are systematic reviews that have described burnout among EPs, none have focused on the gender gap in burnout among EPs.[5–7] Therefore, the Female Leadership Academy for Medical Excellence (FLAME) members of the World Academic Council of Emergency Medicine performed a systematic review to describe the gender disparity in burnout among EPs at a global level. To the best of our knowledge, this is the first systematic review focusing on gender disparity in burnout among EPs as measured by the validated MBI tool.

METHODS

We performed a systematic review following the PRISMA methods[8] using the protocol published in PROSPERO (CRD42024558794).

Search Strategy

We searched two open access databases, PubMed and Epistemonikos on June 30, 2024, for peer -reviewed articles on burnout and emergency physicians. We operationalized different permutations of each keyword as follows:

Burnout: "Maslach burnout inventory" OR MBI OR burnout OR burn-out OR "burned out" OR depersonalization OR "emotional exhaustion" OR "compassion fatigue"

Emergency Physician: "emergency physician*" OR "emergency doctor*" OR "EM physician*" OR "EM doctor*" OR "emergency resident*" OR "EM resident*" OR "emergency consultant*" OR "EM consultant*" OR "emergency faculty*" OR "EM faculty*" OR "emergency professor*" OR "EM professor*" OR "emergency attending*" OR "EM attending*"

We applied the field "All fields" for searching on PubMed and "Title and Abstracts" for searching the same combination of keywords in Epistemonikos.

Screening and Eligibility

We applied a series of inclusion and exclusion criteria. Articles were included if they were 1) written in English, 2) published in a peer-reviewed journal, 3) original articles, and 4) applied any version of the MBI-HSS to measure burnout. They were excluded if they 1) did not describe the results separately by sex, 2) did not include EPs in their study, or 3) were a systematic review.

Extraction and Analysis

Extraction was performed by two investigators independently. The following information was extracted: study characteristics (first author, year of publication, country, number of participants that responded); characteristics of participants (mean age, proportion of males and females); and outcome data (proportion of high burnout in males and females, proportion of males and females with high EE, high DP and low PA, mean scores in males and females for EE, DP or PA and odds of burnout or its subcomponents—EE, EP, or PA—in female EPs.

Study Quality

We used the Joanna Briggs Institute's critical appraisal checklist for evaluation of the quality of the prevalence studies.[9] The tool assessed quality using nine questions. A score of 1 was assigned for a "Yes" as an answer, and a score of 0 was assigned for an answer that was "No," "Unclear," or "Not Applicable." The scores were graded as low, moderate or high if the total score was ≤ 4, 5–7, and ≥ 8, respectively. The quality assessment was performed independently by two investigators, and any disagreement was settled by discussion.

RESULTS

Literature Search

Our initial search resulted in 331 articles in PubMed and 13 in Epistemonikos, which were imported into EndNote reference management software (Clarivate Analytics, Philadelphia, PA). Of these 344 articles, nine were found to be duplicates, leaving a total of 335 articles for the screening and eligibility stages (Figure). Of the 335 articles screened, we excluded 226 that did not meet the inclusion criteria, leaving us with 109 articles for retrieval. We reviewed these 109 full texts for eligibility, resulting in the exclusion of the following:

- 3 articles that were systematic reviews
- 7 articles that were not peer-reviewed original articles

- 5 articles that did not include emergency physicians
- 41 articles that did not use the Maslach Burnout Inventory for measuring burnout
- 35 articles that did not report their data by sex,

This left a total of 18 articles for the final review. The process of screening and selecting studies is shown in the PRISMA flow diagram (Figure).

STUDY CHARACTERISTICS

We included 18 studies from 10 different countries in the final analysis (Table 1). The total number of EPs studied in these 18 studies was 26,939, including 8,864 (33%) female EPs, resulting in a male-to-female ratio of 2:1. Fifteen of these studies used the 22-item MBI-HSS tool for measuring burnout, while two studies used the two-item tool based on the MBI-HSS, and one included the nine-item MBI tool (Table 1). All were multicentric studies except for one, which was a single-center study. Included were EPs of both sexes in all studies except for one, which included only female EPs. All included studies were conducted in the last 10 years (2014 to present), except for one study conducted in 1996. Six studies were scored as high quality, while the remaining 12 were moderate quality studies. The response rates varied from 30–94.1%.

OUTCOME ANALYSIS

Burnout calculated by Maslach Burnout Inventory

Seven studies reported the burnout proportions separately in male and female EPs (Table 2). The studies that included the 22-item MBI-HSS tool had a total of 1,181 male and 542 female EPs, with an average pooled proportion of high burnout at 58.7% and 58.3%, respectively ($P = 0.8$). Two studies used the two-item MBI, including a total of 4,868 male and 2,736 female EPs, with an average pooled proportion of high burnout at 27% and 34%, respectively ($P < 0.001$).

Subcomponents of MBI

Seven studies reported individual components of the MBI-HSS, specifically the proportion of participants with high

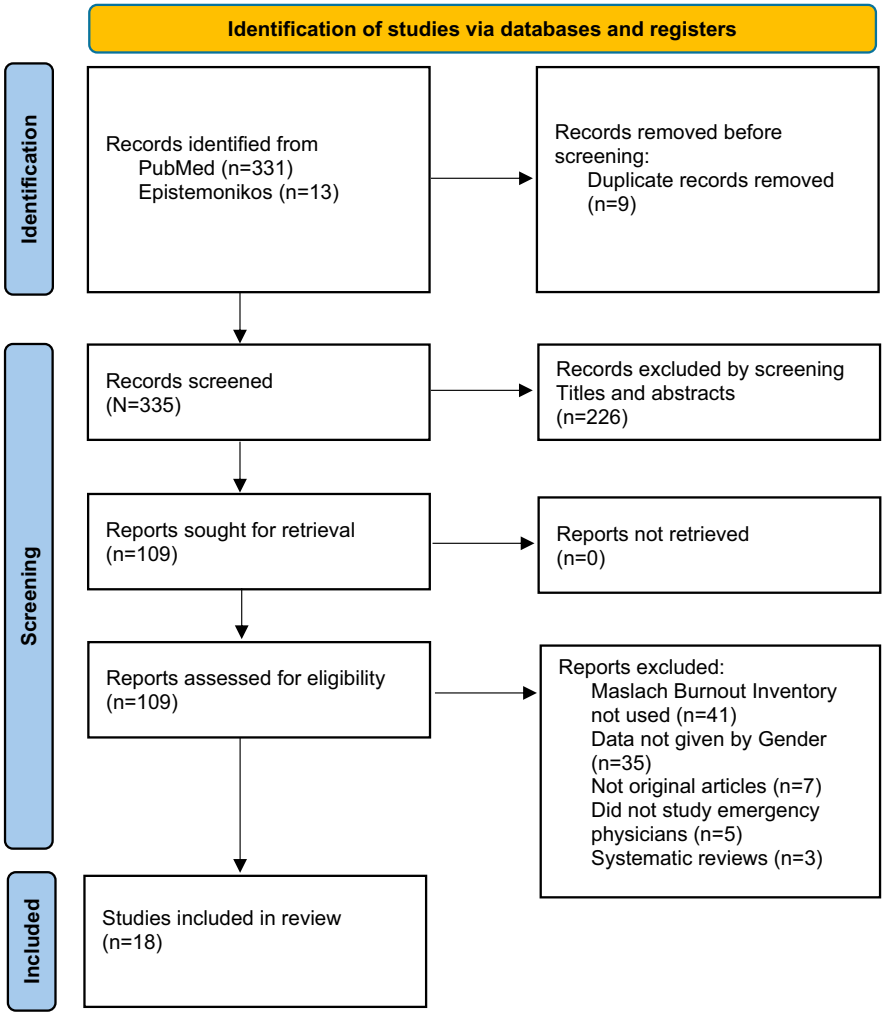

Figure. Prisma flow diagram.

Table 1. Characteristics of the included studies.

First author	Year	Country	Response	Quality	MBI tool	Total N=26,939	Males n=18,075 (67%)	Females n=8,864 (33%)
Batur A[18]	2023	Türkiye	NA	7	22 item	389	223	166
De Wit K[19]	2020	Canada	40%	7	2 item	467	240	227
Elhadi M[20]	2021	Libya	77%	7	9 item	154	82	72
Erdur B[21]	2015	Türkiye	85%	7	22 item	174	138	36
Feeks C[22]	2020	US	31%	7	22 item	139	49	90
Goldberg R[23]	1996	US	NA	7	22 item	1,272	945	327
Iyer S[24]	2022	Tanzania	77%	7	22 item	29	20	9
Jalili M[25]	2013	Iran	88%	8	22 item	164	150	14
Kimo TJ	2014	US	75%	9	22 item	218	129	89
Liu R[27]	2020	Canada	30%	7	22 item	65	38	27
Lovell LP[28]	2022	Barbados	63%	8	22 item	111	49	62
Lu DW[29]	2022	US	94.1%	7	2 item	7,466	4,768	2,698
Mercuri M[30]	2021	Canada	58%	8	22 item	416	214	202
Morikawa M[31]	2023	Japan	81.9%	9	22 item	267	214	53
Salmoirago BE[32]	2016	US	32.7%	7	2 item	138	100	38
Sarwar S[33]	2023	Pakistan	NA	6	22 item	150	66	84
Soltanifar A[34]	2018	Iran	71%	8	22 item	77	0	77
Yan S[35]	2021	China	NA	8	22 item	15,243	10,650	4,593

MBI, Maslach Burnout Inventory.

Table 2. Proportion of male and female emergency physicians with high levels of burnout.

Author	MBI	Males (n=1,181)	Burnout (%) n=695 (58.8%)	Females (n=542)	Burnout (%) n=317 (58.4%)	*P*-value (Fisher exact)
22-item MBI tool						
Feeks C[22]	22 item	49	6 (13%)	90	35 (39%)	0.8
Goldberg R[23]	22 item	945	567 (60%)	327	203 (62%)	
Iyer[24]	22 item	20	13 (65%)	9	6 (69%)	
Kimo TJ	22 item	129	88 (68%)	89	54 (61%)	
Liu R[27]	22 item	38	21 (55%)	27	19 (69%)	
2-item MBI tool						
		(n=4,868)	n=1,502 (31.4%)	(n=2,736)	n=903 (33%)	
Lu DW[29]	2 item	4,768	1,478 (31%)	2,698	890 (33%)	0.05
Salmoirago BE[32]	2 item	100	24 (24%)	38	13 (35%)	

MBI, Maslach Burnout Inventory.

EE, high DP, and low PA separately for male and female EPs (Tables 3 and 4). Four of these studies reported the proportion of participants with subcomponents suggestive of burnout (Table 3), and three of these studies reported the mean and standard deviations of the MBI subcomponents (Table 4). Female EPs had proportionately higher EE and lower PA than male EPs ($P < 0.001$). The DP levels were similar among male and female EPs (Table 3). The combined mean EE score was higher in female EPs ($P < 0.001$), while the combined PA score was higher and the DP score was lower in female EPs compared to male EPs ($P < 0.001$) (Table 4). Four studies presented their results in the form of odds or relative risk (Table 5), and three of these showed higher odds among females of burnout while one had lower odds. Three of these studies reported only one subcomponent of MBI-HSS (ie, EE) (Table 5).

Table 3. Proportion of participants with high levels of emotional exhaustion, high depersonalization, and low sense of personal accomplishment, the individual components of the Maslach Burnout Inventory, among male and female emergency physicians.

Author	Male (n=371)	High EE	Low PA	High DP	Female (n=399)	High EE	Low PA	High DP
Batur A[18]	223	135 (61%)	69 (31%)	-	166	119 (72%)	83 (50%)	-
Elhadi M[20]	82	51 (62%)	21 (25%)	39 (47%)	72	53 (74%)	13 (18%)	35 (49%)
Sarwar S[33]	66	26 (39%)	18 (27%)	27 (41%)	84	40 (48%)	22 (26%)	31 (37%)
Soltanifar A[34]	0	-	-	-	77	65 (85%)	62 (81%)	37 (48%)
Total	371	212 (57%)	108 (29%)	66 (44%)	399	277 (69%)	180 (45%)	103 (44%)
P-value (Fisher exact test)						<0.001	<0.001	0.77

EE, emotional exhaustion; *PA*, personal accomplishment; *DP*, depersonalization.

Table 4. Mean (standard deviation) values of subcomponents of the Maslach Burnout Inventory among male and female emergency physicians.

Author	Male (n=10,837)	High EE	Low PA	Low DP	Female (n=4,691)	High EE	Low PA	High DP
Lovell LP[28]	49	29.4 (11.7)	45.5 (8)	11.8 (5.7)	62	32.5 (12.1)	43.4 (6.8)	13 (6.7)
Yan S[35]	10,650	25.4 (16.1)	26.5 (12.8)	8.5 (8.1)	4,593	26.8 (15.7)	27.6 (11.9)	7.4 (7.2)
Erdur B[21]	138	24.6 (6.0)	29.9 (3.9)	10.7 (4.1)	36	24.1 (6.7)	30.0 (3.4)	11.0 (3.2)
Combined	10,837	25.4 (15.9)	26.6 (12.7)	8.6 (8.0)	4,691	26.8 (15.7)	27.7 (11.9)	7.4 (7.2)
Unpaired *t*-test *P*-value			<0.001	<0.001		<0.001		

EE, emotional exhaustion; *PA*, personal accomplishment; *DP*, depersonalization.

Table 5. Odds or relative risk of burnout or its subcomponents by gender among emergency physicians.

Authors	Males	Females	Reported parameter	Value
De Wit K[19]	240	227	Odds of burnout in males	0.54 (0.22–1.35)
Jalili M[25]	150	14	Relative risk emotional exhaustion in females	1.05
Mercuri M[30]	214	202	Odds of emotional exhaustion in females	2.32
Morikawa M[31]	214	53	Odds of emotional exhaustion in females	0.72 (0.28–1.79)

DISCUSSION

The stressful environment of EM is a known contributor to the negative impacts of burnout.[10] Burnout can be the result of good-intentioned physicians who strive for perfection at work.[10] Emergency physicians become frustrated when their work environment falls short of supporting well-meaning goals, leading to EP burnout.[10]

Moral injury is now recognized as a significant factor contributing to burnout among EPs. They often face challenging decisions such as prioritizing care in life-or-death situations, dealing with resource limitations, and frequently witnessing suffering and death. The emotional toll of moral injury can lead to symptoms of depression, anxiety and stress disorders, which are closely linked to burnout. Female EPs, in addition, face sex-based discrimination, bias, unequal treatment, and fewer opportunities for career advancement.[3] They are more burdened with balancing professional and family responsibilities. Females are expected to display more empathy and provide emotional support to patients and colleagues, which can increase emotional labor and moral injury if they are unable to meet these expectations.

