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Journal

Western Journal of Emergency Medicine: Integrating Emergency Care with Population Health, 25(5)

ISSN

1936-900X

Author

Valenzi, Nicole

Publication Date

2024-09-18

DOI

10.5811/westjem.35466

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WestJEM

Volume 25, Number 5, September 2024 Open Access at WestJEM.com ISSN 1936-900X

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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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Methadone Initiation in the Emergency Department for Opioid Use Disorder

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Section Editor: Marc Martel, MD
Submission history: Submitted October 26, 2023; Revision received April 23, 2024; Accepted April 29, 2024
Electronically published August 1, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18530

Introduction: Overdose deaths from high-potency synthetic opioids, including fentanyl and its analogs, continue to rise along with emergency department (ED) visits for complications of opioid use disorder (OUD). Fentanyl accumulates in adipose tissue; although rare, this increases the risk of precipitated withdrawal in patients upon buprenorphine initiation. Many EDs have implemented medication for opioid use disorder (MOUD) programs using buprenorphine. However, few offer methadone, a proven therapy without the risk of precipitated withdrawal associated with buprenorphine initiation. We describe the addition of an ED-initiated methadone treatment pathway and compared its 72-hour follow-up outpatient treatment engagement rates to our existing ED-initiated buprenorphine MOUD program.

Methods: We expanded our ED MOUD program with a methadone treatment pathway. From February 20–September 19, 2023, we screened 20,504 ED arrivals; 5.1% had signs of OUD. We enrolled 61 patients: 28 in the methadone; and 33 in the buprenorphine pathways. For patients who screened positive for opioid use, shared decision-making was employed to determine whether buprenorphine or methadone therapy was more appropriate. Patients in the methadone pathway received their first dose of up to 30 milligrams (mg) of methadone in the ED. Two additional methadone doses of up to 40 mg were dispensed at the time of the ED visit and held in the department, allowing patients to return each day for observed dosing until intake at an opioid treatment program (OTP). We compared 72-hour rates of outpatient follow-up treatment engagement at the OTP (for those on methadone) or at the addiction treatment center (ATC) (for those on buprenorphine) for the two treatment pathways.

Results: Of the 28 patients enrolled in the methadone pathway, 12 (43%) successfully engaged in follow-up treatment at the OTP. Of the 33 patients enrolled in the buprenorphine pathway, 15 (45%) successfully engaged in follow-up treatment at the ATC (relative risk 1.06; 95% confidence interval 0.60–1.87).

Conclusion: Methadone initiation in the ED to treat patients with OUD resulted in similar 72-hour follow-up outpatient treatment engagement rates compared to ED-buprenorphine initiation, providing another viable option for MOUD. [West J Emerg Med. 2024;25(5)668–674.]

BACKGROUND

The opioid crisis in the United States continues unabated with 106,699 drug-involved fatalities in 2021, primarily involving illicitly manufactured high-potency synthetic opioids, and is further complicated by adulterants such as xylazine and gabapentin.[1–6] Individuals with opioid use disorder (OUD) face the highest risk of death within the first 48 hours following an ED (emergency department) visit for a non-fatal overdose.[7] The ED identification of patients with OUD and initiation of buprenorphine treatment has proven effective and is supported by the American College of Emergency Physicians and the California Bridge network of hospitals.[8–12] However, the rising prevalence of fentanyl in the illicit drug supply complicates treatment due to its accumulation in adipose tissue, potentially causing precipitated withdrawal upon buprenorphine initiation.[13–15] Additionally, abstaining from fentanyl for the required pre-induction period may be difficult for some, leading them to avoid further buprenorphine or favor methadone for their medication for OUD (MOUD).[16–20] Methadone, a synthetic full mu-opioid receptor agonist, avoids these complications, as it does not precipitate withdrawal.[21,22] In response, the University of Vermont Medical Center (UVM) enhanced its existing Start Treatment and Recovery (STAR) program, an ED-based initiative to initiate MOUD in patients with OUD. Originally focused on buprenorphine, the program was expanded to include methadone, adapting to the shifting landscape of opioid use and patient needs. We describe the implementation of an ED-initiated methadone treatment pathway, comparing its 72-hour follow-up outpatient treatment engagement rates to our existing ED-initiated buprenorphine MOUD program.

METHODS

We performed an open trial comparing two MOUD treatment pathways where patients in the ED who met OUD criteria and agreed to treatment chose between initiation onto buprenorphine or methadone. From February 20–September 19, 2023 we screened charts of 20,504 ED arrivals, with 1,051 (5.1%) having signs of OUD. Of these, 903 were determined ineligible, 43 patients declined treatment, and six patients eloped. Patients declining participation due to time constraints or deemed unsuitable for the study at clinician discretion were excluded. Enrollment to initiate MOUD in the STAR program was completed for 61 patients with 28 initiated on methadone and 33 on buprenorphine. Not included in this analysis were an additional 38 patients who were enrolled in STAR but admitted to the hospital (Figure 1). The STAR program coordinators screened patient charts from 9 AM to 9 PM daily and remained on call for enrollments 24/7. They approached identified patients to confirm opioid use, eligibility, and interest in starting MOUD.

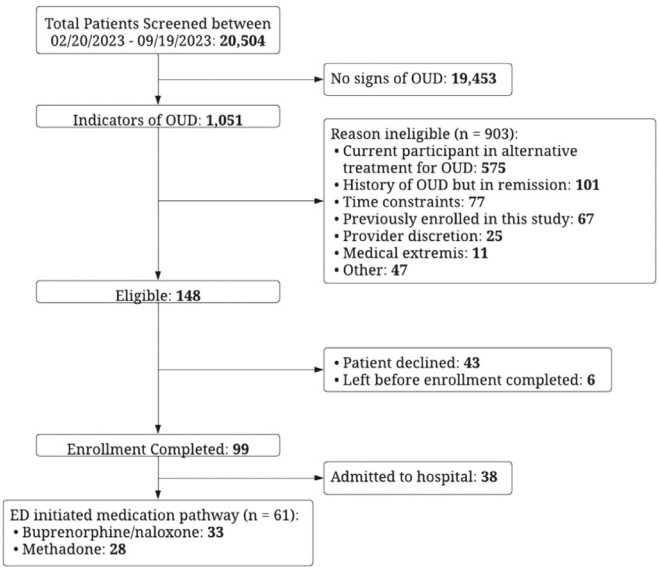


Figure 1. Flow chart of screening of emergency department patients and enrollment in a STAR (start treatment and recovery) program. February 20–September 19, 2023.
ED, emergency department; *OUD*, opioid use disorder.

An emergency clinician then used the *Diagnostic and Statistical Manual of Mental Disorders*, 5th Ed, criteria to confirm the diagnosis of OUD and assess readiness for treatment. Shared decision-making was used to decide on the most appropriate MOUD treatment pathway: methadone or buprenorphine/naloxone. This process involved a discussion between the clinician and the patient that included a review of the risks and benefits of each medication, the severity of OUD, the patient's prior experience/preference, and clinical factors such as drug interactions or QT prolongation. We compared rates of 72-hour follow-up treatment engagement at the opioid treatment program (OTP) (for those on methadone) or at the UVM Addiction Treatment Center (ATC) (for those on buprenorphine) for the two treatment pathways using a chi-square test Stata/SE 18.0 (StataCorp, College Station, TX).

Patients signed a disclosure agreement allowing access to their electronic health record, which was sent to the OTP/ATC via secure email. Patients received details about their outpatient treatment appointment and were provided with transportation vouchers and a cell phone, when necessary. Patients were linked to an ED peer recovery coach who engaged with them during their ED visit and continued support through phone calls for up to 10 days following discharge.

Methadone Treatment Pathway: Patients receiving methadone were given the standard US Food and Drug Administration-recommended starting dose of 30 milligrams (mg) orally with subsequent dosing of 40 mg on the following days if bridging doses were required until the OTP appointment.[23] The initial dose was reduced to 20 mg for patients with known opioid use in the prior four hours, if they

were currently using other sedatives, or with relevant drug interactions. Methadone was not offered if the patient had a respiratory rate <10 breaths/minute, an allergy to methadone, end-stage liver disease, medical extremis, or a known QTc ≥ 500 milliseconds. Electrocardiograms were not routinely required but were obtained for risk factors in patient history or medications. Basic labs and urine drug screen were obtained. Patients were instructed to follow up at the OTP the next business day. If a patient was initiated on methadone on a weekend or holiday, the appropriate number of additional methadone doses were dispensed and held in a lock box in the ED for observed dosing. The patient was instructed to return to the ED to receive follow-up doses. Patients returning for re-dosing were not required to check in as an ED patient but were given their methadone dose, observed, and documented by a nurse using a scripted template (Figure 2).[24]

Buprenorphine/naloxone Treatment Pathway: For patients receiving buprenorphine, the Clinical Opioid Withdrawal Scale (COWS) guided dosing strategies. Patients with a COWS score <8 underwent home initiation. For scores of 8–11, initiation in the ED with 8 mg buprenorphine/naloxone was provided, and for scores >12, a 16 mg dose was administered. All patients received a take-home starter pack with a three-day