The MBI assesses the severity of the three primary symptoms of burnout: exhaustion; depersonalization; and lack of personal accomplishment. Developed in the 1970s, it has become the gold standard for measuring burnout across various professions and industries. The MBI-HSS is specifically designed for use in human services professions such as social work, counseling, and healthcare.[2] A burnout survey of 7,288 US physicians from all specialties, using the MBI-HSS tool, showed that high burnout was reported by 38% of US physicians and that burnout is more common among physicians than other US workers.[11] Among all specialties, EM had the highest burnout rates, with over 60% of EPs reporting high burnout levels.[11] Emergency medicine is a frontline

specialty, and several factors contribute to high burnout in EPs, including night shifts, sleep disorders, job-related strain, fear of making mistakes, and workplace violence.[12]

In recent years, more female physicians have entered the workforce, leading to increased data availability for studying sex differences in burnout symptoms. In some cultures, female patients preferentially ask for female EPs to attend to them in the ED.[13] A recently conducted systematic review of US physicians found that women physicians have a higher likelihood of experiencing burnout compared to male physicians, particularly with respect to the EE dimension of burnout.[14] Studies focusing on EPs corroborate this finding, indicating that female EPs are at higher risk of burnout compared to male EPs. Additionally, females have higher attrition rates compared to their male counterparts.[3,4,15] Factors cited as contributing to the discrepancy in burnout include greater levels of work-family conflict, greater tendencies to emotionally invest in patients/work, and greater discrimination in salaries and promotions by female physicians.[14]

In contrast to the above studies, findings from a systematic review of 16,016 physicians from the Eastern Mediterranean region indicated no significant difference in burnout rates between male and female physicians.[16] However, none of the studies in Doraiswamy's systematic review were designed to compare differences by sex, limiting the interpretations of the findings.[15] Another systematic review that included 109,628 physicians concluded that inconsistencies in definitions and assessment methods for burnout across studies prevented a reliable determination of the association between burnout and the sex of the physician.[17]

These reviews highlight variability in findings across different regions and contexts, suggesting that the relationship between burnout and sex may vary depending on factors such as cultural norms, healthcare system characteristics, and study methodologies. Therefore, while some studies may indicate a gender disparity in burnout, others may not find such differences, emphasizing the need for nuanced interpretation and context-specific understanding of burnout in healthcare professions.

We conducted this systematic review to address inconsistent data on the gender gap in burnout among EPs. Rotenstein et al have highlighted in their review the inconsistencies in the definitions and assessment methods of burnout; therefore, we focused specifically on studies that used the MBI-HSS tool for assessing burnout.[17] Despite using a common assessment tool, the included studies employed various methods for reporting burnout scores. Of the 18 studies included in our review,[18–35] seven reported burnout as the percentage of participants with high burnout; four reported the percentage of participants with high individual components of burnout (EE, DP, PA) but not overall burnout; three reported the mean scores for EE, DP, and PA; and four reported odds ratios and relative risks for EE (Tables 2–5). This approach allowed us to comprehensively examine and compare the gender disparities in burnout among EPs across different studies.

We collated data from studies reporting burnout as a percentage of the population having high burnout and found that of 1,181 male EPs and 542 female EPs, high burnout was reported in 58.8% and 58.4%, respectively, which indicates nearly equal rates of burnout between male and female EPs[22–24,26,27] (Table 2). The two-item tool, known for its brevity and ease of administration, can effectively identify at-risk EM residents showing early signs of burnout.[36] This tool uses two questions from the MBI-HSS and enables consistent, widespread, and longitudinal monitoring of burnout among EM residents at local, regional, and national levels.[36] In our systematic review, we included two studies that used the two-item tool to measure burnout among 4,778 male and 1,502 female EPs. The reported burnout rates were 31% among male EPs and 33% among female EPs ($P = 0.05$).[29,32] This slight difference suggests a trend toward higher burnout among female EPs, as indicated by these specific studies using the abbreviated MBI tool.

Four additional studies included in our systematic review, totalling 317 male and 399 female EPs, reported individual components of burnout (EE, DP, PA) as percentages of participants with high or low scores (Table 3).[18,20,33,34] These studies found that the proportion of female EPs with high EE and low PA was significantly higher compared to male EPs ($P < 0.001$). However, levels of DP were comparable between both genders ($P = 0.77$). This indicates that female EPs may experience greater EE and lower PA, highlighting potential areas of concern for gender-specific burnout interventions in emergency medicine.

Lastly, among the remaining studies that reported odds ratios or relative risks for burnout, 3 of 4 studies indicated a higher risk of burnout among female EPs, while one study showed a higher risk among male EPs (Table 5).[19,25,30,31] Specifically, female EPs were found to have a higher risk for the EE component of burnout compared to male EPs, as suggested by these findings. This underscores the gender disparity in burnout risk within the EM profession, emphasizing the need for targeted interventions to mitigate these disparities and support the well-being of all EPs.

In our systematic review, we encountered challenges in performing a meta-analysis due to the variability in how authors reported their findings using the MBI tool to measure burnout among EPs. Specifically, there were limitations stemming from the limited number of studies that reported results separately for male and female EPs, as well as the diversity in how parameters of burnout were reported across these studies. The variation in reporting included differences in the following:

- Whether burnout was reported as overall scores or individual components (EE, DP, PA)
- The specific metrics used to define high burnout

- The methods used to analyze and present data (percentages, means, odds ratios, etc).

This variability makes it challenging to aggregate data across studies for a meta-analysis, which typically requires a consistent approach to data reporting and statistical measures. As a result, while our review provides valuable insights into the gender disparities in burnout among EPs, the heterogeneity in reporting prevents a quantitative synthesis of the findings.

Moving forward, standardizing the reporting of MBI-HSS results and burnout parameters in future studies would facilitate more robust meta-analytical approaches to further elucidate the gender gap in burnout among EPs and inform targeted interventions to mitigate burnout in this critical healthcare specialty.

As per the originators of the MBI-HSS the pre-2016 versions of the tool used arbitrary classifications of high burnout, dividing the normative population into tertiles labelled as high, moderate, and low burnout. This approach was later acknowledged as a mistake, leading to the removal of these cutoff classifications from all versions of the MBI-HSS starting with the fourth edition in 2016. This change allowed researchers to view burnout as a continuum within the context of specific populations.[37]

In our systematic review, despite including 14 studies conducted after 2016, only three studies reported the mean (±SD) scores of individual components of burnout separately for male and female EPs.[21,28,35] Notably, these studies highlighted significant differences: females exhibited significantly higher EE scores, while males showed significantly higher DP and lower PA scores ($P < 0.001$).[21,28,35] It is important to note that the study by Yan et al in China included a large cohort of 15,243 participants, which may skew the overall findings toward this study's results.[35]

In most other studies included in our review, researchers derived cutoffs by combining results from individual components (EE, DP, PA), which could explain why overall burnout scores appeared equivocal across these studies (Table 2). This variability in reporting underscores the ongoing challenge of harmonizing burnout measurements across different studies and emphasizes the need for standardized reporting practices to facilitate clearer comparisons and meta-analyses in future research.

Twelve of the articles included in our study were published in 2020 or later, and five studies were conducted during the peak of the COVID-19 pandemic in 2020–2021. It is likely that the pandemic caused unusual fatigue and burnout, resulting in different burnout levels among males and females across different regions.

LIMITATIONS

This systematic review encountered several limitations. One major challenge was the variability in how studies reported burnout, even when using the MBI-HSS tool. Some studies focused on overall burnout, while others reported individual components such as EE, DP and PA. Additionally, studies employed different metrics (percentages, means, or odds ratios), making it difficult to aggregate findings for a meta-analysis. The limited number of studies reporting gender-specific data further constrained our ability to make definitive conclusions about the gender gap in burnout among EPs. Moreover, some studies used outdated versions of the MBI-HSS, which relied on arbitrary cutoffs for high burnout, affecting the accuracy of burnout classification. Finally, several studies were conducted during the COVID-19 pandemic, a period marked by increased fatigue and burnout, potentially skewing the findings and limiting their generalizability beyond that time frame.

CONCLUSION

This review highlights that the science of examining physician burnout is complex and influenced by a wide range of factors. No two studies are perfectly comparable, even when using similar assessment tools, such as the Maslach Burnout Inventory-Human Services Survey. Variables like the type of work, workload, acuity of tasks, job satisfaction, hours worked, frequency of rapid decision-making, critical thinking demands, work-life balance, competing interests, cultural beliefs, and societal norms—such as power distance and hierarchy—all impact burnout differently.

Despite the findings that female emergency physicians report higher emotional exhaustion and lower sense of personal accomplishment than their male counterparts, it is essential for societies and countries to delve deeper into this issue, tailoring studies to their specific contexts and cultures. This review underscores the need for gender-specific strategies to combat burnout among EPs. While both men and women experience significant burnout, the nature of their burnout differs, necessitating targeted interventions to support the well-being of all EPs.

Recommendations for Research

1. **Uniform Reporting of Results:** Future studies on burnout among EPs should uniformly report results, including the mean (±SD) for the individual components of the MBI-HSS tool— EE, DP and PA—for both male and female EPs. This standardized approach will facilitate a clearer understanding of the gender gap in burnout across different settings and populations.
2. **Further Research Focus:** There is a critical need for further research to delve into the underlying reasons behind the disparities in EE, DP, and PA between male and female EPs. Understanding these factors is essential for developing targeted interventions that

address the specific needs of each gender, thereby effectively mitigating burnout.

3. **Move Away from Arbitrary Cutoff Scores:** The practice of using arbitrary cutoff scores (high, moderate, low burnout) to categorize burnout levels should be abandoned. This approach, discouraged by the originators of the MBI-HSS tool, does not accurately capture the nuanced experiences of burnout and may lead to misleading conclusions.
4. **Holistic Assessment of Burnout:** Rather than focusing solely on overall burnout scores, future studies should emphasize the detailed assessment of EE, DP, and PA. This holistic approach provides a more comprehensive understanding of burnout dynamics among EPs and allows for targeted interventions based on specific components of burnout.

Call to Action by FLAME

Based on the observations regarding burnout among women in EM and female EPs, we are proposing the following measures:

1. **Increased Awareness and Education:**
   - Enhance awareness and recognition of burnout within the EM community.
   - Incorporate burnout-related sessions into EM residency training and core curriculum.
2. **Proactive Faculty and Leadership:**
   - Faculty and EM leadership should closely monitor all staff, including both female and male EPs, for signs of work-related stress, cognitive overload, and other relevant commitments.
   - Emphasize addressing burnout as a work-related issue rather than a gender-related one, especially when there is no confirmed evidence of gender-specific causes.
3. **Open Discussions on Burnout:**
   - Foster an open, non-judgmental dialogue about burnout during departmental peer-review sessions.
   - Ensure that staff at all levels can share their experiences while maintaining psychological safety.
   - Address burnout openly to prevent it from becoming a "silent crisis."
4. **Psychological Wellness Initiatives:**
   - Leadership and management should implement psychological wellness initiatives, such as "Joy @ Work," iTHRIVE initiatives, and wellness grants.
5. **Peer-Support Committees:**
   - Establish interprofessional peer-support committees or teams.
   - Encourage staff to discuss burnout with peers, who may be more approachable, and share best practices for managing burnout.

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Use and Outcomes of Sugammadex for Neurological Examination after Neuromuscular Blockade in the Emergency Department

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Introduction: Non-depolarizing agents such as rocuronium and vecuronium are frequently used in the emergency department (ED) to facilitate intubation but may lead to delay in neurologic examination and intervention. Sugammadex is used for reversal of neuromuscular blockade by non-depolarizing agents but its role in the reversal of neuromuscular blockade for neurologic examination in the ED is poorly defined.

Methods: This was a multicenter cohort study using retrospective chart review. We reviewed all ED encounters from June 21, 2016–February 9, 2024 of the electronic health record of Mass General Brigham, a large multistate health system, and abstracted all ED administrations of sugammadex to facilitate neurologic examination. We calculated descriptive statistics and assessed outcomes.

Results: In 3,080,338 ED visits during the study period, 48 patients received sugammadex to facilitate neurologic examination. Of those patients, 23 (47.9%) underwent a procedure within 24 hours. Three (6.3%) had bradycardia, and one (2.1%) had hypotension following sugammadex administration. A total of 23 patients (47.9%) ultimately died during their admission, and 24 (50%) died within 30 days.

Conclusion: Patients who received sugammadex in the ED to facilitate neurologic examination during the study period had rare associated adverse effects, high rates of procedures within 24 hours of administration, and significant in-hospital mortality. Prospective data is needed to assess the impact of sugammadex on decision-making. [West J Emerg Med. 2025;26(2)347–352.]

INTRODUCTION

Neuromuscular blockade (NMB) is frequently administered as part of rapid sequence induction in the emergency department (ED) and prehospital settings. Non-depolarizing aminosteroid neuromuscular blocking agents (NMBA) such as rocuronium and vecuronium are commonly administered to facilitate intubation in the ED,[1] but administration may lead to prolonged paralysis and delay in neurologic examination and surgical decision-making in patients presenting with neurological injury. Sugammadex is a modified gamma-cyclodextrin used for the reversal of NMB from aminosteroid NMBAs.[2] When compared to acetylcholinesterase inhibitors such as neostigmine, sugammadex is associated with faster time to reversal, longer duration of action, and lower rates of cholinergic side effects such as bradycardia, nausea, and vomiting.[3] As a result, it does not require the co-administration of atropine or glycopyrrolate. It is

currently recommended over neostigmine as a first-line agent for the reversal of rocuronium in the operating room.[4] Despite this recommendation, little is known about the use of sugammadex in the ED.

Two recent studies have highlighted the potential for its use in the ED setting.[5,6] Our recent review of the use of sugammadex in the ED found that the most common indication was for neurologic examination, with 93.7% of patients receiving sugammadex for this indication.[7] In that series, we found that the use of sugammadex for other indications was rare: one patient received sugammadex after inadvertent NMB administration; one received sugammadex to facilitate terminal extubation; and one received sugammadex following incomplete reversal of NMB at an ambulatory surgery center. No patients received sugammadex for a cannot-intubate-cannot-ventilate scenario. Only two small studies have described the use of sugammadex to facilitate neurological examination. A retrospective study of 11 patients receiving sugammadex in the ED for neurological examination found that the majority of patients who received sugammadex had a change in their examination and concluded its administration to be useful.[8] A second retrospective study that evaluated its use in 24 patients found that dosing of 2 milligrams per kilogram (mg/kg) and 4 mg/kg were equally effective in achieving a train of four (TOF) of four.[9] We sought to further define the safety, efficacy, and outcomes of sugammadex use to facilitate neurologic examination in the ED.

Population Health Research Capsule

What do we already know about this issue?
Little is known about the use of sugammadex in the ED. Prior data has shown it is most commonly used to facilitate neurologic exam.

What was the research question?
What are the outcomes of patients who receive sugammadex for neurologic exam in the ED?

What was the major finding of the study?
47.9% of patients who received sugammadex in the ED ultimately underwent a procedure within 24 hours, and 50% died within 30 days.

How does this improve population health?
This study provides input on the outcomes of patients receiving sugammadex in the ED for neurologic exam, which is done rarely and in high-acuity and time-sensitive clinical situations.

METHODS

This was a multicenter cohort study using retrospective chart review. We adhered to all elements of optimal retrospective chart review in emergency medicine research as previously defined by Worster et al with the exception of interobserver reliability use and testing, as chart abstraction was performed by one author.[10] We performed a structured chart abstraction of all ED encounters between June 21, 2016 (the date of sugammadex addition to the formulary) and February 9, 2024, in the electronic health record (EHR) (Epic Systems, Verona, WI) of Mass General Brigham, a large multistate regional health system with two affiliated academic medical centers and seven affiliated community, acute care hospitals.