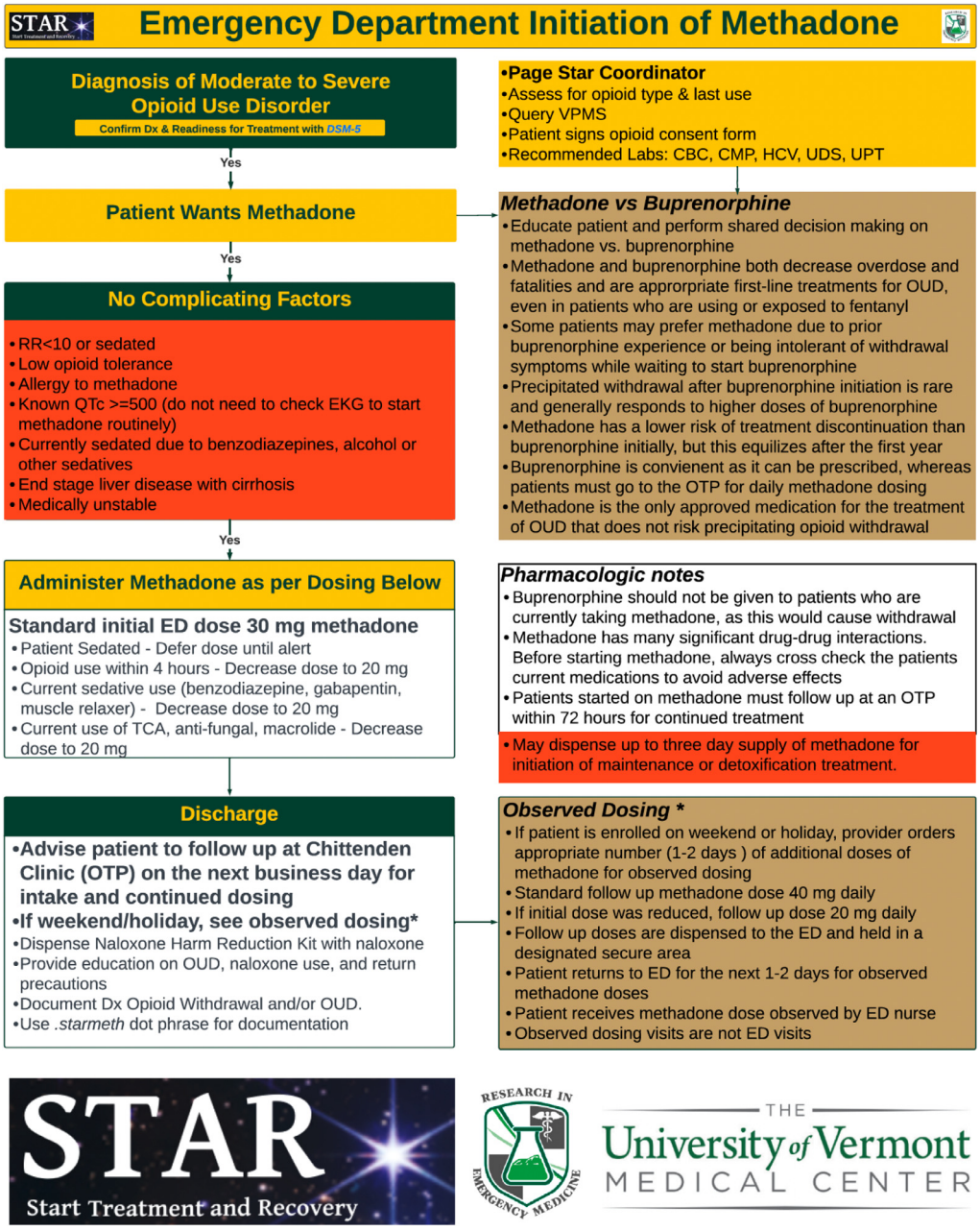


Figure 2. Emergency department initiation of methadone and STAR (start treatment and recovery) pathway.

supply of buprenorphine/naloxone and a follow-up appointment at the ATC within 72 hours (Figure 3).[25]

Institutional Review Board Review: The University of Vermont Research Protections Office deemed this project to meet criteria for research not requiring review.

RESULTS

Patients enrolled in the methadone or buprenorphine pathways had similar demographics with no significant differences between groups by gender, race, ethnicity, age, mode of ED arrival, or ED disposition. Of the 28 patients in the methadone pathway, 12 (43%) attended the OTP for ongoing methadone treatment. Of the 33 patients enrolled in the buprenorphine pathway, 15 (45%) attended the ATC for ongoing buprenorphine/ naloxone treatment. The 72-hour rates of successful follow-up outpatient treatment engagement for patients enrolled in the methadone vs buprenorphine pathways were not significantly different (relative risk 1.06; 95% confidence interval CI, 0.60–1.87).

DISCUSSION

We enhanced our ED's existing buprenorphine-based MOUD program by incorporating a treatment pathway



Figure 3. Emergency department initiation of buprenorphine STAR (start treatment and recovery) pathway.

for initiating methadone. Our findings show that ED-initiation of methadone for OUD is practical and achieves 72-hour follow-up outpatient treatment engagement rates comparable to those of buprenorphine. While previous case studies have documented successful initiation of methadone in the ED, we are one of the first to systematically report on the implementation of a clinical practice pathway for methadone initiation in the ED followed by linkage to ongoing care.[22,26] Traditionally, methadone has not been used in the ED due to the potential to cause fatal respiratory depression if given in doses exceeding an individual's tolerance; however, the ED is an ideal location to safely monitor patients during methadone initiation.[27] Previous federal regulations had restricted the use of methadone to treat OUD to licensed OTPs in the outpatient setting.[28] The Easy Medication Access and Treatment for Opioid Addiction Act improved the flexibility of MOUD by allowing practitioners to dispense up to a three-day supply of narcotics, including methadone, for the purpose of initiating maintenance or detoxification treatment.[29–33]

Patients prefer selecting the optimal treatment pathway through shared decision-making, which involves a thorough comparison of the advantages and disadvantages of buprenorphine vs methadone. This approach fosters informed and collaborative healthcare choices and potentially leads to improved outcomes and adherence.[22,34] We found most patients will directly say which treatment pathway they prefer due to past experiences of treatment and precipitated withdrawal. Buprenorphine is advantageous and preferred as it is logistically easier to take: there is less risk of respiratory depression; the patient can receive take-home medications and prescriptions; and care can ultimately be managed by the patient's primary care physician without daily trips to the methadone clinic for dosing.[19] However, patients who have experienced buprenorphine-precipitated withdrawal or who cannot tolerate cessation of fentanyl for the required pre-buprenorphine induction time (often 72 hours or longer) may benefit from methadone.[35]

Although surveys from other institutions indicate physicians have more comfort initiating buprenorphine over methadone (88% vs 45%), our experience shows clinicians readily adopting the methadone treatment pathway.[36] To foster clinician acceptance of ED MOUD, we implemented several strategies: sharing testimonials from our ED peer recovery coaches; facilitating one-on-one discussions between project champions and clinicians; and leveraging direct clinical experience. These approaches align with existing research, which demonstrates increased exposure to impacted populations effectively reduces stigma towards them.[37] Overcoming these barriers enhanced treatment options through the successful implementation of a methadone initiation pathway for ED patients with OUD.

LIMITATIONS

Limitations of this study include a small sample size that restricts the generalizability of results and impacts statistical significance. Additionally, the absence of long-term outcome data, such as six-month follow-up metrics, limits insights into the intervention's effectiveness. The exclusion of patients concurrently enrolled in other treatment programs introduced selection bias, potentially affecting the study's applicability to the wider OUD population. Finally, individual clinician biases may have influenced both participant selection and treatment choice, potentially affecting study outcomes.

CONCLUSION

ED initiation of methadone for patients with opioid use disorder is practical, achieves 72-hour follow-up treatment engagement rates comparable to those of buprenorphine treatment, and provides another option for MOUD that benefits some patients.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This study was funded by the Substance Abuse and Mental Health Services Administration (SAMHSA) 1H79TI085330 and the 2019 University of Vermont Health Network Innovation Grant. There are no other conflicts of interest or sources of funding to declare.

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Cross-Sectional Study of Thiamine Deficiency and Its Associated Risks in Emergency Care

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Section Editor: Patrick Meloy, MD
Submission history: Submitted September 18, 2023; Revision received January 30, 2024; Accepted April 4, 2024
Electronically published August 1, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18472

Background: Growing data indicates that thiamine deficiency occurs during acute illness in the absence of alcohol use disorder. Our primary objective was to measure clinical factors associated with thiamine deficiency in patients with sepsis, diabetic ketoacidosis, and oncologic emergencies.

Methods: This was an analysis of pooled data from cross-sectional studies that enrolled adult emergency department (ED) patients at a single academic center with suspected sepsis, diabetic ketoacidosis, and oncologic emergencies. We excluded patients who had known alcohol use disorder or who had received ED thiamine treatment prior to enrollment. Investigators collected whole blood thiamine levels in addition to demographics, clinical characteristics, and available biomarkers. We defined thiamine deficiency as a whole blood thiamine level below the normal reference range and modeled the adjusted association between this outcome and age.

Results: There were 269 patients, of whom the average age was 57 years; 46% were female, and 80% were Black. Fifty-five (20.5%) patients had thiamine deficiency. In univariate analysis, age >60 years (odds ratio [OR] 2.5, 95% confidence interval [CI], 1.3–4.5), female gender (OR 1.9, 95% CI 1.0–3.4), leukopenia (OR 4.9, 95% CI 2.3–10.3), moderate anemia (OR 2.8, 95% CI 1.5–5.3), and hypoalbuminemia (OR 2.2, 95% CI 1.2–4.1) were associated with thiamine deficiency. In adjusted analysis, thiamine deficiency was significantly higher in females (OR 2.1, 95% CI 1.1–4.1), patients >60 years (OR 2.0, 95% CI 1.0–3.8), and patients with leukopenia (OR 5.1, 95% CI 2.3–11.3).

Conclusion: In this analysis, thiamine deficiency was common and was associated with advanced age, female gender, and leukopenia. [West J Emerg Med. 2024;25(5)675–679.]

INTRODUCTION

Thiamine (vitamin B1) is a crucial cofactor for numerous metabolic processes, especially carbohydrate metabolism.[1] Its deficiency is associated with diseases with significant morbidity, including Wernicke-Korsakoff syndrome and beriberi.[2] Data in critical illness also shows an association with increased morbidity and mortality independent of these specific syndromes.[3,4]

Thiamine stores are entirely dependent on regular dietary intake or artificial supplementation, and body stores can

become depleted within three weeks without adequate intake.[5–7] Studies indicate that conditions routinely seen in the emergency department (ED) that increase metabolic strain are associated with thiamine deficiency, including diabetic ketoacidosis (DKA), sepsis, and cancer.[3,4,8–13] In studies of severe sepsis and septic shock, up to 35% of patients show thiamine deficiency, with evidence that levels improve with recovery in children.[3,8,9,14] Case reports of Wernicke's encephalopathy in patients with cancer are numerous.[15–19] In recent observational studies of gastrointestinal and hematological cancer patients, thiamine deficiency was common and associated with neurological symptoms.[20] Studies have also demonstrated thiamine deficiency in up to 35% of children and adults with DKA.[10,11]

Although the existing literature demonstrates an association between such diagnoses and thiamine deficiency, further assessment of clinical risk factors for deficiency could define who may benefit most from thiamine treatment. In this study, we sought to explore the association of clinical risk factors with thiamine deficiency in ED patients. Such information could guide future therapeutic and preventative approaches in the management of at-risk patients.

Population Health Research Capsule

What do we already know about this issue?
Emergency patients with high metabolic strain, such as occurs in critical illness, have significant rates of thiamine deficiency in the absence of alcohol use disorder.

What was the research question?
Can clinical factors predict patients most likely to have thiamine deficiency in the absence of alcohol use disorder?

What was the major finding of the study?
Factors such as age >60 years (OR 2.0, 95% CI 1.0–3.8) and leukopenia (OR 5.1, 95% CI 2.3–11.3) are associated with deficiency.

How does this improve population health?
These findings point to the need for further investigation into micronutrient deficiency in populations that emergency clinicians commonly serve.

MATERIALS AND METHODS

Design and Setting

This is an analysis of pooled data from two cross-sectional studies performed at a single-center, urban academic medical center. Enrollment occurred in the center's ED, which has approximately 92,000 patient encounters each year and serves a primarily Black population. This research was approved by the institutional review board, which granted waiver of informed consent for the study.

Population

This analysis was inclusive of adult patients (age ≥18 years) in the ED from two studies. The first study enrolled patients with diabetic or infectious emergencies from April 2015–February 2018. The second study enrolled patients with active malignancy between March 2017–October 2018. For both studies, we excluded patients who had known alcohol use disorder or received thiamine treatment in the ED or through home supplementation prior to enrollment.

Blood Samples and Data Collection

Eligible patients provided a whole blood sample in the ED, which measures thiamine-diphosphate. The samples were protected from light, frozen, and sent to an offsite laboratory (Warde Medical Laboratory, Ann Arbor, MI) for thiamine-level testing using gas chromatography–mass spectrometry. We collected demographics, clinical characteristics, and in-hospital mortality data on all patients. We also recorded laboratory information obtained during routine care in the ED, including chemistries and blood counts. To account for missing laboratory data for serum albumin and hematology results, we performed multiple imputation prior to final analysis. Because preclinical data suggests that metformin may interfere with intestinal thiamine transporters, data specific to metformin use was also collected.[21] Finally, we recorded any clinical documentation of abnormal gait or diagnosis of delirium throughout a patient's ED or hospital stay. We did not perform standardized assessment of gait, delirium, or nutritional status.

Statistical Analysis

We evaluated clinical characteristics and overall prevalence of thiamine deficiency using descriptive statistics. Discrete data was reported as frequencies and percentages. We reported continuous data as means or medians where appropriate. Analysis consisted of univariate comparisons and multivariable logistic regression to assess risk factors for the primary outcome of thiamine deficiency, defined as a whole blood level below the central lab's reference range (38–122 micrograms per liter). Based on common clinically meaningful cutoffs, we created categorical variables for age >60 years (primary covariate of interest) and laboratory findings of leukopenia (white blood cell count $<4 \times 10^9$/L), moderate anemia (hemoglobin <10 grams per deciliter [g/dL]), and hypoalbuminemia (serum albumin <3.4 g/dL). With statistically significant categorical variables, we

performed stepwise logistic regression (significance level for entry 0.2 and to stay 0.1) to construct a final model that was inclusive of age >60 years, gender, presence of leukopenia, and hypoalbuminemia. Analysis also included testing for an interaction of gender and age >60 years.

Results are reported as odds ratios (OR) with a 95% confidence interval (CI). A *P*-value <0.05 (two-tailed) was considered statistically significant for all tests. Due to the exploratory nature of this analysis, we did not perform a power analysis and used the sample size available. We used SAS 9.4 (SAS Institute, Inc, Cary, NC) for all analyses.

RESULTS

There were 269 patients enrolled from March 2015–October 2018. Their mean age was 57 years, and 46% were female. Most patients identified as Black (80%). There were 55 (20.5%) patients who had thiamine deficiency. When compared to patients with normal thiamine levels, thiamine-deficient patients were older ($P = 0.001$) and more commonly female ($P = 0.04$). We report demographic and clinical characteristics with comparisons by thiamine status in Table 1.

Significant laboratory findings associated with thiamine deficiency in the cohort included leukopenia, anemia, and hypoalbuminemia. In the adjusted analysis, female gender, leukopenia, and age >60 years were significantly associated with thiamine deficiency. Table 2 demonstrates these unadjusted and adjusted associations. Finally, unadjusted rates of in-hospital mortality, 60-day mortality, findings of abnormal gait, and delirium in patients with or without thiamine deficiency are shown in Table 3.

Table 1. Demographics and clinical characteristics of patients based on presence or absence of thiamine deficiency.

	Normal thiamine N = 214	Thiamine deficiency N = 55	*P*-value
Demographics			
Female, no. (%)	91 (42.5)	32 (58.2)	0.04
Age, years, mean (SD)	54.8 (18.0)	63.6 (17.6)	0.001
Age >60 years, no. (%)	89 (41.6)	35 (63.6)	0.003
Black race, no. (%)	169 (79.0)	47(85.5)	0.28
Medical history, no. (%)			
Diabetes mellitus*	123 (57.5)	22 (40.0)	0.02
Metformin use	33 (15.4)	11 (20.0)	0.41
Myocardial infarction	20 (9.4)	2 (3.6)	0.17
Chronic kidney disease	57 (26.6)	16 (29.1)	0.72
Hypertension	131 (61.2)	35 (63.6)	0.74
Stroke	26 (12.2)	6 (10.9)	0.80
Cancer	74 (34.6)	29 (52.7)	0.01
Congestive heart failure	19 (8.9)	6 (10.9)	0.64
Laboratory values			
White blood cell $\times 10^9$/L, mean (SD)	13.5 (8.1)	8.1 (6.7)	<0.001
White blood cell $<4.0 \times 10^9$/L, no. (%)	18 (8.4)	17 (30.9)	<0.001
Hemoglobin, g/dL, mean (SD)	12.8 (3.2)	10.5 (2.7)	<0.001
Hemoglobin <10 g/dL, no. (%)	41 (19.2)	22 (40.0)	0.001
Creatinine, mg/dL, mean (SD)	2.20 (2.80)	1.64 (1.37)	0.04
Serum albumin, g/dL	3.43 (0.83)	2.86 (0.89)	<0.001
Albumin <3.4 g/dL, no. (%)	99 (46.3)	36 (65.5)	0.01
Body mass index, kg/m^2, mean (SD)	27.2 (7.8)	27.6 (6.9)	0.75

*Diabetes mellitus included any patient with this clinical diagnosis (type 1 or 2). Regardless of being part of the diabetic ketoacidosis cohort.
g/dL, grams per deciliter; *mg*, milligrams; *kg/m^2*, kilograms per square meter.

DISCUSSION

It is well established that thiamine deficiency can result from alcohol use disorder or severe nutritional deficiencies. However, thiamine deficiency is also precipitated by acute illness with high metabolic demand, and data indicates it may be common in conditions such as DKA, sepsis, and cancer. Determining additional clinical factors associated with thiamine deficiency in such populations could aid in tailoring thiamine administration to appropriate patients.

Within this analysis of ED patients with sepsis, DKA, and cancer, we found that 20.5% of patients were thiamine deficient based on ED blood levels. We identified advanced age, female gender, and leukopenia as having greater adjusted odds of thiamine deficiency. These results on gender and leukopenia are unique. Prior data indicates an association between advanced age and thiamine deficiency.[22] Gender or the presence of leukopenia are not well-described risk factors. Prior research indicates that B12 deficiency is more common in men,[23] but we are not aware of data indicating a higher risk of thiamine deficiency based on female gender. The finding that hypoalbuminemia may be associated with thiamine deficiency is also novel, although this finding did not reach statistical significance in an adjusted analysis. It is also noteworthy that this analysis included mostly Black patients. Much of the existing literature on thiamine deficiency in critical illness is inclusive of a mainly White population.[3,10,20,22] Nonetheless, we found

Table 2. Unadjusted and adjusted analysis of patient characteristics and laboratory values associated with thiamine deficiency.

	Unadjusted analysis*		Adjusted analysis	
	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value
Female gender	1.88 (1.03–3.43)	0.039	2.13 (1.11–4.07)	0.02
Age >60 years	2.46 (1.33–4.54)	0.004	1.98 (1.03–3.81)	0.04
Cancer	2.11 (1.16–3.84)	0.015		
Diabetes mellitus	2.03 (1.11–3.71)	0.022		
WBC $<4*10^9$/L	4.87 (2.31–10.30)	<0.001	5.12 (2.31–11.30)	<0.001
Albumin <3.4 g/dL	2.20 (1.19–4.08)	0.012	1.82 (0.94–3.54)	0.08
Hemoglobin <10 g/dL	2.81 (1.49–5.32)	0.002		

*Categorical variables included in stepwise logistic regression model. Adjusted analysis displays only results for retained variables.
CI, confidence interval; *WBC*, white blood cell count.

Table 3. Unadjusted clinical outcomes based on presence or absence of thiamine deficiency.

	Normal thiamine N = 214	Thiamine deficiency N = 55	*P*-value
60-day mortality, no. (%)	34 (15.9)	15 (27.3)	0.05
Abnormal gait, no. (%)	58 (27.1)	25 (45.5)	0.009
Delirium, no. (%)	64 (30.1)	22 (40.0)	0.16

overall comparable rates of thiamine deficiency within a Black cohort.

Nutritional deficiency may be contributory to our findings. While we did not perform nutritional surveys in these cohorts, other research indicates that ED patients have significant rates of malnutrition, approaching as high as 60% in the elderly.[24] Future research in this area could benefit from specific measures of food insecurity and nutritional status in diverse populations. While we could presume that low albumin levels are reflective of poor nutritional status, it is challenging to determine whether hypoalbuminemia is due to poor protein intake vs inflammatory conditions or high metabolic demands that suppress albumin synthesis.[23]

LIMITATIONS

The current study has several notable limitations. First, we included a narrow subset of diagnoses, which limits the generalizability of these findings to other conditions. Overall patient enrollment was low due to limited coordinator coverage, which may have introduced bias in patient selection. As noted, we did not perform standardized nutritional assessments or neurological assessments that might have teased out the clinical impact of thiamine deficiency. Of note, our results highlighted detection of acute deficiency and did not measure global thiamine stores. We performed this in an urban setting with significant rates of food insecurity. Such findings may not translate to suburban settings.