We used chart abstraction to identify all administrations of sugammadex during an ED encounter. Charts were manually reviewed by the senior author (PSJ) to verify usage of sugammadex to facilitate neurological examination. Patient demographics, dosing weight, and laboratory values were automatically abstracted from the EHR for the linked ED encounter. For NMBAs administered within the health system, dosing weight, dose administered, and time of administration were automatically abstracted from the linked record of time of medication administration in the EHR. For NMBAs administered outside of the health system, linked EHRs, triage notes, and ambulance run reports were manually reviewed to determine dose and timing of NMB administration.

Manual chart review and abstraction was then performed by the first author (SDH) to determine the neurological injury type, procedure type and timing, major adverse events, mortality, and in-hospital changes to a comfort-oriented code status.

Where possible, Glasgow Coma Scale (GCS) was abstracted from nursing and physician notes. We calculated a modified Rankin Scale (mRS) based on the physical examination and physical therapy notes included in the discharge summary. Descriptive statistics were calculated. This research was approved by the Mass General Brigham institutional review board.

RESULTS

Patient Demographics

From June 21, 2016–February 9, 2024, there were 3,080,338 ED visits at Mass General Brigham-affiliated acute-care hospitals. Forty-eight patients received sugammadex to facilitate neurological examination. The mean (±SD) age at administration was 59.9 (±20.9) years of age (range 21–94 years). Sixteen patients (33.3%) were female, and 32 patients were male (66.7%) (Table).

Table. Patient characteristics.

Age, mean (SD), years	59.9 (20.89)
Sex, n (%)	
Male	32 (66.7%)
Female	16 (33.3%)
Weight, mean (SD) kg	77.3 (18.9)
Sugammadex dose, mean (SD), mg	345.63 (200)
Sugammadex dose, mean (SD), mg/kg	4 (2.8)
Neurologic injury, n (%)	
Subdural hematoma	6 (12.5%)
Subarachnoid hemorrhage	7 (14.6%)
Multicompartmental hemorrhage	15 (31.3%)
Intraparenchymal hemorrhage	11 (22.9%)
Ischemic stroke	3 (6.3%)
Cervical spine injury	3 (6.3%)
Other	3 (6.3%)
Trauma, n (%)	25 (52%)
Mortality, n (%)	
Within 72 hours of sugammadex	12 (25%)
Within 30 days of sugammadex	24 (50%)
Change to comfort measures only, n (%)	
Within 72 hours of sugammadex	16 (33.3%)
During hospitalization	22 (45.8%)
Location of paralytic, n (%)	
Outside hospital	9 (18.8%)
Prehospital	18 (37.5%)
Interhospital transfer	2 (4.2%)
Emergency department	19 (39.6%)
GCS, median, when recorded	
Pre-sugammadex	3
Post-sugammadex	4
Change pre-/post-sugammadex	4
Procedure performed, n (%)*	
Craniotomy	10 (20.8%)
External ventricular drain	7 (14.6%)
Angiogram/embolization/thrombectomy	4 (8.3%)
Spinal fusion/decompression	3 (6.3%)
Other	5 (10.4%)

*Some patients had more than one procedure.
GCS, Glasgow Coma Score; *kg*, kilogram; *mg*, milligram.

Dosing, Timing, and Location

The mean dosing weight (±SD) was 77.3 kgs (±18.9 kg). Rocuronium was the most common NMBA to be reversed, used in 46 of the 48 patients (95.8%). We were able to abstract accurate dosing of rocuronium for 35 patients, and the mean (±SD) dose was 104.7 mg (±18.3 mg) or a mean of 1.37 mg/kg (±0.30 mg/kg). Accurate dosing of vecuronium was obtained from one patient, who received 10 mg (0.13 mg/kg).

Sugammadex was given at a mean dose of 346 mg (range 100–2,000 mg, interquartile range [IQR] 200–377.5 mg). The most common dose was 4 mg/kg (25 patients) with a mean dose of 4 mg/kg (range 2–18 mg/kg, IQR 2.8–4 mg/kg). The NMB and sugammadex were administered in the same ED encounter for 15 patients. For NMB given in alternate contexts, the most common location was prehospital (18 patients), at a referring hospital (13 patients), and during interfacility transport (two patients). All doses of sugammadex were administered in the two academic medical center EDs. We were able to obtain accurate time of administration for both NMB and sugammadex for 22 patients. The mean (range, ±SD) time from NMB to sugammadex administration was 109.9 (31–283, ±66.8) minutes.

With regard to hepatic and renal clearance, all patients had a creatinine level obtained during the ED visit, and 46 of 48 (96%) had transaminase levels obtained. Thirty-three patients had normal transaminase levels (defined as both aspartate aminotransferase and alanine aminotransferase < 50 units per liter) and 35 patients had normal creatinine levels (defined as < 1.2 mg/deciliter).

Neurological Injury

The primary neurological injury varied, but the majority (40, 83.3%) of patients presented with intracranial hemorrhage. Three (6.3%) presented with acute ischemic strokes; two patients (4.2%) had extracranial vascular injury; one with a Type A aortic dissection causing common carotid artery occlusion and one with a vertebral artery dissection and pseudoaneurysm. Two (4.2%) patients had primary spinal cord trauma, and one patient (2.1%) presented with a brain mass. Twenty-five (52.1%) of the patients presented following trauma.

Outcomes

An accurate GCS was obtained before administration of sugammadex in 43 (89.6%) patients and was 3t in all but one (who was 4t). An accurate GCS was obtained after administration of sugammadex in 35 (72.9%) patients with a mean (±SD) of 6.4 (±2.4). Thirty-four (70.8%) had a reliable GCS obtained before and after administration of sugammadex; the mean (range, ±SD) increase in GCS was 3.38 (−1 to +8, ±2.5) points.

Twenty-three patients (47.9%) underwent an invasive procedure within 24 hours of sugammadex administration, and another three (total of 26 or 54.2%) underwent a procedure within 72 hours (Table 1). Twelve patients (25.0%) died within 72 hours of sugammadex administration, while 24 patients (50%) died within 30 days. The code status was

changed to "comfort measures only" for 16 patients (33.3%) within 72 hours of sugammadex administration, and for 22 patients (45.8%) during the hospitalization. Adverse events were rare, with two (4.1%) patients experiencing hypotension after sugammadex administration, four (8.2%) patients experiencing bradycardia, and no patients experiencing cardiac arrest.

The mRS for neurologic disability[11,12] at discharge (ranging from 0–6, with higher scores indicating more severe disability), excluding all patients with a discharge mRS of 6 (deceased), was an average of 3.9 (SD ±1.36), where a score of 4 indicates moderately severe disability.

DISCUSSION

Non-depolarizing NMBAs are frequently used in both the ED and prehospital setting during airway management of neurologically injured patients. The use of non-depolarizing NMBAs leads to prolonged paralysis, which impairs accurate neurologic examination essential to guide emergent and time-sensitive therapy for neurologic injury. Beyond neurologic examination being a critical part of decision-making regarding therapy, prognosis related to initial neurologic examination may be valuable to families as they consider early goals of care. This is reflected in our dataset as 33.3% of patients receiving sugammadex whose status was changed to "comfort measures only" within 72 hours of receiving sugammadex.

Rocuronium, the most commonly used NMBA in our cohort, has an expected duration of action of 30–60 minutes.[13] However, longer duration of action has been well described.[14–17] The time to administration of sugammadex in our study reflects this, as patients received sugammadex as long as 283 minutes following rocuronium administration with change in neurologic examination. Additionally, we were unable to obtain accurate times for some prehospital and referring hospital administrations of neuromuscular blockade, which may have biased the results toward those administered in the same ED encounter. This potentially extended duration of action for NMB was unlikely due to impairments of renal or hepatic metabolism as these was predominantly normal in our cohort; instead, it may have been due to higher NMB doses used, greater patient age, or to uncharacterized hypothermia or hypovolemia, the latter of which was not captured in our study.[18–20] All doses of sugammadex occurred at the two academic medical centers. We attributed this to both hospitals being referral centers for neurosurgical trauma and for post-stroke care. Because of this, we are unable to draw any conclusions about its use in community hospitals.

Our study replicated previous findings seen in the relevant literature including that sugammadex use in the ED for neurologic exam is overall rare and appears most prevalent at academic medical centers. This likely reflects the capacity for advanced therapeutics and neurosurgical intervention for which rapid NMB reversal for neurologic exam is indicated at these centers and that adverse effects associated with its use are rare.[5,7]

LIMITATIONS

A limitation of our study was lack of recorded TOF monitoring. Without TOF monitoring, it is difficult to comment on whether the sugammadex doses administered were adequate at fully reversing NMB. Because of the retrospective nature of the study, we were unable to determine the exact time of neurological examination. Additionally, it is possible that documented change in GCS was due to other factors such as changes in sedation or underlying neurologic status. An additional limitation of our study was that recorded GCS was based on exams performed by many different individuals with variable training backgrounds including nursing, emergency medicine residents and attendings, neurology and neurosurgery residents, and neurosurgery attendings. Further, the pre- and post-GCS was often based on examinations performed by separate individuals, and variation in exam between clinicians could have contributed to change in GCS, rather than true clinical change. Time of GCS examinations was also not recorded, which also may have affected the results of the exam after sugammadex administration. Although our cohort describes sugammadex use among patients with a range of neurological pathology, we did not capture any patients with status epilepticus as the underlying injury, one potentially relevant disease category for which NMB reversal has been previously described.[5]

An additional limitation was lack of bispectral index monitoring or data regarding awareness during paralysis. Awareness during paralysis is known to occur in ED patients receiving mechanical ventilation, with rocuronium being associated with increased frequency of awareness during paralysis.[21] Furthermore, the impact of the use of sugammadex on clinical decision-making was difficult to determine given the retrospective nature of the study. Accurate neurological examination is an essential aspect of clinical decision-making during neurologic emergencies and likely played an important role in clinical course regardless of whether intervention was performed following repeat exam. Prospective research is needed to determine the impact of sugammadex on clinical decision-making.

Despite these limitations, sugammadex administration was well tolerated, with rare adverse effects. Although there were two episodes of hypotension and four episodes of bradycardia, it was difficult to determine whether these were attributable to sugammadex given possible confounders such as sedation administration and underlying critical illness. Overall, the cohort was associated with high acuity reflective of the critical nature of neurologic emergencies requiring intubation. Mortality was high in this cohort, and mRS at

discharge was reflective of many patients having severe disability at discharge. Despite high mortality and severe disability in survivors, it is difficult to consider sugammadex administration and subsequent procedures as futile as some patients may go on to recover considerably with aggressive rehabilitation.

CONCLUSION

Administration of sugammadex to facilitate neurologic examination is a rare occurrence in the ED. In this multicenter, retrospective study, we found that patients who received sugammadex in the ED during the study period had infrequent associated adverse effects, high rates of procedures within 24 hours of administration, and significant in-hospital mortality. Change in Glasgow Coma Scale was observed despite most patients in this cohort receiving sugammadex greater than one hour after NMB administration with a maximal observed interval of greater than four hours after NMB administration. Code status ultimately changed to "comfort measures only" for nearly half of these patients and, on average, patients discharged from a hospitalization where sugammadex had been administered in the ED had moderately severe neurologic disability. Prospective data is needed to assess the impact of sugammadex on decision-making.

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Analysis of the Highest Altmetrics-scored Articles in Emergency Medicine Journals

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Introduction: Alternative metrics (altmetrics) have emerged as invaluable tools for assessing the influence of scholarly articles. In this study we aimed to evaluate correlations between Altmetric Attention Scores (AAS), and sources and actual citations in articles displaying the highest AAS within emergency medicine (EM) journals.

Methods: We conducted an analysis of EM journals listed in the Science Citation Index Expanded (SCIE) using the Altmetric Explorer tool. We analyzed the journals that received the highest number of mentions, the sources of AAS, the regions most frequently mentioned, and the geographical distribution of mentions. In the subsequent stage of our analysis, we conducted an examination of the 200 top-ranked articles that had received high AAS and were published in SCIE EM journals from January 1, 2013–January 1, 2023. We sought to determine the correlations between the AAS and the citation counts of articles on Google Scholar and the Web of Science (WOS).

Results: Of 40,840 research outputs evaluated, there were 510,047 shares across multiple platforms. The AAS were present for 36,719 articles (89.9%), while 10.1% had no score. In the review of the top 200 articles with the highest AAS, the median score was 382.5 (interquartile range 301.3–510.8). Of the research output evaluated, 38% were observational studies, 13% case reports, and 13% reviews/meta-analyses. The most common research topics were emergency department (ED) management and COVID-19. There was no correlation between AAS and WOS citation numbers ($r_s = -0.041$, $P = 0.563$, 95% confidence interval [CI] −0.175–0.087). There was a weak correlation identified between WOS citations and mentions on X, and a moderate correlation observed for WOS citations and blog mentions ($r_s = 0.330$, $P < .001$, 95% CI 0.174 to 0.458; $r_s^2 = 0.109$, and $r_s = 0.452$, $P < .001$, 95% CI 0.320–0.566; and $r_s^2 = 0.204$, respectively). However, we found a strong positive correlation between WOS citations and the number of Mendeley readers ($r_s = 0.873$, $P < .001$, 95% CI 0.82–0.911, $r_s^2 = 0.762$).

Conclusion: While most articles in EM journals received an AAS, we found no correlation with traditional citation metrics. However, Mendeley readership numbers showed a strong positive correlation with citation counts, suggesting that academic platform engagement may better predict scholarly impact. [West J Emerg Med. 2025;26(2)353–363.]

INTRODUCTION

Alternative metrics (altmetrics) emerged in the early 2010s in response to the limitations of traditional citation-based metrics.[1] Altmetrics use a broader set of indicators such as page views, downloads, social media mentions, news media coverage, and expert recommendations to provide a more comprehensive understanding of an article's influence.[2] Platforms like Altmetric.com and Plum Analytics provide tools for evaluating the reach and impact of scholarly articles, helping to track their online dissemination in real time. An increasing amount of evidence indicates that maintaining an active online presence can directly influence a researcher's credentials as evaluated by conventional measures.[3] By considering various aspects beyond citations alone, altmetrics provides researchers and institutions with a more holistic assessment of their work's societal impact. While the purpose of these metrics is to measure social impact, early social media visibility after publication can also increase and predict citations.[4] Assessing these activities could provide faster evaluations of an article's impact and predict citations, serving as an early identifier for emerging areas of research growth.[5]

Within the medical field specifically, these metrics offer insights into both scholarly recognition and public reception of research findings. Moreover, the relationship between these metrics underscores the changing landscape of scholarly communication, as researchers, clinicians, and the public alike engage with and contribute to the dissemination of research findings through online platforms. With the growth of digital communication and social media, the speed and the scale of information-sharing have accelerated, making altmetrics an invaluable tool for assessing real-time impact of articles.[6] Emerging trends can be key to a more efficiently functioning field of medicine.[7]

Emergency medicine (EM) thrives on the timely dissemination of research and information that directly impacts patient care.[8] The first altmetrics analysis in EM conducted by Barbic et al found that the most-cited articles on social media in EM from 2011 were often published in non-EM biomedical journals.[9] Although this may suggest that authors in the field of EM select high-impact journals to increase the effectiveness of their publications, altmetric scores and journal impact factors are not correlated.[10] The social impact of an article may be better assessed by focusing on individual altmetric score sources rather than the overall score.[11] This was supported by a recent study that found a direct correlation between X (formerly Twitter) mentions and article citations among EM research.[12] Our aim in this study was to investigate the correlations between the altmetric scores, their sources, and citations.