The study was also underpowered to assess certain drugs associated with thiamine deficiency such as furosemide.[25] Nonetheless, these results add to a growing body of evidence on thiamine deficiency in ED patients with conditions such as DKA, sepsis, and cancer who do not have alcohol use disorder.[3,10,11,20] Further testing in broader populations is needed to measure how age, gender, nutritional status, and other clinical factors interrelate with thiamine deficiency.

CONCLUSION

In our unique study population of ED patients without a history of alcohol use disorder who had sepsis, cancer or diabetic ketoacidosis, independent risk factors for thiamine deficiency were advanced age, female gender, and leukopenia. Further research is indicated to define the epidemiology of thiamine deficiency in a broad cohort of adults with acute illness.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Funding for the work was through a unrestricted physician scientist award given to Joseph Miller by Henry Ford Health (grant number A20300). There are no other conflicts of interest or sources of funding to declare.

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Emergency Department Blood Pressure Treatment and Outcomes in Adults Presenting with Severe Hypertension

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Section Editor: Kenneth Scott Whitlow, DO
Submission history: Submitted May 14, 2023; Revision received April 13, 2024; Accepted April 16, 2024
Electronically published July 17, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18126

Background: Patients who present to the emergency department (ED) with severe hypertension defined as a systolic blood pressure (SBP) ≥180 millimeters of mercury (mm Hg) or diastolic (DBP) ≥120 (mm Hg) without evidence of acute end-organ damage are often deemed high risk and treated acutely in the ED. However, there is a dearth of evidence from large studies with long-term follow-up for the assessment of major adverse cardiovascular events (MACE). We conducted the largest study to date of patients presenting with severe hypertension to identify predictors of MACE and examine whether blood pressure at discharge is associated with heightened risk.

Methods: We enrolled ED patients with a SBP of 180–220 mm Hg but without signs of end-organ damage and followed them for one year. The primary outcome was MACE within one year of discharge. Secondarily, we performed a propensity-matched analysis to test whether SBP ≤160 mm Hg at discharge was associated with reduced MACE at 30 days.

Results: A total of 12,044 patients were enrolled. The prevalence of MACE within one year was 1,865 (15.5%). Older age, male gender, history of cardiovascular disease, cerebrovascular disease, diabetes, smoking, presentation with chest pain, altered mental status, dyspnea, treatment with intravenous and oral hydralazine, and oral metoprolol were independent predictors for one-year MACE. Additionally, discharge with an SBP ≤160 mm Hg was not associated with 30-day MACE-free survival after propensity matching (hazard ratio 0.99, 95% confidence interval 0.78–1.25, $P = 0.92$).

Conclusion: One-year MACE was relatively common in our cohort of ED patients with severe hypertension without acute end-organ damage. However, discharge blood pressure was not associated with 30-day or one-year MACE, suggesting that BP reduction in and of itself is not beneficial in such patients. [West J Emerg Med. 2024;25(5)680–689.]

INTRODUCTION

Background

Hypertensive emergencies are a significant concern when patients present to the emergency department (ED) with severely elevated blood pressure (BP), defined as ≥180 millimeters of mercury (mm Hg) systolic or ≥120 mm Hg diastolic pressure.[1] Nevertheless, very few of these patients have evidence of acute end-organ damage. (EOD) and often have only severely uncontrolled chronic hypertension (HTN).[2,3] Severely elevated BP, but without EOD, is often called "hypertensive urgency." There is significant long-term evidence regarding characteristics associated with increased major adverse cardiovascular events (MACE) for patients with chronically elevated BP, but there is a lack of long-term evidence regarding characteristics associated with increased MACE in those presenting with hypertensive urgency in the ED.[2] Even without this long-term evidence, there is temptation and expectation to acutely lower BP. Recent retrospective ED studies suggest that there may be no immediate benefit from acutely reducing BP in the setting of severe hypertension without EOD.[4,5] This could be because there is evidence to suggest a greater risk for severe adverse effects with antihypertensives in the setting of severely elevated BP without EOD.[5,6] However, larger outcome data for reaching a lower target BP for this population prior to discharge is lacking.

Population Health Research Capsule

What do we already know about this issue?
Patients with worsening levels of uncontrolled blood pressure have increasing risk of long-term cardiovascular events.

What was the research question?
How common are major adverse cardiovascular events (MACE) within one year for patients discharged from the ED with severe hypertension?

What was the major finding of the study?
While 15.5% had a cardiovascular event within a year, we found no association with initial ED encounter for so-called "hypertensive urgency."

How does this improve population health?
Severe hypertension in the absence of hypertensive emergency identifies patients at significant risk of MACE, but acute BP reduction in the ED may not be immediately beneficial.

Rationale

Given that there are significantly more patients presenting to the ED with severe HTN without EOD, identifying characteristics associated with MACE in this cohort has become increasingly more important.[1,3,7] Likewise, there is uncertainty regarding the value of reaching a significantly lower target pressure prior to discharge from the ED for this cohort. Assessing the impact of reaching a target BP on MACE would also provide clinical utility for emergency physicians.

Objective

To address these uncertainties, we conducted the largest observational cohort study to date to identify risk factors for MACE at one year among patients discharged home from the ED who presented with severely elevated BP without EOD. We also tested whether targeting a lower systolic blood pressure (SBP) prior to discharge was associated with reduced MACE at 30 days in this cohort. Our hypothesis for our primary analysis was that patients with SBP between 180–220 mm Hg without documented EOD and treated with anti-hypertensives would have less MACE at one year. We used an SBP greater than 180 mm Hg as this is the cutoff for hypertensive crisis according to the American Heart Association (AHA).[8] Our secondary hypothesis was that propensity-matched patients with an initial SBP between 180–220 mm Hg without documented evidence of EOD, but who were discharged with a lower target SBP (≤160 mm Hg), would have less MACE at 30 days. We used a SBP ≤160 mm Hg, as >160 mm Hg is the cutoff for Grade 2 hypertension and has been shown to be associated with a high risk of EOD.[8]

METHODS

Study Setting and Population

Subjects included patients between 18–90 years of age who presented to one of eight EDs in an integrated health system (Henry Ford Health System, Detroit, MI) for treatment of any medical condition between January 2014–July 2015. These EDs consisted of one tertiary-care academic teaching hospital, three community teaching hospitals, and four freestanding EDs. The ED locations served urban communities with low socioeconomic status as well as suburban, more affluent communities. We included ED encounters that resulted in discharge from the ED and did not result in admission or being placed in observation. Adult patient encounters were abstracted from the electronic health record (EHR) shared by all EDs included in the study (Epic Systems Corporation, Verona, WI). We incorporated all ED encounters for adults for initial abstraction. Of these encounters, we excluded patient encounters with SBP >220 mm Hg or below <180 mm Hg and encounters with missing or incorrectly coded patient variables. For this study

we defined acute EOD as an entered clinical diagnosis at presentation of acute coronary syndrome, stroke, heart failure exacerbation, or acute kidney injury in the EHR.

Study Design

The study was approved by the international review board (IRB) at Henry Ford Hospital System. Data collection included the patient's first ED BP and discharge BP, demographic information, comorbidities, insurance status, tobacco use, and clinical presentation. We used chief complaint as the primary symptom for their visit. We also recorded whether they were referred to the ED primarily for hypertension (HTN). Comorbidities included history of cardiovascular disease, stroke, diabetes, and chronic kidney disease. We classified insurance status into insured (Medicare, Medicaid, commercial) or not insured. We also collected the median income for the ZIP code where each patient resided. The median incomes for each ZIP code were grouped into quartiles for subsequent analysis. The patient's antihypertensive therapies during the visit were recorded.

We used a method criterion described by Worster et al.[9] 1) Two data abstractors were trained with the study criteria described above;. 2) The inclusion and exclusion criteria used were as stated above. 3) Variables were defined prior to analysis. 4) We used a standard abstraction form. 5) Abstractor performance was based on the number of records screened and verified based on accuracy of incorporating the criteria in record selection. 6) Abstractors during abstraction of records were blinded to the hypothesis. 7) Interobserver reliability was discussed, 8) but it was was not measured due to low number of observers to perform a statistical test. 9) The health record database was identified. 10) Method of sampling was described previously. 11) Any missing variable data of preidentified variables of interest resulted in removal of the entire patient record from the study. 12) The IRB did review the study.

Primary and Secondary Outcomes

Each patient was tracked in the health system's EHR up to one year following the date of the patient's first ED encounter. We considered patients to have the primary outcome, MACE, if they had a documented diagnosis of acute heart failure, acute stroke (hemorrhagic or ischemic), acute coronary syndrome, or death within one year following their ED visit. We selected a one-year follow-up period to increase the number of events and thereby improve statistical power given the sample size.

If a patient had more than one cardiovascular event in the 12-month period, we only counted their first event for the purpose of the primary study outcome. Documented MACE from Epic's Care Everywhere network was also included, so that we would not miss any MACE if the patient presented to an outside healthcare system within the state of Michigan using the same EHR. This incorporates deaths identified by the state of Michigan; however, if an event occurred outside the state, then this could not be incorporated. The Care Everywhere network incorporates the EHRs of multiple care systems in the state of Michigan, and records created within these care systems are automatically uploaded and validated in Care Everywhere. However, outside records may have been missed and, thus, may be a limitation to the study.

The secondary outcome was time-to-MACE within 30 days from discharge: a) because events that occur near discharge are more plausibly causally related than are events that occur long after discharge; and b) to test for differences in instantaneous risk velocity (ie, hazard ratio [HR]) conditional on survival (ie, to identify factors that are associated with shorter intervals-to-MACE at 30 days).

Primary Analysis and Secondary Statistical Analyses

We used descriptive statistics to assess baseline demographic and clinical characteristics of the cohort. Continuous variables were expressed as median interquartile range (IQR), while categorical data were expressed as frequencies and proportions (ie, %). The Mann-Whitney U-test and the chi-square test were used to examine differences in distributions and proportions, respectively. In the primary regression analysis, we used logistic regression to estimate magnitudes of association between patient characteristics and MACE at one year. We chose logistic regression because the symmetric nature of the odds ratio (OR) enables inferences about associations between antecedents and outcomes or vice versa, unlike relative risk.[10] Symmetry is ideal given the potential for confounding by indication in non-randomized clinical studies; that is, only ORs allow inferences about treatment given outcome and vice versa.[10,11] Potential confounders were defined a priori as factors that are associated with both an exposure and outcome whose adjustment alters the estimated magnitude of association by >10%. We employed a two-stage model selection strategy. Firstly, we selected all factors that were associated with discharge SBP and MACE both in our study and based on prior knowledge (ie, full model). Next, to reduce the number of covariables and potential impact of multicollinearity, we used an agnostic strategy that optimized model accuracy measured by partial area under the curve at a 10% fixed-false-positive rate across 1,000 bootstrap replicates of training (70%) and testing datasets (30%). When considering ZIP code characteristics, we included a random intercept to account for similarities among patients nested in the same geographic area.

In the secondary regression analysis, we used the Cox proportional hazards model to estimate the magnitude of association between patient factors at ED discharge and time-to-MACE at 30 days. Given the potential for confounding by indication, and because we wanted to examine the clinical relevance of discharge SBP, we performed a propensity-matched analysis to balance the

distribution of potential confounders between study groups that had SBP ≤160 mm Hg or >160 mm Hg.[12] We used the MatchIt R-package to find pairs of observations with similar propensity scores but that differ in treatment status.[13] That is, the primary logistic regression model was used to derive propensity-matched groups; factors that nevertheless differed between propensity-matched groups were included in the final multivariable Cox model as potential confounders. In both the primary and secondary analyses, magnitudes of association (ie, OR and HR) with 95% confidence intervals (CI) that do not include the null estimate (ie, '1.0') are statistically significant. All analysis was performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Demographics and Clinical Characteristics

Of 222,028 ED encounters reviewed during the study period, 13,042 (5.8%) patients met inclusion criteria. There were 12,044 (92.4%) who had complete records and were used for subsequent analysis. The overall number of patients that had MACE within one year was 1,865 (15.5%), inclusive of 176 deaths (9.5%).

Table 1 demonstrates the overall demographic and clinical characteristics of the cohort. Univariate analysis found that patients with MACE within one year following ED discharge were significantly more likely to be older (ages 65–90, OR 6.66 [95% CI 5.44–8.24] $P < 0.001$), and male (779/1,865 [41.8%] vs 3,719/10,179 [36.5%]; OR 1.25 [1.13–1.38], $P < 0.001$), but less likely to be Black (646/1.865 [34.6%] vs 3,814/10,179 [37.5%]; OR 0.89 [0.80–0.98], $P < 0.05$). Also significantly associated with MACE within one year were history of cardiovascular disease (495/1,865 [26.5%] vs 251/10,179 [2.47%], OR 14.3 [13.2–16.8], $P < 0.001$); cerebrovascular disease (202/1,865 [10.8%] vs 136/10,179 [1.33%], OR 8.97 [7.18–11.2], $P < 0.001$); diabetes mellitus (607/1,865 [32.5%] vs 1,092/10,179 [10.7%], OR 4.02 [3.58–4.51], $P < 0.001$); and chronic kidney disease (352/1,865 [18.9%] vs 337/10,179 [3.31%], OR 6.80 [5.80–7.97], $P < 0.001$). Patients who used tobacco, had insurance, and those who lived in a ZIP code with a median annual income of $54,973–$70,439 US (75% quartile) were more likely to have MACE within one year in comparison to those with less than $44,583 (25% quartile) (OR 2.59 [2.24–2.87], $P < 0.001$, 3.81 [2.78–5.39], $P < 0.001$, and 1.17 [1.02–1.34], $P < 0.05$, respectively).

Table 1. Patient characteristics and univariate logistic regression comparisons for outcomes.

Variable	Total	No 1-year MACE	1-year MACE	OR (95% CI)	*P*-value
	12,044	10,179/12,044 (84.5%)	1,865/12,044 (15.5%)		
Demographic					
Age range in years, n(%)					
18–45	2,243/12,044 (18.6%)	2,139/10,179 (21.0%)	104/1,865 (5.58%)		
46–65	4,995/12,044 (41.5%)	4,409/10,179 (43.3%)	586/1,865 (31.4%)	2.74 (2.22–3.41)	$P < 0.001$
65–90	4,806/12,044 (39.9%)	3,631/10,179 (35.7%)	1,175/1,865 (63.0%)	6.66 (5.44–8.24)	$P < 0.001$
Male, n(%)	4,498/12,044 (37.3%)	3,719/10,179 (36.5%)	779/1,865 (41.8%)	1.25 (1.13–1.38)	$P < 0.001$
Black, n(%)	4,460/12,044 (37.0%)	3,814/10,179 (37.5%)	646/1,865 (34.6%)	0.89 (0.80–0.98)	$P < 0.05$
Medical history					
Cardiovascular disease, n(%)	746/12,044 (6.19%)	251/10,179 (2.47%)	495/1,865 (26.5%)	14.3 (12.2-16.8)	$P < 0.001$
Cerebrovascular disease, n(%)	338/12,044 (2.81%)	136/10,179 (1.33%)	202/1,865 (10.8%)	8.97 (7.18–11.2)	$P < 0.001$
Diabetes mellitus, n(%)	1,699/12,044 (14.1%)	1,092/10,179 (10.7%)	607/1,865 (32.5%)	4.02 (3.58–4.51)	$P < 0.001$
Chronic kidney disease, n(%)	689/12,044 (5.72%)	337/10,179 (3.31%)	352/1,865 (18.9%)	6.80 (5.80–7.97)	$P < 0.001$
Social history					
Tobacco smoker, n(%)	3,176/12,044 (26.3%)	2,358/10,179 (23.1%)	818/1,865 (43.8%)	2.59 (2.24–2.87)	$P < 0.001$
Has insurance, n(%)	11,258/12,044 (93.5%)	9,431/10,179 (92.7%)	1,827/1,865 (98.0%)	3.81 (2.78–5.39)	$P < 0.001$
ZIP code median annual income range in $US					
Less than 44,583, n(%)	4,663/12,044 (38.7%)	3,979/10,179 (39.1%)	684/1,865 (36.7%)		
44,584–54,972, n(%)	1,857/12,044 (15.4%)	1,549/10,179 (15.2%)	308/1,865 (16.5%)	1.16 (1.00–1.34)	0.05
54,973–70,439, n(%)	2,634/12,044 (21.9%)	2,192/10,179 (21.5%)	442/1,865 (23.7%)	1.17 (1.02–1.34)	$P < 0.05$

(*Continued on next page*)

Table 1. Continued.

Variable	Total	No 1-year MACE	1-year MACE	OR (95% CI)	*P*-value
Over 70,440, n (%)	2,889/12,044 (24.0%)	2,459/10,179 (24.2%)	431/1,865 (23.1%)	1.02 (0.89–1.16)	0.77
Presentation					
Headache, n (%)	398/12,044 (3.31%)	346/10,179 (3.41%)	52/1,865 (2.79%)	0.81 (0.60–1.08)	0.70
Chest pain (%)	990/12,044 (8.22%)	799/10,179 (7.86%)	191/1,865 (10.2%)	1.34 (1.13–1.58)	$P < 0.001$
Altered mental status (%)	92/12,044 (0.772%)	53/10,179 (0.530%)	39/1,865 (2.09%)	4.01 (2.63–6.05)	$P < 0.001$
Dyspnea (%)	465/12,044 (3.86%)	329/10,179 (3.23%)	136/1,865 (7.29%)	2.36 (1.91–2.89)	$P < 0.001$
Referral for hypertension (%)	781/12,044 (6.48%)	675/10,179 (6.63%)	106/1,865 (6.02%)	0.85 (0.68–1.04)	0.13
Systolic blood pressure range in mm Hg (%)					
180–200	9,572/12,044 (79.5%)	8,158/10,179 (80.1%)	1,414/1,865 (75.8%)		
201–220	2,472/12,044 (20.5%)	2,021/10,179 (19.9%)	451/1,865 (24.2%)	1.288 (1.15–1.45)	$P < 0.001$
Diastolic blood pressure range in mm Hg (%)					
Less than 80	1,530/12,044 (12.7%)	1,182/10,179 (11.6%)	348/1,865 (18.6%)		
80–100	6,600/12,044 (54.8%)	5,577/10,179 (54.8%)	1,023/1,865 (54.9%)	0.62 (0.54–0.72)	$P < 0.001$
Greater than 101	3,914/12,044 (32.5%)	3,420/10,179 (33.6%)	494/1,865 (26.5%)	0.49 (0.42–0.57)	$P < 0.001$
Treatment	3,528/12,044 (29.3%)	2,345/10,179 (23.0%)	1,183/1,865 (63.3%)	5.80 (5.22–6.44)	$P < 0.001$
Clonidine oral (%)	1,220/12,044 (10.1%)	897/10,179 (8.81%)	323/1,865 (17.3%)	2.17 (1.89–2.49)	$P < 0.001$
Enalaprilat IV (%)	114/12,044 (0.946%)	74/10,179 (0.727%)	40/1,865 (2.14%)	2.99 (2.01–4.39)	$P < 0.001$
Labetalol oral (%)	241/12,044 (2.00%)	159/10,179 (1.56%)	82/1,865 (4.40%)	2.90 (2.20–3.79)	$P < 0.001$
Labetalol IV (%)	827/12,044 (6.87%)	559/10,179 (5.49%)	268/1,865 (14.4%)	2.89 (2.47–3.37)	$P < 0.001$
Metoprolol oral (%)	1,603/12,044 (13.3%)	809/10,179 (7.95%)	794/1,865 (42.6%)	8.59 (7.64–9.65)	$P < 0.001$
Metoprolol IV (%)	316/12,044 (2.62%)	174/10,179 (1.71%)	142/1,865 (7.61%)	4.74 (3.77–5.95)	$P < 0.001$
Hydralazine oral (%)	655/12,044 (5.44%)	319/10,179 (3.13%)	336/1,865 (18.0%)	6.79 (5.78–7.99)	$P < 0.001$
Hydralazine IV (%)	1,086/12,044 (9.01%)	656/10,179 (6.4%)	430/1,865 (23.1%)	4.35 (3.81–4.97)	$P < 0.001$
Outcome					
Discharge systolic blood pressure ranges in mm Hg (%)					
90–160	4,356/12,044 (36.2%)	3,641/10,179 (35.8%)	715/1,865 (38.3%)		
160–220	7,688/12,044 (63.8%)	6,538/10,179 (64.2%)	1,150/1,865 (61.6%)	0.90 (0.81–0.99)	$P < 0.05$
Acute coronary syndrome (%)	1,190/12,044 (9.88%)		1,190/1,865 (63.8%)		
Heart failure admission (%)	705/12,044 (5.85%)		705/1,865 (37.8%)		
Stroke (%)	488/12,044 (4.05%)		488/1,865 (26.2%)		
Death (%)	176/12,044 (1.46%)		176/1,865 (9.47%)		

MACE, major adverse cardiac event; *OR*, odds ratio; *CI*, confidence interval; *mm HG*, millimeters of mercury; *IV*, intravenous.