Population Health Research Capsule

What do we already know about this issue?
Altmetrics emerged in the 2010s to address the limitations of traditional citation-based metrics in evaluating research impact.

What was the research question?
We explored the correlations between Altmetric Attention Scores, their sources, and citation counts for articles published in EM journals.

What was the major finding of the study?
No correlation was found between AAS and Web of Science; it was weak for X mentions, moderate for blogs, but strong for Mendeley readership ($r_s = 0.873$, 95% CI 0.822–0.911).

How does this improve population health?
Focusing on article dissemination through individual altmetric sources, rather than total scores, can help researchers more effectively reach their target audiences.

METHODS

In the first stage of the study, we used the Altmetric Explorer tool from Altmetric.com (Altmetric LLP, London, UK) to assess the Altmetric Attention Scores (AAS) of scholarly articles published in EM journals indexed in the Science Citation Index Expanded (SCIE). The AAS is a metric that evaluates the attention a research output receives using a weighted system that assigns distinct values to various sources, such as news outlets, blogs, and social media platforms. Sources with greater impact, such as news articles, are attributed higher weights compared to social media mentions. The score is calculated by a sophisticated algorithm that factors in not only the number of mentions but also variables such as duplicate posts and the credibility of the news sources.[13]

All Altmetric Explorer assessments were conducted and downloaded as a CSV file on September 2, 2023. The initial analysis focused on examining the distribution of altmetric data by country and journal, as well as evaluating the sources of AAS scores over time. The 2022 Journal Citation Indicator (JCI) scores for the journals were obtained from the Web of Science (WOS) Master Journal List. These JCI scores represent the average citation impact of articles published between 2019–2021.

In the second stage we identified the top 200 articles with the highest AAS published in SCIE EM journals between January 1, 2013–January 1, 2023. We assessed the AAS of these articles along with the sources of their mentions. Citation counts for these articles were evaluated using both

WOS and Google Scholar. To calculate the annual citation number, we divided the total citation counts obtained from the search engines by the number of years since the articles' publication. We obtained full-text access for the articles to determine the article's subject (eg, emergency department management, trauma, toxicology, resuscitation, critical care, COVID-19) and type (randomized controlled trial, observational study, case reports, reviews (systematic review and meta-analysis). Additionally, we determined the country of the first-named author of each article.

We assessed the correlation between the AAS and citation counts of the articles. Furthermore, two EM specialists from the research team independently reviewed the AAS and all screening processes of the study. In cases where the two evaluators did not reach a consensus, a third EM specialist conducted the evaluation. The study was approved by the Local Ethics Committee of İzmir Provincial Health Directorate Dr. Behcet Uz Pediatric Diseases and Surgery Training and Research Hospital.

Statistical Analysis

We performed statistical analysis using SPSS 29.0 for Windows (SPSS Statistics, IBM Corp, Armonk, NY). Categorical variables were evaluated using the Kolmogorov-Smirnov test. Among the variables, those that fit the normal distribution were presented as the mean ± standard deviation, and those that did not fit the normal distribution were presented as median (interval) or median (interquartile range [IQR]). We used Mann-Whitney U and Kruskal-Wallis tests to compare numerical variables. Spearman correlation analysis was used to assess the relationship between AAS, their sources (mentions), and WOS and Google Scholar citation numbers. Spearman correlation analysis was used to analyze distributions of AAS, the source of the scores (mentions), and WOS and Google Scholar citation numbers. We interpreted the correlations as weak, moderate, strong, and very strong based on the resulting coefficients.[14] Statistical significance was recognized when $P < 0.05$.

RESULTS

Of the 40,840 research outputs evaluated, 510,047 were shared across multiple platforms. Altmetric Attention Scores were present for 36,719 articles (89.9%), while 10.1% had no score. The online engagement for this content included 459,391 tweets from 114,708 unique tweeters in 206 countries, 14,355 Facebook posts on 2,141 unique pages in 60 countries, 19,571 news stories by 1,988 unique outlets in 86 countries, and 2,791 policy documents from 79 unique sources in 18 countries. The top 10 journals had no mentions on Pinterest, Syllabi, or LinkedIn. Only two journals received mentions on the Chinese microblogging platform Weibo, each mentioned once. Figure illustrates the frequency of mentions corresponding to the publication years.

The Altmetrics–X demographics data revealed the top five countries contributing to mentions for the analyzed content. The country was not specified in 193,148 posts (42.0%) and 54,517 profiles (47.5%). The largest number of posts were from the United States (Table 1).

Overall, 90% of the 36,780 articles had an AAS ≥ 1. The median (IQR) values for these articles were as follows: AAS 3 (1–9), X mentions 3 (1–9); Mendeley readership 24 (9–50); Dimensions citations 5 (1–15); and blog mentions 0 (0–24). We found a strong correlation between AAS and X mentions ($r_s = 0.712$, 95% CI 0.707–0.717, $P < .001$) and a weak correlation between AAS and the number of Mendeley readers ($r_s = 0.338$ to 356, $P < .001$).

We found two journals that lacked AAS. The median total mentions for EM journals were 14,154 (ranging from

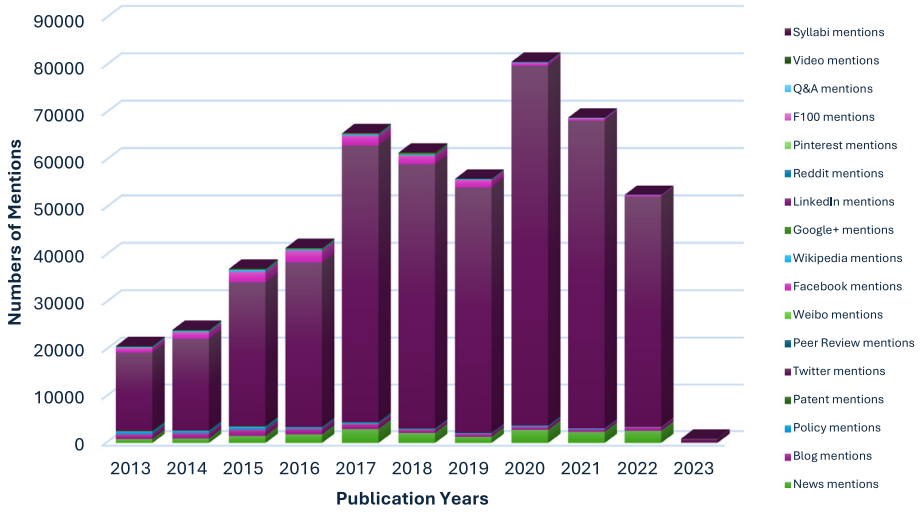

Figure. The number of mentions in altmetric score resources over publishing years.

Table 1. Country distribution of altmetrics-X demographics.

Country name	Number of posts* (n [%])	Number of profiles** (n [%])
Country not specified	193,148 (42.0%)	54,517 (47.5%)
Unites States	89,876 (19.6%)	18,734 (16.3%)
United Kingdom	50,504 (11.0%)	9,208 (8.0%)
Canada	27,916 (6.1%)	4,297 (3.7%)
Australia	15,307 (3.3%)	2,435 (2.1%)
Spain	13,538 (2.9%)	3,863 (3.4%)

*A post refers to an individual mention or engagement on a social media platform (such as an X mention, Facebook post, blog entry, etc) where a specific research output is shared or discussed.
**A profile refers to the unique social media account or user (eg, an X or Facebook account) that made the post or mention.

57–77,460). Mentions on X had a median of 12,284 (ranging from 56–68,078), Facebook mentions had a median of 234 (ranging from 0–2,180), blog mentions had a median of 126.5 (ranging from 0–1,866), and news mentions had a median of 288 (ranging from 0–5,040).

The EM journals with the highest total number of mentions were *Annals of Emergency Medicine, Resuscitation, and the American Journal of Emergency Medicine*. Conversely, the AAS per article was highest for *Academic Emergency Medicine, Annals of Emergency Medicine, and the Emergency Medicine Journal*, respectively (Table 2). We found a moderate correlation ($r_s = 0.518$, $P = 0.07$, 95% CI 0.152–759) between the 2022 JCI and the total number of mentions.

In the review of the top 200 articles with the highest AAS, the median score of the articles was 382.5 (IQR 301.3–510.8). The AAS with sources and number of citations of the top 50 articles are provided in Table 3. The median WOS citations for the articles was 16 (IQR 5–39), with an annual citation count of 4.7 (IQR 1.8–8.9). The median Google Scholar citations was 29 (IQR 11–65), with an annual citation count of 7.5 (IQR 3.2–15.1). Among these articles, 38% were observational studies, while case reports and reviews/meta-analyses constituted 13%. The most common research topics were ED management and COVID-19 (Table 4).

The AAS of reviews and guidelines were lower, while observational studies and case presentations were higher ($P = 0.02$). The AAS was higher for topics related to toxicology, COVID-19, and critical care ($P = 0.02$). While there was an increase in AAS and WOS citations in COVID-19-related papers, these variations were not significant ($P = 0.09$ and $P = 0.08$, respectively).

There was no significant correlation between AAS and WOS citation numbers ($r_s = -0.041$, $P = 0.56$, 95% CI −0.175–0.087, $r_s^2 = 0.0017$) or Google Scholar citations ($r_s = -0.038$, $P = 0.59$, 95 % CI −0.174–0.101, $r_s^2 = 0.0014$). However, there was a very strong positive correlation between WOS and Google Scholar citation numbers ($r_s = 0.973$, $P < .001$, 95% CI 0.955–0.984, $r_s^2 = 0.947$). Despite the weak correlation identified between WOS citations and X mentions, and the moderate correlation observed for blog mentions ($r_s = 0.330$, $P < .001$, 95 % CI 0.174 to 0.458, $r_s^2 = 0.109$, and $r_s = 0.452$, $P < .001$, 95% CI 0.320 to 0.566, $r_s^2 = 0.204$, respectively), there was a very strong positive correlation observed in the number of Mendeley readers. ($r_s = 0.873$, $P < .001$, 95% CI 0.822–0.911, $r_s^2 = 0.762$). No correlation was observed between news mentions ($r_s = -0.107$, $P = 0.10$, 95% CI −0.246–0.046, $r_s^2 = 0.0012$), and video mentions ($r_s = 0.037$, $P = 0.60$, 95% CI −0.078 to 0.145, $r_s^2 = 0.0013$).

DISCUSSION

This study examined altmetrics of EM journal articles from the 2013–2023. Ten percent of EM journal articles were never mentioned on social media. Compared to Barbic et al's investigations from 2011, AAS for the most cited publications have increased significantly in the subsequent decade.[9] Social media followers for EM journal articles have increased significantly in recent years. Interestingly, three-quarters of the 200 most-cited articles were published after this study, with 45% published after the COVID-19 pandemic. Social media followers for EM journal articles have increased significantly in recent years.

Kolahi et al identified a weak but positive correlation between AAS and citations in their meta-analysis; the authors emphasized the importance of continuing to examine the temporal dynamics of this relationship.[15] In our study, although no correlation was found between AAS and traditional citation counts, we observed a weak correlation between AAS and X mentions, and a moderate correlation between AAS and blog mentions. Notably, there was a very strong correlation observed between AAS and the Mendeley readership numbers.

The AAS is calculated based on the source and frequency of sharing. In this calculation, news, blog mentions, Wiki pages, policy documents, and patents have the most weight, while X has less weight. Mendeley readership and citations are not considered.[16] It should be noted that the primary purpose of altmetrics is to measure social interest in a given topic, rather than to predict the potential citation count of an

Table 2. Journals with the highest total number of mentions.

Journal title[δ]	JCI[Δ]	Total number of mentions	Total number of mentions per article	News	Blog	Policy	Patent	X	Peer review	Facebook	Wikipedia	Google+	Reddit	F1000	Q&A	Video
Academic Emergency Medicine	1.56	46,945	23.97	2,332	1,109	199	58	41,615	10	1,178	99	258	22	5	0	61
Annals of Emergency Medicine	2.3	77,460	20.85	5,040	1,866	221	58	68,078	19	1,830	136	107	40	16	0	51
Emergency Medicine Journal	1.2	46,196	16.92	1,025	1,094	159	16	42,303	2	1,374	80	114	18	2	0	10
Resuscitation	1.87	64,941	15.08	1,532	845	400	151	59,341	1	2,180	149	218	32	29	3	61
The Western Journal of Emergency Medicine	1.06	20,345	14.91	793	390	106	28	18,298	3	520	101	81	2	3	0	21
Canadian Journal of Emergency Medicine	0.75	25,414	14.88	265	390	177	15	23,791	1	620	107	37	5	1	0	7
Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine	1.32	16,901	14.81	224	145	48	18	16,021	3	286	49	75	19	3	0	10
Journal of Emergency Medicine	1.2	35,634	12.66	1,298	798	147	33	32,356	3	631	188	94	28	5	2	51
American Journal of Emergency Medicine	1.47	50,028	9.63	2,156	1,190	335	55	44,442	16	1,502	172	68	17	10	1	64
Pediatric Emergency Care	0.77	16,921	5.52	308	430	97	6	14,434	4	1,534	43	12	0	4	0	50

[Δ]JCI: Journal Citation Indicator.
[δ]The journals are ranked based on the total mentions per article.

Table 3. Top 50 articles with highest altmetric scores.

Number	Title	Journal	Year	News mentions	Blog mentions	X mentions	Facebook mentions	Wikipedia mentions	Number of mendeley readers	Number of dimensions citations	Altmetric attention score	WOS citations	Google Scholar citations
1	N95 respirator cleaning and reuse methods proposed by the inventor of the N95 mask material	*J Emerg Med*	2020	120	2	4848	1	0	162	48	2621	39	67
2	Association between delays to patient admission from the emergency department and all-cause 30-day mortality	*Emerg Med J*	2022	156	6	2467	0	1	100	39	2040	25	59
3	Excited delirium: a systematic review	*Acad Emerg Med*	2017	447	3	190	8	2	120	49	1516	39	65
4	Vaccine-induced myocarditis in two intern doctors in the same night shift	*Prehosp Disaster Med*	2022	0	0	2868	1	0	7	3	1430	0	3
5	Loperamide abuse associated with cardiac dysrhythmia and death	*Ann Emerg Med*	2017	161	8	203	13	2	96	80	1319	66	103
6	A lay perspective and commentary on the association between delays to patient admission from the emergency department and all-cause 30-day mortality	*Emerg Med J*	2022	162	2	47	1	0	2	1	1269	1	1
7	Characteristics of paediatric out-of-hospital cardiac arrest in the United States	*Resuscitation*	2020	152	0	50	0	0	33	20	1173	17	23
8	A coronavirus disease 2019 (COVID-19) patient with bilateral orchitis	*Am J Emerg Med*	2021	23	2	1707	1	0	72	38	1128	23	45
9	The association of treatment with hydroxychloroquine and hospital mortality in COVID-19 patients	*Intern Emerg Med*	2020	1	1	3650	0	0	130	24	1096	18	29
10	Priapism in a patient with coronavirus disease 2019 (COVID-19)	*Am J Emerg Med*	2021	101	3	530	0	0	100	35	1083	22	50
11	Esophageal rupture after ghost pepper ingestion	*J Emerg Med*	2016	124	8	143	11	4	22	4	1021	3	5
12	Accidental occupational exposure to a large volume of liquid fentanyl on a compromised skin barrier with no resultant effect	*Prehosp Disaster Med*	2022	27	2	1228	2	0	8	1	999	1	3
13	Vitamin D deficiency is associated with higher risks for SARS-CoV-2 infection and COVID-19 severity: a retrospective case–control study	*Intern Emerg Med*	2022	5	1	1469	0	0	48	19	994	13	20
14	Characterization of in-flight medical events involving children on commercial airline flights	*Ann Emerg Med*	2020	132	1	31	4	0	57	10	963	8	13
15	Interrogation of patient smartphone activity tracker to assist arrhythmia management	*Ann Emerg Med*	2016	110	9	169	10	0	103	33	963	20	46
16	AWARE—AWAreness during REsuscitation—A prospective study	*Resuscitation*	2014	113	19	269	123	8	357	133	946	93	258
17	Alarming trends in US domestic violence during the COVID-19 pandemic	*Ann Emerg Med*	2020	127	10	53	0	2	542	507	929	356	732
18	Use of antibiotic coated intramedullary nails in open tibia fractures: a European medical resource use and cost-effectiveness analysis	*Injury*	2021	127	0	5	0	0	19	12	924	7	12
19	Bilateral retinal detachments in a healthy 22-year-old woman after Moderna SARS-COV-2 vaccination	*J Emerg Med*	2021	0	0	3901	0	0	45	12	922	12	16
20	Stopping haemorrhage by application of rope tourniquet or inguinal compression (SHARC study)	*Emergency Medicine Australasia*	2021	198	2	37	0	0	6	0	915	0	0

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Table 3. Continued.