Symptoms and Presenting BP

Patients presenting with chest pain, altered mental status, dyspnea and a SBP of 201–220 instead of 180–200 mm Hg were significantly more likely to suffer MACE (OR 1.34 [1.13–1.58], $P < 0.001$, 4.01[2.63–6.05], $P < 0.001$, 2.36 [1.91–2.89], $P < 0.001$, and 1.29 [1.15–1.45], $P < 0.001$), respectively. A chief complaint of headache or referral for HTN was not significantly associated with MACE (OR 0.81 [0.60–1.08], $P = 0.17$ and OR 0.85 [0.68–1.04], $P = 0.13$). Patients with a presenting diastolic blood pressure ranging from 80–100 mm Hg or 101 mm Hg and greater were less likely to suffer MACE (OR 0.62 [0.54–0.72], $P < 0.001$; 0.49 [0.42–0.57], $P < 0.001$).

Treatment and Outcomes

There were 3,528/12,044 (29.3%) patients who had any antihypertensive treatment during their ED visit, and this treatment was significantly associated with a higher rate of MACE within one year compared to those who did not receive antihypertensive treatment (OR 5.80, 95% CI

5.22–6.44). Univariate analysis for each type of antihypertensive medication demonstrated that each was associated with MACE at one year. Furthermore, patients who were discharged with a SBP above 160–220 mm Hg were less likely to suffer MACE at one year (OR 0.90, 95% CI 0.81–0.99, Table 1).

Primary Analysis

To create a parsimonious multivariable logistic regression model, the bootstrap receiver operating curve model retained age, gender, history of cardiovascular disease, cerebrovascular disease, diabetes mellitus, chronic kidney, smoking status, presentation with chest pain, altered mental status, dyspnea, treatment with hydralazine (oral and IV), oral metoprolol, and discharge SBP as variables (Supplement S1). The before-variable selection AUC was 0.842, and the after-variable selection AUC 0.839. Given that the estimated variance from the random effect of patient ZIP codes was low (0.0759, SD 0.275), this random effect was not included in our final analysis. In the adjusted model, older age range, male gender, history of cardiovascular disease, cerebrovascular disease, diabetes mellitus, smoking, presentation with chest pain, altered mental status, treatment with IV and oral hydralazine, and oral metoprolol were significant independent predictors for MACE at one year (Table 2). The model had a pseudo-R^2 of 0.260. Retrospective power analysis performed with GPower 3 (https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower.html) showed a statistical power of this study over 90%.[14]

Table 2. Multivariable logistic regression of patient characteristics with a major adverse cardiac event (MACE) at one-year vs those without a MACE.

	OR (95% CI)	*P*-value
Age range in years		
18–45		
46–65	1.90 (1.53–2.39)	$P < 0.001$
65–90	4.04 (3.27–5.04)	$P < 0.001$
Male	1.35 (1.19–1.52)	$P < 0.001$
History of cardiovascular disease	4.62 (3.78–5.66)	$P < 0.001$
History of cerebrovascular disease	4.62 (3.48–6.15)	$P < 0.001$
History of diabetes mellitus	1.64 (1.41–1.91)	$P < 0.001$
History of chronic kidney disease	1.19 (0.96–1.48)	0.11
Tobacco smoker	1.35 (1.19–1.54)	$P < 0.001$
Chest pain	1.38 (1.13–1.68)	$P < 0.01$
Altered mental status	3.27 (1.92–5.49)	$P < 0.001$
Dyspnea	1.47 (1.11–1.93)	$P < 0.001$
Treated with hydralazine IV	1.98 (1.67–2.35)	$P < 0.001$
Treated with hydralazine oral	2.15 (1.74–2.65)	$P < 0.001$
Treated with metoprolol oral	4.88 (4.26–5.59)	$P < 0.001$
Discharge systolic blood ranges in mm Hg		
90–160		
161–220	0.94 (0.83–1.06)	0.295

Multivariate logistic regression results after achieving parsimony with ROC-bootstrap method.
CI, confidence interval; *IV*, intravenous; *mm Hg*, millimeters of mercury.

Secondary Analysis

We compared short-term outcome (30-day MACE-free survival) for patients who were discharged with a SBP ≤160 mm Hg vs those with SBP >160 mm Hg. There were significant group differences for age, gender, history of cerebrovascular disease, smoking, presentation of headache, chest pain, presenting SBP, and reception of antihypertensive treatments between those who were discharged with a SBP ≤160 mm Hg compared to those with a SBP >160 mm Hg (Table 3).

After propensity-score matching, 4,356 controls with SBP >160 mm Hg and 4,356 patients with SBP ≤160 mm Hg were matched. Chest pain was the only variable that remained significantly different between patients with SBP >160 mm Hg vs those with SBP <160 mm Hg. This was included as a variable for adjustment for the following Cox regression analysis for 30-day MACE (Table 4). In the propensity-score matched analysis a chief complaint of chest pain was independently associated with an increased risk of 30-day MACE (HR 1.76, 95% CI 1.30–2.37, $P < 0.001$, Table 4).

However, discharge with an SBP ≤160 mm Hg was not associated with 30-day MACE-free survival after adjusting for covariates (HR 0.99, 95% CI 0.78–1.25, $P = 0.92$). Survival curve shows no significant survival benefit for patients who were discharged with a SBP ≤160 mm Hg vs those discharged with SBP >160 mm Hg (Figure 1).

DISCUSSION

This study represents a large cohort of ED patients with severely elevated BP without EOD. There were high MACE rates at one year (15.5%) in our cohort. Independent risk factors for MACE at one year after an ED visit where severely elevated BP was noted included advanced age, male gender, history of cardiovascular disease, cerebrovascular disease, diabetes mellitus, and smoking. Presenting signs of chest pain and altered mental status, but not headache, were also found to be independent risk factors for MACE. Treatment with hydralazine or metoprolol was associated with higher rates of MACE at one year as well. Similar to findings by Patel et al, we found that referral to the ED for BP management by a clinic was not associated with an increased risk of MACE at one year.[4]

We used propensity-matched analysis to measure the association between reducing SBP in the ED and more immediate, 30-day MACE-free survival. In this analysis,

Table 3. Pre- vs post-propensity score matching patient characteristics between patients discharged with a systolic blood pressure ≤160 vs >160.

Group characteristics for secondary analysis	Pre-match			Post-match		
Variable	**Discharge SBP >160 mm Hg**	**Discharge SBP ≤160 mm Hg**	***P*-Value**	**Discharge SBP >160 mm Hg**	**Discharge SBP ≤160 mm Hg**	***P*-value**
n	7,688	4,356		4,356	4,356	
Median age in years (IQR)	62 (50–74)	60 (49–72)	$P < 0.001$	60 (48–72)	60 (49–72)	0.36
Male (%)	2,954/7,688 (38.4%)	1,544/4,356 (35.4%)	$P < 0.001$	1,522/4.356 (34.7%)	1,544/4,356 (35.4%)	0.62
History of cardiovascular disease (%)	477/7,688 (6.2%)	269/4,356 (6.18%)	0.949	277/4,356 (6.29%)	269/4,356 (6.18%)	0.72
History of cerebrovascular disease (%)	198/7,688 (2.58%)	140/4,356 (3.21%)	$P < 0.05$	145/4,356 (3.26%)	140/4,356 (3.21%)	0.76
History of diabetes mellitus (%)	1,086/7,688 (14.1%)	614/4,356 (14.1%)	0.979	597/4,356 (13.4%)	614/4,356 (14.1%)	0.60
History of chronic kidney disease (%)	458/7,688 (5.97%)	231/4,356 (5.30%)	0.132	209/4,356 (5.07%)	231/4,356 (5.30%)	0.28
Tobacco smoker (%)	1,972/7,688 (25.7%)	1,204/4,356 (27.6%)	$P < 0.05$	1,289/4,356 (28.0%)	1,204/4,356 (27.6%)	0.72
Headache (%)	223/7,688 (2.90%)	176/4,356 (4.03%)	$P < 0.01$	212/4,356 (4.82%)	176/4,356 (4.04%)	0.06
Chest pain (%)	422/7,688 (5.48%)	569/4,356 (13.0%)	$P < 0.001$	421/4,356 (9.69%)	569/4,356 (13.1%)	$P < 0.001$
Altered mental status (%)	56/7,688 (0.73%)	37/4,356 (0.85%)	0.476	45/4,356 (0.90%)	37/4,356 (0.85%)	0.38
Dyspnea (%)	229/7,688 (2.98%)	236/4,356 (5.41%)	$P < 0.001$	228/4,356 (5.23%)	236/4,356 (5.42%)	0.70
Presenting median SBP in mm Hg (IQR)	190 (184–199)	190 (184–198)	$P < 0.001$	189 (184–198)	190 (184–198)	0.45
Received antihypertensive treatment (%)	2,158/7,688 (28.1%)	1,370/4,356 (31.5%)	$P < 0.001$	1,390/4,356 (30.6%)	1,370/4,356 (31.5%)	0.65

Pre- vs post-propensity demographics, presentation characteristics and outcomes. *T*-test comparisons are shown.
SBP, systolic blood pressure; *mm Hg*, millimeters of mercury; *IQR*, interquartile range,

there was no significant association between a reduction in SBP ≤160 mm Hg upon ED discharge and 30-day MACE. This was found even after propensity matching for reception of antihypertensive agents. This data adds to prior observational studies showing no associated benefit with a target BP prior to discharge from the ED.[5]

Table 4. Cox regression analysis for 30-day MACE*-free survival after propensity matching.