Number	Title	Journal	Year	News mentions	Blog mentions	X mentions	Facebook mentions	Wikipedia mentions	Number of mendeley readers	Number of dimensions citations	Altmetric attention score	WOS citations	Google Scholar citations
21	The use of the word "quiet" in the emergency department is not associated with patient volume: a randomized controlled trial	*Am J Emerg Med*	2022	1	3	1521	3	0	25	2	879	2	3
22	Aromatherapy versus oral ondansetron for antiemetic therapy among adult Emergency department patients: a randomized controlled trial	*Ann Emerg Med*	2018	5	10	1968	13	0	139	19	832	3	29
23	Cyclic vomiting presentations following marijuana liberalization in Colorado	*Acad Emerg Med*	2015	103	8	60	9	1	104	95	825	72	120
24	Removal of iliosacral screws: the washer problem	*Injury*	2021	112	0	10	0	0	2	0	819	0	0
25	Persistent hiccups as an atypical presenting complaint of COVID-19	*Am J Emerg Med*	2020	57	1	2774	0	0	146	27	813	26	54
26	It isn't like this on TV: revisiting CPR survival rates depicted on popular TV shows	*Resuscitation*	2015	91	10	117	0	0	131	53	808	45	78
27	In-hospital cardiac arrest outcomes among patients with COVID-19 pneumonia in Wuhan, China	*Resuscitation*	2020	7	6	1369	4	0	440	239	802	178	332
28	Identifying safe corridors for anterior pelvic percutaneous instrumentation using computed tomography-based anatomical relationships	*Injury*	2022	167	0	0	0	0	2	0	792	0	0
29	Risk of acute kidney injury after intravenous contrast media administration	*Ann Emerg Med*	2017	54	24	540	14	0	414	187	789	167	260
30	Acute kidney injury after computed tomography: a meta-analysis	*Ann Emerg Med*	2018	49	12	638	5	3	303	127	785	100	175
31	Trends in inequities in the treatment of and outcomes for women and minorities with myocardial infarction	*Ann Emerg Med*	2022	133	2	12	0	0	8	5	763	2	6
32	Single versus dual incision approaches for dual plating of bicondylar tibial plateau fractures have comparable rates of deep infection and revision surgery	*Injury*	2022	180	0	0	0	0	1	2	737	0	2
33	Comparison of oral ibuprofen at three single-dose regimens for treating acute pain in the emergency department: a randomized controlled trial	*Ann Emerg Med*	2019	6	3	1160	6	0	104	30	713	28	41
34	Young woman with paraplegia following a motor vehicle crash	*Ann Emerg Med*	2016	0	0	1042	12	0	5	0	698	0	0
35	Association between the opening of retail clinics and low-acuity emergency department visits	*Am J Emerg Med*	2017	96	7	52	0	0	46	31	660	25	50
36	STEMI mimic: focal myocarditis in an adolescent patient after mRNA COVID-19 vaccine	*J Emerg Med*	2021	1	3	2112	0	0	58	13	644	10	15
37	One-year mortality of patients after emergency department treatment for nonfatal opioid overdose	*Ann Emerg Med*	2020	36	14	563	2	0	134	126	644	103	157
38	Academic emergency medicine physicians' anxiety levels, stressors, and potential stress mitigation measures during the acceleration phase of the COVID-19 pandemic	*Acad Emerg Med*	2020	79	4	16	0	0	286	117	605	86	168
39	Bystander CPR is associated with improved neurologically favourable survival in cardiac arrest following drowning	*Resuscitation*	2017	81	0	28	3	0	64	36	603	35	49

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Table 3. Continued.

Number	Title	Journal	Year	News mentions	Blog mentions	X mentions	Facebook mentions	Wikipedia mentions	Number of mendeley readers	Number of dimensions citations	Altmetric attention score	WOS citations	Google Scholar citations
40	Cold anaphylaxis: a case report	*J Emerg Med*	2020	86	11	11	0	0	9	0	594	0	0
41	Hospital volume and post-arrest care: a complex topic with more questions than answers	*Resuscitation*	2017	75	0	1	0	0	8	0	578	0	0
42	The impact of race and disease on sickle cell patient wait times in the emergency department	*Am J Emerg Med*	2013	64	5	36	1	0	97	93	572	77	153
43	Gender disparities in the application of public-access AED pads among OHCA patients in public locations	*Resuscitation*	2020	0	0	4546	0	0	36	7	564	5	9
44	Are there disparities in the location of automated external defibrillators in England?	*Resuscitation*	2022	70	1	14	1	0	28	8	564	6	13
45	United States 2020 emergency medicine resident workforce analysis	*Ann Emerg Med*	2022	73	1	20	0	0	14	4	563	3	5
46	Expert consensus guidelines for stocking of antidotes in hospitals that provide emergency care	*Ann Emerg Med*	2018	53	0	231	8	0	132	46	560	40	69
47	Longitudinal trends in U.S. drug shortages for medications used in emergency departments (2001–2014)	*Acad Emerg Med*	2015	78	9	38	1	0	39	35	554	26	48
48	Avoiding potential harm by improving appropriateness of urinary catheter use in 18 emergency departments	*Ann Emerg Med*	2014	68	0	4	0	0	58	19	534	16	30
49	Rapid adoption of low-threshold buprenorphine treatment at California emergency departments participating in the CA Bridge Program	*Ann Emerg Med*	2021	63	3	60	0	0	75	37	532	31	40
50	Cool running water first aid decreases skin grafting requirements in pediatric burns: a cohort study of two thousand four hundred ninety-five children	*Ann Emerg Med*	2020	28	4	444	7	0	76	37	511	25	51

Table 4. The citations are categorized based on the topics and types of the top 200 articles with the highest Altmetric Attention Scores.

	n (%)	Altmetric attention scores (median/IQR)	Number of WOS citations (median/IQR)	Number of scholar citations (median/IQR)
Article type				
Observational studies	76 (38)	432.5 (337.8–560.8)	18.0 (7.3–45.5)	30.0 (12.3–63.5)
Reviews	26 (13)	323.0 (272.5–386.8)	30.5 (7.0–72.3)	53.0 (11.8–130.8)
Case reports	26 (13)	433.0 (295.8–972.0)	11.5 (1.8–24.5)	21.0 (3.8–47.0)
Randomized controlled trials	21 (10.5)	330.0 (279.5–408.0)	21.0 (7.5–33.0)	40.0 (25.5–69.5)
Guidelines	7 (3.5)	280.0 (257.0–340.0)	35.0 (14.0–40.0)	69.0 (28.0–79.0)
Other	44 (22)	387.0 (344.0–475.5)	9.0 (4.0–29.5)	15.5 (4.3–48.3)
Topics				
ED management	39 (19.5)	369.0 (295.0–452.0)	21.0 (9.0–41.0)	36.0 (16.0–66.0)
COVID-19	29 (14.5)	427.0 (327.5–925.5)	22.0 (10.5–91.5)	36.0 (15.5–163.0)
Toxicology	24 (12.0)	440.5 (340.8–623.0)	27.5 (4.0–44.8)	42.0 (8.8–71.3)
Trauma	23 (11.5)	319.0 (261.0–468.0)	5.0 (0.0–10.0)	7.0 (2.0–24.0)
Critical care	19 (9.5)	425.0 (347.0–578.0)	19.0 (7.0–56.0)	34.0 (15.0–78.0)
Other	66 (33.0)	378.0 (299.0–489.8)	5.0 (0.0–16.0)	29.0 (10.0–62.8)
Analysis of COVID-19 articles				
COVID-19	29 (14.5)	427.0 (327.5–925.5)	22.0 (10.5–91.5)	36.0 (15.5–163.0)
Non-COVID-19	171 (75.5)	380.0 (298.0–485.0)	16.0 (5.0–37.0)	29.0 (9.0–64.0)

ED, emegency department; *IQR*, interquartile range; *WOS*, Web of Science.

article. Traditional citations remain the gold standard for academic recognition. However, the relationship between social media and citations supports the positive impact of researchers and scientific journals using social media to enhance the visibility and influence of their articles. Incorporating the impact of social media into the gold standard of citation counts could be a way to acknowledge this evolving landscape.

The results of a study examining the impact of promoting Cochrane systematic reviews in the field of pediatric EM using X and blog posts revealed a significant increase of 10 times in the AAS of the reviews.[17] The distribution pattern of articles on social media might vary based on the nature of the sharing. Infographics are visual representations of data meant to enhance engagement and streamline the key elements of a given study.[18] Some data suggests that presenting research findings visually on social media may lead to a 5–7 times higher number of interactions compared to studies without visual content.[19,20] Although using visual presentations to share results can reach a larger audience, this effect may only apply to specific areas of expertise.

The extent to which sharing influences the number of downloads and citations of a paper remains uncertain.[21] However, altmetrics today play a crucial role as markers for assessing the spread of content via social media to reach the intended audience. Temporal patterns in article altmetrics exhibit variation across different data sources. A study investigating altmetrics temporal trends reported that X engagement started and ended quickly, while Mendeley readership increased steadily over the next few years.[22] An excellent way to maintain interest in published articles is to use altmetrics data sources in combination with methods that engage the target audience and regularly update the content.

During the COVID-19 pandemic, there was a notable increase in the dissemination of information on social media platforms, with healthcare professionals using these platforms more frequently. Our analysis shows that nearly half of the top 200 publications in EM journals were published after the onset of the pandemic. Additionally, when evaluating the comprehensive altmetrics of articles in EM journals, we found there was a clear rise in mentions during 2020–2021. The evaluation undertaken in this study encompasses references made until the start of 2023. While future studies will determine whether this upward trend will persist, it is foreseeable that the surge in researchers using social media to monitor scientific information will continue as a result of the COVID-19 pandemic. This rise can be linked to the surge in sharing activities associated with COVID-19. Nevertheless, our investigation found no discernible distinction between AAS and WOS citations when comparing papers linked to COVID-19 and those unrelated to it.

LIMITATIONS

This study has several limitations, particularly its emphasis on quantitative data analysis and the use of a single data source. The current Altmetric database mainly emphasizes the number of mentions, and our analysis exclusively compared these metrics. In approximately 50% of the mentions on X we were unable to determine the country associated with the account. In addition to the increased interaction of the attributes of social media shares, it is more important to evaluate the relationship of the information to the target audience, reference, and download.[20] In the early part of the study, we analyzed all articles published in EM journals, but we made comparisons with traditional references for only 200 articles. In contrast to previous studies, we evaluated articles with the highest AAS instead of the altmetrics of the most cited articles in traditional reference indices. Another limitation of this study is the inability to fully differentiate the impact of increased social media usage during the COVID-19 pandemic on AAS. The surge in online content and interactions during the pandemic may have artificially inflated AAS values, particularly for articles published during this period, potentially affecting the relationship between AAS and traditional citation counts.

CONCLUSION

There has been a notable rise in Altmetrics Attention Scores in recent years, driven by increased use of social media for following scientific research, particularly during the COVID-19 pandemic. Articles focusing on toxicology, COVID-19, and resuscitation/critical care tend to receive the highest AAS. While no correlation was found between total AAS and citation counts from WOS and Google Scholar, there is a strong positive correlation between WOS citations and the number of Mendeley readers. Additionally, weak and moderate correlations were observed for mentions on X and blogs, respectively. Further research is needed to explore the relationship between altmetrics and traditional citation metrics, as well as the impact of social media on academic research visibility in EM.

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Effort During Ethanol Breath Testing Impacts Correlation with Serum Ethanol Concentration

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Introduction: The gold standard for quantifying ethanol intoxication in patients is serum testing. However, breath testing is faster, less expensive, and less invasive. It is unknown whether perceived effort during a breath ethanol test impacts the accuracy of the test and the correlation with serum concentration. In this study we analyzed whether perceived "poor" effort during breath ethanol testing would result in worse correlation than perceived "normal" breath-testing effort with respect to serum ethanol concentration.

Methods: Subjects were identified retrospectively over a 49-month period if they had both a breath ethanol test and a serum ethanol test obtained during the same ED visit within 60 minutes of each other, if they had their effort during the breath test recorded as "normal" or "poor" by the person administering the test, and had non-zero breath and serum ethanol concentrations. We completed descriptive and correlation analyses.

Results: A total of 480 patients were enrolled, 245 with normal and 235 with poor effort. The patients with normal breath-test effort had mean breath and serum concentrations of 0.19 grams per deciliter (g/dL) and 0.23 g/dL, respectively. The patients with poor breath-test effort had mean breath and serum concentrations of 0.19 and 0.29 g/dL, respectively. The correlation coefficient between breath and serum ethanol values was 0.92 (95% confidence interval (CI) 0.84–0.96) for good effort and 0.63 (95% CI 0.53–0.74) for poor effort.

Conclusion: The assessment of breath exhalation effort is meaningful in determining how well a patient's breath ethanol level correlates with the serum ethanol concentration. Poor breath effort, when compared to normal breath effort, was associated with higher ethanol levels as well as a larger difference and a greater variability between breath and serum values. If an accurate ethanol level is important for clinical decision-making, a physician should not rely on a poor-effort breathalyzer value. [West J Emerg Med. 2025;26(2)364–366.]

INTRODUCTION

Breath testing for ethanol has been discussed in medical literature for nearly 150 years.[1] Ethanol testing is often used in emergency departments (ED) and has historically included blood testing, breath testing, or both. Breath testing has been used as a surrogate for the gold standard serum testing and has distinct advantages over blood: it is faster, less invasive, and less expensive.[2] Despite longstanding study of the topic

and wide acceptance of its use, it has not been well established whether a poor expiratory effort, as judged by the tester, affects the accuracy of the test.

When administering a breath ethanol test, the operators of the device will often comment on the expiratory effort of the patient. The inference is that an effort deemed "poor" by the tester will not be as accurate as a "normal"-appearing expiratory effort. The impact of apparent exhalation effort on the correlation between breath and serum levels has not been clearly established. Clarifying this could impact patient care and could provide utility in forensic evaluation. Our primary objective in this study was to determine whether a patient's expiratory effort, as perceived by the tester, affected the breath ethanol test results when compared to serum. Secondary objectives included determining overall correlations between breath and blood testing within a single hospital encounter.

METHODS

This study was approved by the Health Partners institutional review board. A retrospective electronic health record (EHR) inquiry was performed to include all patients over a 49-month period who had breath ethanol testing with documented perceived exhalation effort ("normal" or "poor") and serum ethanol testing completed during a single ED visit at a large, tertiary-care hospital. At this hospital, the individual performing the breath test, typically an emergency medicine technician or registered nurse, chooses one of these two effort categories as an electronic checkbox when entering the ethanol value into the EHR. The assessment of effort is done using their own clinical judgment. All breath ethanol tests were performed using the Alco-Sensor FST (AlcoPro Inc, Knoxville, TN). All serum ethanol tests were done using the ARCHITECT c8000 (Abbott Laboratories, Abbott Park, IL).

Data collected for this study included the following: time of breath ethanol test; the patient's perceived breath testing effort; the result of the breath ethanol test; the time of the blood draw for serum ethanol testing; and the result of the serum ethanol test. Subjects were included if they had both a blood and breath ethanol test done within a 60-minute time interval. Subjects were excluded if either the breath or serum concentration was 0 grams per deciliter (g/dL). This was done because some of the blood draw and breath tests had enough time between them in the same subject such that a 0 g/dL value may have inaccurately impacted the correlation calculations, as the patient may have naturally reached a level of 0 g/dL well before the second test occurred.

Statistics

The associations between breath and serum ethanol levels, controlling for breath effort, appeared highly linear on initial graphical visualization of the data. Therefore, the relationships between these variables were explored further using a combination of zero-order Pearson correlations and linear regression. We examined the properties of breath ethanol concentrations, serum ethanol concentrations, and the associations between them.

RESULTS

A total of 480 subjects were included in the study. Of these subjects, 245 showed normal effort and 235 were documented as poor effort. Additionally, 237 patients had a time interval of less than 15 minutes between breath and serum values, 112 had a time interval of 16–30 minutes, and 131 had a time interval of 31–60 minutes. There were 184 patients who had blood drawn before the breathalyzer and 288 who had blood drawn after the breathalyzer; eight patients were tested concurrently. Among all patients, the mean breath ethanol was 0.19 g/dL, while the mean serum ethanol was 0.26 g/dL. The patients with normal breath test effort had mean breath and serum concentrations of 0.19 g/dL and 0.23 g/dL, respectively. The patients with poor breath test effort had mean breath and serum concentrations of 0.19 and 0.29 g/dL, respectively. The correlation coefficient between breath and serum was 0.92 (95% confidence interval [CI] 0.84-0.96) with normal effort and 0.63 (95% CI 0.53-0.74) with poor effort. Descriptive results and correlation analysis between the tests are presented in the Table. A plot displaying individual breath and serum values, as well as lines of best fit by effort group, is presented in the Figure.

Table. Patient ethanol levels (breath and serum; grams per deciliter) and correlation coefficients.

	Both effort groups	Normal effort	Poor effort
Number of patients	480	245	235
Mean breath EtOH	0.19	0.19	0.19
Mean serum EtOH	0.26	0.23	0.29
Mean EtOH difference within individual patients [95% CI]	−0.07 [0.09, −0.23]	−0.04 [0.04, −0.12]	−0.10 [0.10, −0.30]
Correlation coefficient between breath and serum [95% CI]	0.75 [0.7, 0.82]	0.92 [0.84, 0.96]	0.63 [0.53, 0.74]

EtOH, ethanol; *CI*, confidence interval.

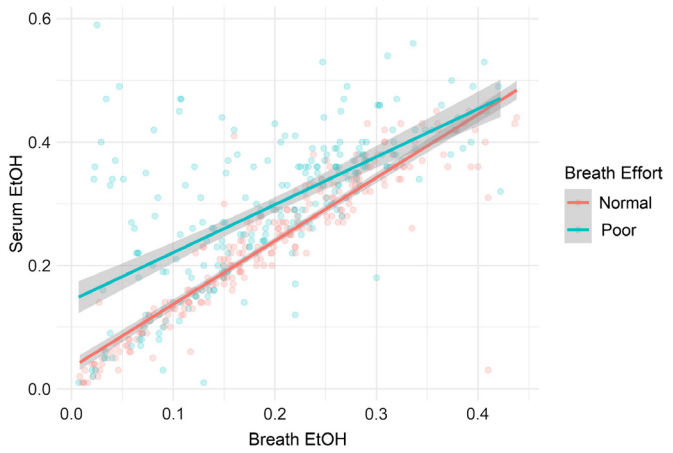

Figure. Plot of breath and serum ethanol values and lines of best fit for "normal"- and "poor" effort groups.

DISCUSSION

Our primary objective in this study was to determine whether the perceived level of expiratory effort during a breath ethanol test impacts the accuracy of the breath test when compared to a serum ethanol test. We documented the subject's effort as perceived by the tester because it reflects a common assessment in the clinical setting. Clinicians are often given the result of the breath test along with the assessor's subjective description of the breath effort.

The results of this study indicate that the assessment of breath exhalation effort is meaningful in determining how well a patient's breath ethanol level correlates with their serum ethanol concentration. While breath ethanol values were generally lower than serum ethanol values (regardless of effort), this difference was both greater and more variable among patients with poor effort. This is shown by a greater difference in values for those patients with poor effort (Table), by a higher standard deviation in difference values, and by a lower correlation coefficient in this group (Table and Figure). This is consistent with prior findings in a study by Gibb et al who examined whether "cooperativeness" with the breathalyzer was associated with differences in breath vs serum values.[2] Cooperation was defined as whether a patient "understood and followed through with the instructions to perform a smooth, forced expiration into the analyzer." While this was an informative study, in practice, documentation is related to effort and not to cooperation. Thus, our study is a more practical assessment of real-world experience.

The "poor effort" group also demonstrated substantially higher serum alcohol concentrations than the "normal effort" group (0.29 g/dL vs 0.23 g/dL). This is perhaps unsurprising and suggests possibly reduced ability to coordinate a good expiratory effort or less motivation to participate in testing. We did not extend the analysis past a 60-minute interval between breath and serum tests because any conclusions beyond this time frame were not felt to be clinically applicable. Analysis of subjects with a narrow time difference between breath and serum testing is important to minimize any possible impact of ongoing ethanol metabolism between execution of the different testing modalities.

LIMITATIONS

Assessment of patient expiratory effort in breath ethanol testing is a subjective measure. However, it is the same subjective measure assessed during real patient care. More formal measurement of expiratory capacity could add perspective and potentially accuracy as well. In addition, given the retrospective observational nature of our data, breath testing and blood samples for serum testing were often not performed simultaneously. We did use a narrow time frame for analysis, thus negating much metabolism. A prospective study obtaining blood samples for serum ethanol testing at the time of breath ethanol testing would be necessary to eliminate this potential confounder. Finally, while the breathalyzer used at our hospital is a commonly used device, other devices may be used elsewhere, and their measurement properties may vary.

CONCLUSION

Breath ethanol concentrations were generally lower than serum ethanol concentrations. Poor exhalation effort on breath ethanol testing correlated with a larger difference between breath and serum ethanol concentrations and with greater variability in the difference between the two. This can be relevant in clinical and forensic settings.

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Blood Pressure Variability and Outcome Predictors for Traumatic Brain Injury Patients with Diffuse Axonal Injury: A Retrospective Cohort Study

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Background: Diffuse axonal injury (DAI), a feature seen in severe traumatic brain injury (TBI), is associated with substantial morbidity and mortality. Although blood pressure variability (BPV) has been shown to impact TBI outcomes overall, its relevance in DAI cases remains uncertain. We investigated whether 24-hour post-injury BPV and other clinical factors were linked to patient outcomes.

Methods: We conducted a retrospective analysis of Level I trauma center-admitted TBI patients with radiographic DAI diagnosis (computed tomography/magnetic resonance imaging). Hospital disposition (home, nursing facility, hospice/death) and Glasgow Coma Scale (GCS) on hospital day 5 (HD5GCS) were outcomes of interest. We assessed associations with clinical factors using ordinal logistic regression.

Results: Among 153 patients (mean age 49 ± 20 years, 74% male), median admission GCS was 5.0 (3.0-12.5), HD5GCS was 8.0 (6.0-11), and median hospital stay was 25 (15.5-34.5) days. The BPV, measured as successive variation in systolic blood pressure (SBP_{SV}) and standard deviation in systolic blood pressure (SBP_{SD}), was not significantly associated with hospital disposition. SBP_{SV} and SBP_{SD} were also not associated with our secondary outcome of HD5GCS. Initial international normalized ratio (INR) (Coefficient -3.67, odds ratio [OR] 0.03, 95% confidence interval [CI] 0.00-0.70), cerebral contusion (Coeff -2.39, OR 0.09, 95% CI 0.01-0.75), and HD5GCS (Coeff 0.59, OR 1.80, 95% CI 1.30-2.49) were associated with increased odds of discharge to hospice or death. Administration of blood products (Coeff 1.06, OR 2.89, 95% CI 1.10-7.60), vasopressors (Coeff 1.40, OR 4.05, 95% CI 1.37-11.96), and hyperosmolar therapy (Coeff 1.23, OR 3.41, 95% CI 1.36-8.54), and concurrent intraventricular hemorrhage (Coeff 0.99, OR 2.70, 95% CI 0.86-6.49) were linked to poorer HD5GCS.

Conclusion: Blood pressure variability was not correlated with outcomes in patients with diffuse axonal injury. Low Glasgow Coma Score on hospital day 5, high initial INR, and concomitant cerebral contusion were associated with poorer outcomes. [West J Emerg Med. 2025;26(2)367–377.]

BACKGROUND

Diffuse axonal injury (DAI), also referred to as traumatic axonal injury, is an increasingly recognized component of traumatic brain injury (TBI), now estimated to occur in over 40% of patients hospitalized with other forms of TBI.[1,2] DAI is caused by rotational acceleration-deceleration inertial forces that shear the white matter tracts in the brain. This mechanism disrupts axonal transport, leading to axonal swelling, secondary axonal disconnection, and subsequent degeneration.[3] This injury is most often associated with high-velocity events, such as motor vehicle collisions or long falls from height. Clinical manifestations can vary widely, ranging from minimal significance to profound neurological impairment, depending on injury severity.

Severe cases of DAI often lead to persistent comas or substantial deficits in neurological recovery and are associated with significant mortality.[4] Lesions associated with DAI may not initially be apparent or detectable on computed tomography (CT); patients with suspected DAI—often due to persistence of poor mental status in the absence of significant edema on CT or following neurosurgical evacuation of extra-axial hematoma—are often evaluated with magnetic resonance imaging (MRI) for diagnosis.[4,5] The severity of DAI appreciated on MRI is characterized according to the degree and location of identified white matter lesions; Grade 1 is primarily associated with lesions in the cortex, Grade 2 in the corpus callosum, and Grade 3 in the brainstem.[6]

Given the variability in clinical manifestations and potentially high rates of cognitive morbidity and mortality associated with DAI, numerous studies have sought to identify features associated with improved or poor patient outcomes, such as radiographic findings, initial Glasgow Coma Scale (GCS) scores, and hypertension (defined as systolic blood pressure [SBP] ≥160 millimeters of mercury (mm Hg), among others.[4,7–9] The role of blood pressure variability (BPV) has not yet been investigated in patients with DAI; BPV describes oscillations in blood pressure between consecutive measurements or within a defined timeframe. Variations in blood pressure are common after TBI, possibly due to impaired cerebrovascular autoregulation or decreased "baroreflex sensitivity" as a result of the injury, and prior research suggests a link to poor outcomes.[10]

Blood pressure variability has been associated with deviations from optimal cerebral perfusion pressures (CPPopt), which are in turn linked to unfavorable outcomes in TBI patients.[11] We have previously investigated the connection between BPV and outcomes in patients with traumatic intraparenchymal hemorrhage and found an association with lower rates of discharge to home, indicating worse functional outcomes upon discharge.[12] In addition to TBI, BPV has been previously associated with adverse outcomes in ischemic cerebrovascular accidents and spontaneous intracranial hemorrhage (ICH).[13–17]

Population Health Research Capsule

What do we already know about this issue?
Blood pressure variability (BPV) has been associated with poorer outcomes in patients with traumatic brain injury (TBI).

What was the research question?
Is BPV associated with worse disposition outcomes in TBI patients with diffuse axonal injury (DAI)?

What was the major finding of the study?
For TBI patients with DAI, blood pressure variability did not impact discharge destination.

How does this improve population health?
While BPV was not associated with poorer outcomes in our study, further studies are needed to determine whether other interventions can impact outcomes in these patients.

In this study we investigated the impact of BPV in the initial 24 hours following hospital arrival on outcomes in patients with DAI and evaluated clinical features that may correlate with patient outcomes, with the goal of improving the accuracy of prognostic assessments and providing important information to guide future strategies in managing post-injury TBI and patients diagnosed with or suspected of having DAI.

METHODS

Study Setting

This study was performed at R. Adams Cowley Shock Trauma Center, a regional, quaternary trauma center and neurotrauma specialty center that admits trauma patients directly from the field and acts as a referral center for other hospitals within the state. Upon arrival at our institution, patients are first evaluated by the trauma team and undergo appropriate screening imaging studies, including CT, as clinically indicated. Patients with identified ICH or contusion are evaluated emergently by the neurosurgery team. Patients with CT or clinical characteristics suggestive of DAI subsequently undergo a brain MRI for confirmation and further characterization of disease severity when they are clinically stable enough to tolerate MRI. Previous studies have identified that radiographic presence of DAI on MRI is

itself independently associated with poor outcomes[7,18]; thus, we chose patients who also had an MRI performed during their acute hospitalization within 30 days from their admission even if DAI was suspected on their initial CT images. This approach allowed us to better evaluate specific radiographic features such as hemorrhagic volume of burden and lesion location.

Study Design, Patient Selection, and Data Collection

We conducted a retrospective cohort study of all adult trauma patients (≥18 years old) admitted to our hospital between January 1, 2016–December 31, 2019 with the diagnosis of TBI. Patients with radiographic evidence of DAI who underwent both CT and MRI within 30 days of admission were eligible. We excluded patients who did not have complete clinical information or imaging studies. Patients with a radiographic diagnosis of DAI were identified from our institution's Radiology Information System, a database used for the management of radiographic images; further data was collected from the patient's electronic health record (EHR).

Data abstraction followed previously published methodological guidelines on retrospective chart review.[19] Prior to data collection, investigators evaluated sets of five patient charts and directly compared their findings to those of the senior investigator and principal investigator (Q.T.) until accuracy reached 90%. Data collectors were not blinded to the hypothesis. Radiographic information was interpreted and provided by an attending radiologist. An Excel spreadsheet (Microsoft Corporation, Redmond, WA) with standardized categories was used to record clinical data from de-identified patients.