Variable	30 day-MACE HR (95% CI)	*P*-value
Chest pain	1.76 (1.30–2.37)	$P < 0.001$
Discharge SBP ≤160	0.99 (0.78–1.25)	0.92

Cox regression analysis for 30-day MACE-free survival; discharge SBP≤160 variable is adjusted for chest pain as presenting clinical symptom after propensity score matching.
**MACE*, major adverse cardiac event; *HR*, hazard ratio; *CI*, confidence interval; *SBP*, systolic blood pressure.

There was an association with certain antihypertensive treatments in the ED and higher one-year MACE. While it is unlikely that this antihypertensive treatment led to higher rates of MACE up to one year following treatment, it is plausible that clinicians perceive a clinical need to treat BP or heart rate immediately in patients with higher risk for MACE. This finding coincides with our previous work illustrating that severely hypertensive patients who were at higher risk for MACE were more likely to be given medications that quickly lower BP in the ED, such as nitrates, clonidine, hydralazine, metoprolol, labetalol, enalapril, and nicardipine, in addition to continuing their chronic HTN medications.[5] As recent data shows an association with inpatient antihypertensive treatment and higher rates of acute kidney injury at 30 days, future work may consider this outcome in assessing the practice of acute BP lowering in the ED.[15]

Of note, we found no association between Black race and one-year MACE in patients with severe HTN on adjusted

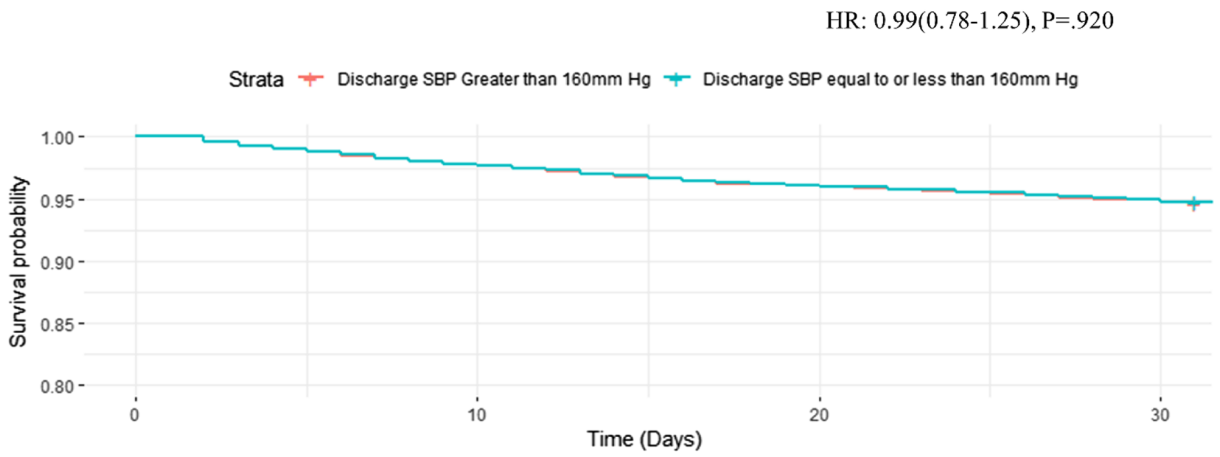


Figure 1. 30-day MACE*-free survival curve for discharging patient with an SBP ≤160 after propensity score matching and adjusting for chest pain as presenting clinical symptom.
**MACE,* major adverse cardiac event; *HR*, hazard ratio; *SBP,* systolic blood pressure; *mm Hg*, millimeters of mercury.

analyses. Studies have previously demonstrated significant association between Black race and increased incidence of MACE, attributing causation to higher prevalence of cardiovascular comorbidities, genetics, lower socioeconomic status, and different treatment received during hospitalization.[16,17] Severe HTN is more common in Blacks and is present at a younger age in comparison to other races; therefore, there may be a protective bias among this population. It is important to note, however, that chronic HTN is different from an acute presentation of severe HTN, in which it is well established that Blacks have significantly worse outcomes.[18]

In our cohort, chest pain, altered mental status, and dyspnea were three chief complaints independently associated with one-year MACE. Prior data has indicated that patients who present to the ED with chest pain, with or without elevated BP, have about a 5% chance of developing MACE at one year.[19] Of the 990 patients in this study who presented with a chief complaint of chest pain and had severely elevated BP, 191 (19.3%) developed MACE at one year. Of the 92 patients who presented with altered mental status, 39 (42.4%) developed MACE. Additionally, of the 465 patients who presented with dyspnea, 136 (29.2%) developed MACE. The combination of severely elevated BP and these complaints may indicate poor control of comorbid conditions, which contributes to vascular endothelial dysfunction and acute end-organ injury. While headache in the setting of severely elevated BP is considered by some to be indicative of a hypertensive emergency, it is notable that we found no association between this and MACE in our study.

Clinical Perspectives

While hypertensive emergencies require emergent treatment, best practices remain controversial when patients have severely elevated BP and lack acute EOD.[1] Often termed "hypertensive urgency," a misnomer that implies some type of urgent intervention is needed, current guidance for management of such patients is largely based on expert opinion and varies significantly.[20] Observational data shows no associated benefit for outpatient clinic referral to the ED for asymptomatic severe HTN.[4,21] Guidance from the American College of Emergency Physicians recommends against antihypertensive therapy in the ED for patients with asymptomatic severe BP elevation.[22] While some have advocated that the potential for developing EOD is concerning enough with severely elevated BP to justify urgent management in the ED, particularly in populations with poor ED follow-up care, there is no definitive evidence that intervening in such a manner improves short- or long-term outcomes.[20] In fact, our study provides new evidence suggesting that the increase in long-term risk of MACE in this cohort is mostly due to established cardiovascular risk factors. Reaching a lower target SBP does not appear to be beneficial. While observational studies support this conclusion, a randomized clinical study is warranted to help confirm this statement. Management of severely elevated BP should be reserved for the outpatient setting. We identified key predictors for mortality in this population, and efforts should concentrate on better outpatient management of patients with these characteristics.

LIMITATIONS

An important limitation to this study is the potential for unmeasured confounders that may have affected outcomes. Neither did we account for prior medication adherence or newly diagnosed HTN, factors that may impact a clinician's approach to treatment in the ED.[5,21] Another limitation is the lack of longitudinal follow-up BP and antihypertensive medication use over one year following the ED visit. While

other published reports indicate that ED patients with severely elevated BP often continue to have uncontrolled BP, we did not collect such longitudinal data.[4] Furthermore, we failed to collect potentially relevant biomarkers such as troponin and B-type natriuretic peptide to more accurately define patients with EOD. Thus, it is possible that clinicians may have missed diagnosing patients who may have been suffering from EOD. Events that occurred outside this health system, which were not documented in the Care Everywhere network, were not captured, and patients may have suffered subclinical or unreported events. It is unknown how many hospitals are registered in the Care Everywhere network. Together, these considerations may have led to an underestimation of the total number of events.

CONCLUSION

Our study shows that the risk of subsequent major adverse cardiovascular events in ED patients with severely elevated blood pressure without end-organ damage is high. Patients at higher risk of MACE often suffer from well-established cardiovascular risk factors. While these patients stand to benefit from carefully coordinated follow-up for cardiovascular risk reduction, reaching a target BP in the ED is not associated with improved outcomes. This data adds to mounting evidence against the utility of having a target BP prior to discharge from the ED and suggest that the term "hypertensive urgency" be avoided to describe such individuals, as there is no need for urgent intervention.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Neutrophil-to-Lymphocyte Ratio Predicts Sepsis in Adult Patients Meeting Two or More Systemic Inflammatory Response Syndrome Criteria

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Section Editor: Patrick Meloy, MD
Submission history: Submitted September 14, 2023; Revision received March 28, 2024; Accepted April 4, 2024
Electronically published June 28, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18466

Introduction: Determining which patients who meet systemic inflammatory response syndrome (SIRS) criteria have bacterial sepsis is a difficult challenge for emergency physicians. We sought to determine whether the neutrophil-to-lymphocyte ratio (NLR) could be used to exclude bacterial sepsis in adult patients who meet ≥2 SIRS criteria and are being evaluated for sepsis.

Methods: Consenting adult patients meeting ≥2 SIRS criteria and undergoing evaluation for sepsis were enrolled. We recorded patient age, gender, vital signs, and laboratory results. We then later reviewed health records for culture results, end organ dysfunction, survival to discharge, and final diagnoses. Patients were classified as having sepsis if they met ≥2 SIRS criteria and were ultimately diagnosed with a bacterial source. We analyzed data using descriptive statistics and sensitivity and specificity analyses. A receiver operating characteristic curve (ROC) was created to determine test characteristics.

Results: A total of 231 patients had complete datasets. Patients' median age was 69 (interquartile range [IQR] 54–81), and 49.6% were male. There were 154 patients (66.7%) ultimately diagnosed with sepsis with an identified bacterial source, while 77 patients with ≥2 SIRS criteria had non-infectious reasons for their presentations (33.3%). Septic patients had a median NLR 12.36 (IQR [interquartile range] 7.29–21.69), compared to those without sepsis (median NLR 5.62, IQR 3.89–9.11, $P < 0.001$). The NLR value of 3 applied as a cutoff for sepsis had a sensitivity of 96.8 (95% confidence interval [CI] 92.2–98.8), and a specificity of 18.2 (95% CI 10.6–29.0). The ROC for NLR had an area under the curve of 0.74.

Conclusion: The neutrophil-to-lymphocyte ratio is a sensitive tool to help determine which patients with abnormal SIRS screens have bacterial sepsis. [West J Emerg Med. 2024;25(5)690–696.]