Demographics and clinical data of interest, selected a priori according to a previous study,[18] included the following: patient's age; sex; past medical history; serum lactate level; international normalized ratio (INR); mechanism of injury; initial GCS at admission and highest recorded GCS at hospital day 5 (HD5GCS); administration of blood products (packed red blood cells, fresh frozen plasma, platelets, cryoprecipitate); vasopressors (norepinephrine, vasopressin, or epinephrine are the most commonly used vasopressors for this patient population at our institution); hyperosmolar therapy (hypertonic saline or mannitol); intravenous (IV) antihypertensives, antiepileptic medications, location and volume of DAI burden; concurrent presentation with seizures, intracranial contusion, intracerebral hemorrhage, intraventricular hemorrhage (IVH), or subarachnoid hemorrhage (SAH); and all recorded SBP measurements within the first 24 hours of admission. For patients who left the hospital or expired before hospital day 5, their HD5GCS levels were input as 3 (for expired patients) or the last recorded GCS prior to hospital discharge.

Blood Pressure Variability

All blood pressure measurements were collected as they were recorded in patients' charts by nursing staff. Our institution's clinical standard dictates that patients admitted to intensive care units have at least one set of vital signs documented per hour. We collected all blood pressure measurements, as documented by our nursing staff, even if they exceeded more than one set of vital signs per hour. Methodology of obtaining blood pressure, either by manual blood pressure cuff, automatic blood pressure cuff, or by arterial blood pressure monitoring (radial or femoral access) was decided by the bedside clinicians. At our institution, invasive monitoring with arterial blood pressure monitoring is strongly encouraged for all patients who receive antihypertensives or vasopressor infusions. For patients who had documentation of both arterial blood pressure and cuff pressure, we collected the arterial blood pressure values.

Blood pressure variability quantifies blood pressure fluctuations over a specified time interval. The BPV can be studied with respect to SBP, diastolic blood pressure, and mean arterial pressure (MAP). Here, we examined variability in SBP, as specific SBP goals are traditionally used for management of patients with ICH or TBI.[20] We evaluated three different modalities of measuring and reporting systolic BPV: successive variation of systolic blood pressure (SBP_{SV}); standard deviation in systolic blood pressure (SBP_{SD}); and coefficient of variation in systolic blood pressure (SBP_{CV}).[21] We also collected SBP_{max} and SBP_{min} from the first 24 hours of admission. The SBP_{SV} is the square root of the averaged squared difference between any two successive SBP measurements and demonstrates the rate of change between consecutive measurements. The SBP_{SD} represents the extent of variation or dispersion of individual SBP measurements around the average SBP within a given timeframe, indicating the level of fluctuation or stability in blood pressure values. The SBP_{CV} is calculated as the ratio of the standard deviation of SBP to the mean SBP and offers a standardized measure of SBP variability relative to the average SBP.

Imaging Analysis

The presence of DAI was established based on MRI findings, which were interpreted and documented by an attending radiologist. The imaging information provided included the location of DAI within seven regions: the corpus callosum; basal ganglia; thalami; parahippocampal region; cerebellum; brainstem; and gray-white junction. The volume of DAI hemorrhage burden noted on susceptibility weighted images was measured in each location using the 3D slicer version 4.10 2 (https://www.slicer.org) sphere brush paint tool and quantification module. Additionally, presence or absence of concomitant injuries, specifically contusion, SAH, IVH, and intraparenchymal hemorrhage, were documented using radiology reports.

Outcomes

Our primary outcome was hospital discharge disposition, used as a surrogate marker for neurocognitive disability at discharge among patients with TBI. Discharge destinations included home, rehabilitation facilities, and hospice/death. Being discharged home directly from the hospital signifies a favorable outcome with a higher likelihood of functional recovery and preservation of independent living. On the other hand, being discharged to a rehabilitation facility suggests the need for ongoing support and therapy due to significant neurologic deficits.[22] Hospice/death represents the poorest outcome. The secondary outcome of HD5GCS has been shown to have prognostic value in predicting long-term outcomes and is considered an important indicator of neurological recovery in patients with spontaneous ICH.[23,24]

Statistical Analysis

We used descriptive statistics to present continuous data as mean (standard deviation) or median (interquartile range), depending on the distribution of the data after the data's histograms were inspected. The *t*-test or Mann-Whitney U test was employed for continuous data comparisons, while categorical data comparisons were conducted using the chi-square test or Fisher exact test, as appropriate. We used ordinal logistic regressions for the outcomes of both hospital disposition and HD5GCS. Hospital disposition was ranked in three orders from lowest to highest severity: 0 (home); 1 (rehabilitation); and 2 (hospice/death). Patients' HD5GCS scores were ranked in order from 0 (GCS 3-8), 1 (GCS 9-12), 2 (GCS 13-14), or 3 (GCS 15). For the ordinal logistic regressions, the coefficients represent the association of the independent variables and the outcomes. A positive coefficient indicated increased odds of association with the lowest number rank (rank 0), while a negative coefficient was associated with the highest rank of the outcomes.

We performed all descriptive analyses and ordinal regressions with Minitab version 19 (Minitab LLC, State College, PA). All analyses with 2-tail $P = < 0.05$ were considered statistically significant.

RESULTS

Patient Characteristics

From the initial 174 patients identified in the EHR fitting our inclusion criteria, we included 153 in the final analysis. The remaining 23 patients were excluded due to inadequate recording of blood pressure, laboratory, or other clinical data (Figure). The mean age of included patients was 49 years (SD 20), and 113 (74%) were male (Table 1). Motor vehicle collisions were the most common mechanism of injury, accounting for 66% of the patients' cause of injuries. Median GCS at admission was 5 (3-13). Among the study population, 141 patients (92%) required mechanical ventilation during their stay, and 94 patients (61%) underwent a tracheostomy

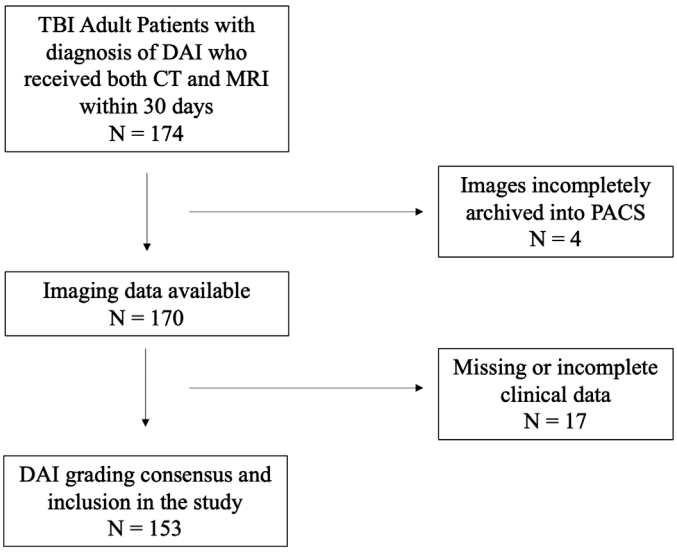

Figure. Flow diagram for patient selection.
TBI, traumatic brain injury; *CT*, computed tomography; *MRI*, magnetic resonance imaging; *PACS*, picture archiving and communication system.

procedure. The most common location of DAI burden was the corpus callosum (58%) followed by the parahippocampus (35%), basal ganglia (27%) and thalami (25%) (Table 1). Within the first 24 hours, all patients had received some form of opioid medication, 98% of the patients received IV fluids (IVF), 95% received a sedative medication, 87% received an anti-epileptic medication, and 82% required vasopressor support (Table 2).

Primary Outcome: Hospital Disposition

Our analysis identified no significant association between two separate measurements of BPV– SBP_{SV} (Coefficient -0.02, OR 0.98, 95% CI 0.87-1.10, $P = 0.74$) and SBP_{SD} (Coeff 0.03, OR 0.97, 95% CI 0.81-1.16, $P = 0.74$)–and hospital disposition among patients admitted for TBI and diagnosed with DAI. We found that 11.8% of patients with DAI either died in the hospital or were discharged to hospice care. This group of patients had a higher mean age of 63 (19) and lower GCS scores at 24 hours and 5 days (5 [4-6.3] for both) than survivors (Table 1). All these patients required intubation, all were diagnosed with a concurrent brain contusion, and 94% had a concurrent IVH. The corpus callosum was identified as the predominant location of DAI among patients who died, and a higher volume of hematoma was observed in the corpus callosum of this group when compared to survivors (Table 1). No significant differences were found in terms of sex, past medical history of hypertension and diabetes, or mechanism of injury.

We used ordinal logistic regression analysis to investigate the relationship between demographic and clinical factors and the likelihood of a significant discrepancy in the primary

Table 1. Demographics and clinical features of patients with diffuse axonal injuries for the outcome of mortality.

	All patients N = 153	**Alive N = 135**	**Dead/hospice N = 18**	***P*-value**
Age, years, mean (SD)	49 (20)	47 (19)	63 (19)	**0.002**
Sex, N (%)				
Male	113 (74)	99 (73)	14 (78)	0.67
Female	40 (26)	36 (27)	4 (22)	0.67
Past medical history, N (%)				
Hypertension	75 (49)	67 (50)	8 (44)	0.68
Diabetes	17 (11)	16 (12)	1 (6)	0.30
Clinical variables				
Hospital lengths of stay (days), median [IQR]	25.0 [15.5–34.5]	26.2 [17.9–37.1]	13.3 [8.3–17.0]	<**0.001**
GCS at admission, median [IQR]	5 [3–12]	6 [3–13]	4 [3–7]	0.16
GCS at 24 hours, median [IQR]	7 [5–10]	7 [6–15]	5 [4–6]	<**0.001**
GCS at 5 days, median [IQR]	8 [6–11]	9 [6–11]	5 [4–6]	<**0.001**
GCS 3–8, N (%)	83 (54)	67 (50)	16 (89)	<**0.001**
GCS 9–12, N (%)	41 (27)	40 (30)	1 (6)	<**0.001**
GCS 13–14, N (%)	14 (9)	14 (10)	0 (0)	<**0.001**
GCS 15, N (%)	14 (9)	14 (10)	0 (0)	<**0.002**
Admission lactate, mean (SD) (mg/dL)	3.8 (2.4)	4.0 (2.4)	3.0 (1.4)	**0.01**
Admission INR, mean (SD)	1.2 (0.3)	1.2 (0.18)	1.4 (0.6)	0.11
Mechanical ventilation, N (%)	141 (92)	123 (91)	18 (100)	<**0.001**
Tracheostomy, N (%)	94 (61)	92 (68)	2 (11)	<**0.001**
EVD, N (%)	57 (37)	51 (38)	6 (33)	0.71
Any IPH, N (%)	39 (25)	33 (24)	6 (33)	0.45
Any IVH, N (%)	93 (61)	76 (56)	17 (94)	<**0.001**
Any SAH, N (%)	125 (82)	111 (82)	14 (78)	0.67
Any contusion, N (%)	129 (84)	111 (82)	18 (100)	<**0.001**
Any seizure during hospitalization, N (%)	25 (16)	23 (17)	2 (11)	0.46
Any pneumonia	24 (16)	21 (16)	3 (17)	0.91
Any ARDS, N (%)	74 (48)	67 (50)	7 (39)	0.38
Mechanism of injury N (%)				
MVC	101 (66)	91 (67)	10 (56)	0.34
Fall	26 (17)	22 (16)	4 (22)	0.57
Penetrating trauma	1 (0.6)	1 (0.7)	0 (0)	0.32
Other blunt trauma	25 (16)	21 (16)	4 (22)	0.52
Location of injury, N (%)				
Corpus callosum	88 (58)	74 (55)	14 (78)	**0.03**
Basal ganglia	41 (27)	39 (29)	2 (11)	**0.03**
Thalami	38 (25)	35 (26)	3 (17)	0.33
Parahippocampus	53 (35)	47 (35)	6 (33)	0.90
Cerebellum	32 (21)	28 (21)	4 (22)	0.89
Brainstem	68 (44)	59 (44)	9 (50)	0.62
Volume of burden by location of injury, (mm^3) median [IQR]				
Gray-white matter junction	1.4 [0.5–4.8]	1.4 [0.5–4.2]	1.7 [0.17–9.5]	0.73

(*Continued on next page*)

Table 1. Continued.

	All patients N = 153	Alive N = 135	Dead/hospice N = 18	*P*-value
Corpus callosum	0.02 [0–0.2]	0.02 [0–0.2]	0.2 [0.003–0.5]	**0.04**
Basal ganglia	0 [0–0.01]	0 [0–0.03]	0 [0–0]	0.17
Thalami	0 [0–0]	0 [0–0]	0 [0–0.5]	0.57
Parahippocampus	0 [0–0.03]	0 [0–0.03]	0 [0–0.2]	0.89
Cerebellum	0 [0–0]	0 [0–0]	0 [0–0.03]	0.75
Brainstem	0 [0–0.1]	0 [0–0.04]	0.01 [0–0.3]	0.30

Bolded values indicate statistical significance.
CI, confidence interval; *IQR*, interquartile range; *GCS*, Glasgow Coma Score; *mg*, milligram; *dL*, deciliter; *INR*, international normalized ratio; *EVD*, external ventricular drain; *IPH*, intraparenchymal hemorrhage; *IVH*, intraventricular hemorrhage; *SAH*, subarachnoid hemorrhage; *ARDS*, acute respiratory distress syndrome; *MVC*, motor vehicle collision; *mm*, millimeter.

Table 2. Clinical features within 24 hours for patients with diffuse axonal injuries.

	All patients N = 153	Alive n = 135	Dead/hospice n = 18	*P*-value
Clinical interventions N (%)				
Any IVF	150 (98)	132 (98)	18 (100)	0.08
Any anti-seizure medication	133 (87)	118 (87)	15 (83)	0.66
Any hyperosmolar therapy	85 (56)	73 (54)	12 (67)	0.29
Any opioid	153 (100)	135 (100)	18 (100)	1.00
Any sedative	146 (95)	128 (95)	18 (100)	0.01
Any antihypertensive	102 (67)	88 (65)	14 (78)	0.24
Any vasopressor	123 (82)	108 (80)	15 (83)	0.72
Any tracheostomy	94 (61)	92 (68)	2 (11)	<0.001
Any blood products N (%)				
Platelets	19 (12)	15 (11)	4 (22)	0.27
PRBC	103 (67)	89 (66)	14 (78)	0.26
FFP	34 (22)	27 (20)	7 (39)	0.12
Cryoprecipitate	4 (3)	3 (2)	1 (6)	0.55
No blood products	103 (67)	95 (70)	8 (44)	0.04
Blood pressure variability				
SBP_{max}, mean (SD)	166 (40)	166 (39)	169 (53)	0.77
SBP_{min}, mean (SD)	97 (27)	97 (27)	92 (32)	0.52
$SBP_{max-min}$, mean (SD)	69 (35)	68 (33)	77 (43)	0.41
SBP_{SV}, mean (SD)	20.2 (9.4)	20.0 (9.4)	21.8 (9.2)	0.45
SBP_{SD}, mean (SD)	20.3 (8.8)	20.1 (8.9)	21.8 (8.2)	0.42
SBP_{CV}, mean (SD)	0.15 (0.07)	0.15 (0.07)	0.16 (0.01)	0.76
Hospital disposition, N (%)				
Home	12 (8)	12 (9)	0 (0)	<0.001
Nursing facility	123 (80)	123 (91)	0 (0)	<0.001

DAI, diffuse axonal injury; *IVF*, intravenous fluid; *PRBC*, packed red blood cells; *FFP*, fresh frozen plasma; *SBP*, systolic blood pressure; *max*, maximum; *min*, minimum; SBP_{SV}, systolic blood pressure successive variation; SBP_{SD}, systolic blood pressure standard deviation; SBP_{CV}, systolic blood pressure coefficient of variation.

Table 3. Results from ordinal logistic regression assessing association between patients' demographic and clinical factors and patients' disposition, where order of hospital disposition was ranked from 0 = home, 1 = acute rehab, to 2 = hospice/death. All independent variables reported in this table were added in the model.

Variables	OR	95% CI	*P*-value	Coefficient
Age	0.97	0.93–1.00	**0.05**	–0.03
Sex: female	0.88	0.20–3.86	0.86	–0.13
Past medical history				
Hypertension	3.47	0.80–14.97	0.10	1.24
Diabetes	0.49	0.05–4.78	0.49	–0.72
Clinical factors				
Initial lactate	1.21	0.89–1.66	0.23	0.19
Initial INR	0.03	0.00–0.70	**0.03**	–3.67
Any blood products	0.36	0.08–1.58	0.18	–1.02
Any vasopressors	0.58	0.11–2.95	0.51	–0.54
Any hyperosmolar	0.75	0.17–3.33	0.71	–0.28
Any anti-hypertensives	0.22	0.04–1.06	0.06	–1.53
Any seizure	2.72	0.40–18.68	0.31	1.00
Any contusion	0.09	0.01–0.75	**0.03**	–2.39
Any AED	3.73	0.49–28.60	0.21	1.32
GCS at 5 days	1.80	1.30–2.49	<**0.001**	0.59
Location and burden of injury				
Corpus callosum	0.38	0.08–1.75	0.22	–0.96
Basal ganglia	5.02	1.02–24.62	**0.05**	1.61
Thalami	0.25	0.05–1.34	0.11	–1.37
Parahippocampus	1.27	0.26–6.26	0.77	0.24
Cerebellum	0.89	0.18–4.40	0.88	–0.12
Brainstem	0.71	0.18–2.82	0.63	–0.34
Any SAH	7.26	1.14–46.42	**0.04**	1.98
Any IVH	0.35	0.08–1.60	0.18	–1.05
Any IPH	2.94	0.68–12.80	0.15	1.08

Bolded *P*-values indicate statistical significance.
OR, odds ratio; *CI*, confidence interval; *GCS*, Glasgow Coma Score; *INR*, international normalized ratio; *AED*, antiepileptic drugs; *IPH*, intraparenchymal hemorrhage; *IVH*, intraventricular hemorrhage; *SAH*, subarachnoid hemorrhage.

Table 4. Results from ordinal logistic regression assessing association between blood pressure variability and patients' disposition, where order of hospital disposition was ranked from 0 = home, 1 = acute rehab, to 2 = hospice/death.

Blood pressure variability	OR	95% CI	*P*-value	Coefficient
SBP_{max}	1.00	0.96–1.04	0.92	–0.002
SBP_{min}	1.00	0.96–1.05	0.92	0.002
SBP_{SV}	0.98	0.87–1.10	0.74	–0.02
SBP_{SD}	0.97	0.81–1.16	0.74	–0.03

OR, odds ratio; *CI*, confidence interval; *SBP*, systolic blood pressure; SBP_{SV}, systolic blood pressure successive variation; SBP_{SD}, systolic blood pressure standard deviation; SBP_{CV}, systolic blood pressure coefficient of variation.

outcome of disposition (Table 3). The SBP variation measurements did not demonstrate an association with the disposition outcome (Table 4). Other clinical factors such as age, contusions, GCS scores, basal ganglia involvement, and the presence of SAH were found to be associated with discharge destination.

Among the demographic factors, age demonstrated a marginal association with the outcome (OR 0.97, 95% CI 0.93-1.00, $P = 0.05$, Coeff -0.03), suggesting that younger patients may be more likely to achieve favorable outcomes in terms of disposition. The presence of any cerebral contusion (OR 0.09, 95% CI 0.01-0.75, $P = 0.03$, Coeff -2.39) and higher initial INR (OR 0.03, 95% CI 0.00-0.70, $P = 0.03$, Coeff -3.67) correlated with poor disposition outcomes. These negative coefficients indicate that if there is contusion present or the value of the initial INR increases, the association with higher outcome numbers strengthens; in this case the highest outcome number is hospice/death.

Additionally, we identified GCS at five days as a significant factor affecting the outcomes of disposition (OR 95% CI 1.30-2.49, $P = < 0.001$, Coeff 0.59). Higher GCS scores at five days were strongly associated with an increased probability of achieving more favorable outcomes, such as discharge to home or rehabilitation. Regarding the location of burden, patients with involvement of the basal ganglia had poorer prognosis (OR 5.02, 95% CI 1.02-24.62, $P = 0.05$, Coeff 1.61). The presence of SAH was unexpectedly identified with better disposition outcomes (OR 7.26, 95% CI 1.14-46.42, $P = 0.04$, Coeff 1.98).

Secondary Outcome: GCS at Hospital Day 5

The SBP_{SV} (Coeff 0.02, OR 1.02, 95% CI 0.95-1.1, $P = 0.51$) and SBP_{SD} (Coeff 0.02, OR 1.02, 95% CI 0.91-1.13, $P = 0.75$) were not associated with our secondary outcome of HD5GCS (Table 5). Receiving any blood products (OR 2.89, 95% CI 1.10-7.60, $P = 0.03$, Coeff 1.06), as well as treatment with vasopressors (OR 4.05, 95% CI 1.37-11.96, $P = 0.01$, Coeff 1.40), hyperosmolar therapy (OR 3.41, 95% CI 1.36-8.54, $P = 0.01$, Coeff 1.23), and the presence of concurrent IVH (OR 2.70, 95% CI 0.86-6.49, $P = 0.03$, Coeff 0.99) were all associated with an increased likelihood of a lower HD5GCS (Table 6). On the other hand, the use of antiepileptic drugs (OR 0.27, 95% CI 0.07-0.99, $P = 0.05$, Coeff -1.31) was associated with an increased likelihood of a higher HD5GCS.

DISCUSSION

In this study we investigated the impact of 24-hour systolic BPV on outcomes in patients diagnosed with DAI and sought to identify relevant clinical features that may correlate with patient outcomes to improve prognostic assessments. We did not find a significant association between BPV and outcomes in patients with DAI. This stands in contrast to prior studies, such as that by Svedung Wettervik et al, who linked BPV to deviations from optimal CPPopt and unfavorable outcomes in patients with TBI.[25] It has been proposed that the negative impact of BPV on patient outcomes may be attributed to the development of compromised cerebral blood flow regulation in TBI and the potential for secondary injuries such as cerebral hypoperfusion or hyperemia; however, the exact pathways and underlying processes are not fully understood.[26,27] There are also several nuances, such as the duration and frequency of BPV monitoring, the timing of BPV in relation to the onset of injury, and the sensitivity of different BPV parameters, such as diastolic blood pressure or MAP variability, that require additional investigation and may also play a role in predicting outcomes.[28,29]

It is also unknown what role blood pressure management might play in mitigating the impacts of BPV. It is standard practice at our institution to manage hypertension (defined at the time of this study as SBP >160 mm Hg for patients with TBI) and hypotension (MAP <65 mm Hg) in patients with TBI using titratable infusions of antihypertensives and vasopressors. Strict management of blood pressure may have dampened BPV and limited our ability to detect an effect on patient outcomes. Lastly, BPV may have no impact on improving the damage caused by axonal shearing in DAI, or in preventing secondary axotomy. Additional studies are needed to clarify the interplay between BPV, cerebral hemodynamics, and DAI pathology, as well as to determine the most relevant and sensitive BPV parameters for predicting outcomes.

Table 5. Results from ordinal logistic regression assessing association between blood pressure variability and patients' hospital day five Glasgow Coma Score (GCS), which was ranked in order from 0 (GCS 3-8), 1 (GCS 9-12), 2 (GCS 13-14), 3 (GCS 15).

Blood pressure variability	OR	95% CI	*P*-value	Coefficient
SBP_{max}	0.99	0.96–1.02	0.38	–0.01
SBP_{min}	1.01	0.98–1.04	0.41	0.01
SBP_{SV}	1.02	0.95–1.10	0.51	0.02
SBP_{SD}	1.02	0.91–1.13	0.75	0.02

GCS, Glasgow Coma Score; *OR*, odds ratio; *CI*, confidence interval; *SBP*, systolic blood pressure; SBP_{SV}, systolic blood pressure successive variation; SBP_{SD}, systolic blood pressure standard deviation; SBP_{CV}, systolic blood pressure coefficient of variation.

Table 6. Results from ordinal logistic regression assessing association between patients' demographic and clinical factors and patients' hospital day five Glasgow Coma Score (GCS), which was ranked in order from 0 (GCS 3-8), 1 (GCS 9-12), 2 (GCS 13-14), 3 (GCS 15). All independent variables reported in this table were added in the model.

Variables	OR	95% CI	*P*-value	Coefficient
Age	1.01	0.99–1.04	0.27	0.01
Sex: female	1.39	0.54–3.57	0.50	0.33
Past medical history				
Hypertension	0.74	0.29–1.88	0.53	–0.30
Diabetes	1.06	0.23–5.02	0.94	0.06
Clinical factors				
Initial lactate	1.00	0.84–1.19	0.98	0.003
Initial INR	3.80	0.58–24.93	0.16	1.33
Any blood products	2.89	1.10–7.60	**0.03**	1.06
Any vasopressors	4.05	1.37–11.96	**0.01**	1.40
Any hyperosmolar	3.41	1.36–8.54	**0.01**	1.23
Any anti-hypertensives	2.36	0.94–5.93	0.07	0.86
Any seizure	0.42	0.14–1.29	0.13	–0.86
Any contusion	1.18	0.36–3.88	0.78	0.17
Any AED	0.27	0.07–0.99	**0.05**	–1.31
Location of burden				
Corpus callosum	1.13	0.42–3.06	0.80	0.13
Basal ganglia	0.81	0.27–2.40	0.70	–0.21
Thalami	1.17	0.36–3.73	0.80	0.15
Parahippocampus	1.28	0.45–3.63	0.65	0.24
Cerebellum	1.03	0.33–3.21	0.96	0.03
Brainstem	3.24	1.33–7.86	**0.01**	1.17
Gray-white matter junction	0.39	0.01–17.59	0.63	–0.93
Any SAH	2.58	0.86–7.73	0.09	0.95
Any IVH	2.70	0.86–6.49	**0.03**	0.99
Any IPH	1.47	0.52–4.18	0.47	0.39

Bolded *P*-values indicate statistical significance.
GCS, Glasgow Coma Score; *OR*, odds ratio; *CI*, confidence interval; I*NR*, international normalized ratio; *AED*, antiepileptic drugs; *IPH*, intraparenchymal hemorrhage; *IVH*, intraventricular hemorrhage; *SAH*, subarachnoid hemorrhage.

Our study revealed several clinical factors correlating with patient outcomes, specifically increased initial INR, concurrent cerebral contusion, and low GCS at hospital day 5. Our identification of initial INR as a poor prognostic factor with respect to hospital disposition contributes to the growing body of evidence on the association between coagulopathy and poor clinical outcomes in patients with TBI, specifically those with DAI.[30,31] The disturbance in coagulation status at admission may exacerbate bleeding and contribute to a poorer prognosis. Coagulopathy induced by TBI follows a distinct pathogenic pathway, separate from coagulopathy induced by extracranial trauma and hemorrhagic shock. It can involve disruptions in the blood-brain barrier, which allow leakage of fluid and release procoagulant substances. These substances may also accelerate and enhance fibrinolysis. Early monitoring and management of coagulation abnormalities hold the potential to improve patient survival and reduce rates of mortality.[30]

Concurrent cerebral contusions, which contribute to secondary brain injury, and low GCS scores at day 5 of hospitalization, while not always intervenable, play crucial roles in identifying patients at higher risk of poor neurologic outcomes. Although our findings show that concurrent IVH in patients with DAI was not associated with increased mortality, it was associated with lower HD5GCS, which is a

predictor of poor outcomes. These results align with prior research that suggests that the presence of IVH is associated with severe DAI.[32]

This study also highlighted that patients who received blood products, vasopressors, or hyperosmolar therapy in the first 24 hours of admission had a higher likelihood of a low GCS score at hospital day 5. This follows clinical reasoning in suggesting that these therapies and interventions are more common among patients with more severe impairment in neurological function who are at higher risk for poorer outcomes, although based on our findings we cannot conclude whether these therapies themselves may be a driver of poor outcomes. The presence of IVH was also associated with a higher likelihood of a lower GCS score, further emphasizing the impact of concurrent IVH on neurological impairment. In contrast, the use of antiepileptic drugs (AED) was associated with a higher likelihood of achieving a higher GCS score on hospital day 5, suggesting a potential beneficial effect of AEDs in preserving neurological function. Within this context, it is interesting to note that there was no significant association between seizure during admission and HD5GCS. Further studies are needed to establish a conclusive association between AED use and improved GCS scores in DAI patients, and to investigate whether this association varies across different AEDs. (Our institution typically uses a prophylactic regimen of levetiracetam 1.5 grams [g] followed by 1g BID for seven days.) The potential neuroprotective effects of AEDs warrant additional investigation.

LIMITATIONS

The retrospective design of our study and the reliance on EHR for data collection introduced inherent biases and constraints to accuracy of data collection that we were unable to audit, such as the possibility of manual input errors or inaccurate time measurements. It is important to acknowledge that the collection of blood pressure values in our study lacked standardization. Variations in the type of equipment used, whether invasive or non-invasive readings were employed, and the timing of data collection could have introduced variability into the measured BP values.

As patients with DAI are associated with severe TBI, our population was also likely to have been more critically ill. This is also evidenced by the percentage of our study population requiring mechanical ventilation (92%) and eventual tracheostomy (61%). This may have introduced an indication bias, in which there was closer monitoring and tighter control of blood pressure parameters. Another limitation is that our analysis was conducted at a single center, which is a regional, quaternary trauma and neurotrauma specialty center. This setting potentially limits the generalizability of our findings to patients with DAI presenting in other healthcare settings. Variations in patient characteristics, treatment protocols, and access to resources across different centers may influence the observed associations. Additionally, the relatively small sample size of our study may have limited the statistical power to detect smaller associations between BPV and DAI outcomes.

CONCLUSION

Patients with radiographically diagnosed diffuse axonal injuries face high rates of morbidity and mortality; only 8% of patients within our study population were discharged home directly from the hospital. Blood pressure variability was not identified as a predictor of discharge disposition. We identified that Glasgow Coma Score at hospital day 5, initial INR, and concurrent cerebral contusion as potential drivers of poor outcomes. It is unclear from our study whether interventions aimed at these variables (eg, correcting an elevated INR) would have affected patients' outcomes, or whether tight control of patients' blood pressures with titratable infusions (both antihypertensives and vasopressors) may have masked the impact of BPV on outcomes.

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