INTRODUCTION

The clinical progression of systemic inflammatory response syndrome (SIRS) from a serious infection to sepsis to septic shock is a major cause of patient morbidity and mortality. Sepsis affects 1.7 million adults in the United States each year, resulting in at least 350,000 deaths.[1] Worldwide, sepsis is the leading cause of death, passing cardiovascular disease and cancer.[2]

The healthcare costs associated with sepsis are also high, with an estimated annual economic burden of $57 billion in the US in 2019.[3] Not surprisingly, the cost incurred from any individual case of sepsis increases with increasing disease severity, and disease severity increases over time.[4,5] Therefore, rapid identification and treatment of sepsis has been a high priority within the hospital setting for decades, and performance improvement programs with standardization and protocolization of sepsis management have demonstrated improvement in outcomes.[6–8] Since 87% of cases of sepsis are present upon arrival to the hospital (as opposed to being hospital acquired), emergency physicians play a crucial role in promptly recognizing and intervening with these high-risk patients.[1,9] Emergency physicians are also tasked with limiting unnecessary use of broad-spectrum antibiotics as part of the antibiotic stewardship goals outlined by the Infectious Disease Society of America, the Society for Healthcare Epidemiology of America, and the Pediatric Infectious Disease Society.[10]

Identification of sepsis continues to be a challenge. Screening tools based on clinical and/or laboratory criteria, such as Quick Sequential Organ Failure Assessment (q-SOFA) and SIRS, are commonly used to identify patients with sepsis, but 15–60% of patients who meet those criteria do not go on to have an actual diagnosis of sepsis.[11–13] Cardiac dysrhythmias, primary lung disease, viral illness, trauma, endocrine disease, and numerous other processes can result in a positive SIRS or q-SOFA screen; more importantly, for risk- stratification tools, high sensitivity is critically important to avoid missing cases of sepsis. In multiple trials, SIRS with suspicion for infection outperforms qSOFA in terms of sensitivity but is inferior for specificity.[14–18] Lactate is another tool commonly used primarily for prognostication and assessment of response to treatment in patients with diagnoses of sepsis.[19,20] Although specific lactate values are used as defining criteria in the diagnoses of severe sepsis and septic shock, lactate is neither sensitive nor specific during early sepsis.

The neutrophil-to-lymphocyte ratio (NLR) has been demonstrated to be a reliable and easy-to-obtain measure of patient immune response to a variety of different infectious and non-infectious conditions.[21] A normal NLR is generally considered <3, although neonatal literature uses more conservative cutoffs.[21] The NLR has been associated with the presence of bacteremia and appears to be relevant to prognosis and progression in sepsis.[22–25] In neonates, research demonstrates that the NLR can be predictive of both early and late sepsis.[26–28] In this study, we sought to determine whether the NLR could be used to exclude sepsis in adult patients who met two or more SIRS criteria or had a positive q-SOFA screen who were being evaluated for sepsis.

Population Health Research Capsule

What do we already know about this issue?
Current screening for bacterial sources of sepsis is neither sensitive nor specific.

What was the research question?
Can the neutrophil lymphocyte ratio (NLR) be used to exclude bacterial sepsis in patients meeting ≥2 SIRS criteria for systemic inflammatory response syndrome?

What was the major finding of the study?
An NLR value of 3 had a sensitivity of 96.8% (CI 92.2–98.8), and a specificity of 18.2% (10.6–29.0). The ROC for NLR had an area under the curve of 0.74.

How does this improve population health?
Bacterial sepsis is a major cause of morbidity and mortality. The NLR is a sensitive and inexpensive tool that can help determine which patients have bacterial sepsis.

MATERIALS AND METHODS

Study Design

This was a prospective cohort study of adult (≥18 years) emergency department (ED) patients who were being evaluated for sepsis. All patients completed written informed consent or had surrogate informed consent. The study was reviewed and approved by the institutional review board.

Study Setting and Population

The study took place at a single academic ED with an annual census of 50,000 patients. Patients were enrolled from April 2019–March 2020. Adult patients were eligible for enrollment if they were positive on SIRS screening (≥2 values present) or on q-SOFA screening on arrival to the ED and were undergoing evaluation for sepsis. The SIRS criteria are temperature >100.4°F or temperature <96.8°F; heart rate >90 beats per minute; respiratory rate (RR) >20 or pCO_2 < 32 millimeters of mercury (mm Hg); and white blood cell count >12,000 or <4,000, or band count >10%. A qSOFA score is calculated by giving the patient a point for altered mental status, systolic blood pressure less than 100 mm Hg, or RR ≥22, with ≥2 points considered indicative of high risk. Patients were identified through the electronic health record (EHR) (Epic Systems Corporation, Verona, WA), which generates an automatic computer alert for patients with positive qSOFA and SIRS screens. After identification of

potential patients through the computer alert, eligibility forms were completed by clinicians.

Patients were required to provide written informed consent. In cases where patients were too ill, cognitively impaired, or intubated and could not consent, consent was sought from their healthcare proxy, if available. We excluded non-English-speaking patients and patients for whom their evaluations could not be delayed to accommodate the consent process. Pregnant patients and patients triaged to the trauma bay were also excluded. Trauma bay triage criteria are listed in Appendix 1.

Study Protocol and Measurements

After eligibility forms were completed by clinicians involved in the patients' care, the forms were screened by study investigators who then approached the patients to obtain consent. Once consent was completed, we recorded clinical data for each SIRS-positive and qSOFA patient enrolled, including age, gender, vital signs, complete blood count (CBC) and lactate levels. We later reviewed health records out to 90 days for culture results; end organ dysfunction (including renal failure, shock liver, pulmonary failure, cardiac failure, delirium); survival to discharge; disposition (home, rehab, nursing facility, or death within 90 days); and final diagnoses. We collected data in a standardized Excel spreadsheet (Microsoft Corp, Redmond, WA) on a password-protected computer belonging to a study investigator. All data was entered from a prepopulated pull-down menu to reduce data entry errors. Once all clinical data collection was complete, the database was purged of patient identifiers prior to analysis.

Patients were classified as having sepsis if they met ≥2 SIRS criteria or 2+ qSOFA criteria and were ultimately diagnosed with a bacterial source. Patients were classified as not having sepsis if they met SIRS/qSOFA criteria but were diagnosed with an alternative source for those abnormalities and had no bacterial source identified. Bacterial sources of sepsis were classified as urinary, pulmonary, central nervous system, intra-abdominal, skin and soft tissue, hematogenous, or other. Cutoff values for analysis of NLR were 3, which is a commonly reported number in the literature as being abnormally high, and 10, which is a value reported to have negative prognostic implications.

Investigator and Enrollee Training

Only physicians who had completed mandatory CITI training and good clinical practice training consented and enrolled patients in this study. Although all clinicians working in the ED were informed and reminded of the study during weekly educational time and were permitted to complete eligibility forms, only trained investigators were permitted to enroll patients. In addition to mandatory research training, investigators met with the principal investigator (AY) who designed the data collection tool and were trained in its use.

Data Analysis

We analyzed data using descriptive statistics. Sensitivity and specificity calculations were performed using MedCalc (MedCalc Software Ltd, Ostend, Belgium) and VassarStats (Richard Lowry 1998–2023). We created receiver operating characteristic (ROC) curves to determine test characteristics.

RESULTS

We enrolled 233 patients. Two had incomplete data sets, leaving 231 patients for data analysis. The patients' median age was 69, with an interquartile range of 54–81; 49.6% were male. Twenty-five patients (10.7%) were admitted to the intensive care unit, 18 patients (7.7%) died in the hospital during the index visit or were discharged to hospice, and 32 (13.7%) died within 90 days of follow-up. Five patients were enrolled despite not meeting SIRS or qSOFA criteria on initial presentation. They were included in this analysis on an intent-to-treat basis. Further patient characteristics are shown in the Table.

Of the 231 eligible patients, 154 patients (66.7%) were ultimately diagnosed with sepsis with an identified bacterial source (Figure 1). Seventy-seven had non-infectious sources identified (33.3%). The most commonly identified sources were pulmonary and urinary tract, followed by bacteremia and soft tissue infections (Figure 2). Some patients had more than one identified source. The most commonly identified reasons for patients meeting SIRS criteria without bacterial source of sepsis were viral syndromes (28 patients); congestive heart failure (10); asthma/chronic obstructive pulmonary disease exacerbations (5); medication/drugs (5); malignancy related (5); pneumonitis (5); and complications of endocrine disease (3). Patients with sepsis with an identified bacterial source had a median NLR of 12.36 (interquartile range [IQR] 7.29–21.69), compared to a median NLR of 5.62 (IQR 3.89–9.11) in those that did not have a bacterial source ($P < 0.001$) (Figure 3).

The NLR value of 3 applied as a cutoff for sepsis had a sensitivity of 96.8 (95% confidence interval [CI] 92.2–98.8), and a specificity of 18.2 (CI 10.6–29.0). In this population with a high prevalence of disease, the positive predictive value of NLR was 70.3 (CI 63.6–76.2), with a negative predictive value of 73.7 (CI 48.6–89.9), with a performance odds ratio of 6.86 (CI 2.37–19.89) for having disease. When an NLR cutoff of 10 was used, the specificity increased significantly to 73%, although with a marked sacrifice of sensitivity down to 60.5%. The ROC for NLR yielded an area under the curve of 0.74 (Figure 4).

DISCUSSION

Most hospitals use some variation of screening for sepsis as required to meet core sepsis metrics implemented by the

Table. Characteristics of patients undergoing evaluation for bacterial source of sepsis.

	Total (N = 231)
Median age (IQR)	69 (54–81)
Gender (%)	
Male	114 (49.4)
Female	117 (50.6)
Disposition from index visit (%)	
Home	156 (67.5)
Assisted living and nursing home	55 (23.8)
Hospice	14 (6.1)
Death	5 (2.2)
Unknown	1 (0.4)
Number of SIRS criteria (%)	
0	0 (0)
1	6 (2.6)
2	102 (44.2)
3	93 (40.3)
4	26 (11.3)
5	4 (1.7)
Number of qSOFA criteria (%)	
0	94 (40.7)
1	113 (48.9)
2	23 (10)
3	1 (0.4)

IQR, interquartile range; *SIRS*, systemic inflammatory response syndrome; *qSOFA*, quick Sequential Organ Failure Assessment.

Centers for Medicare and Medicaid Services. These are typically based on SIRS and/or qSOFA criteria with suspicion for infection. Many hospitals have best practice advisory warnings automatically implemented into the EHR based on these stratification tools to help clinicians earlier identify potentially ill patients who may benefit from escalation of care. This initial recognition of a higher risk cohort of patients is an important first step. Because these initial screens are historically insensitive (both with sensitivities of about 50%) but also not adequately specific, a secondary screen would be useful to help determine which patients might have sepsis as the reason for their presentation.[13,29] A NLR is a simple calculation requiring only a complete blood count (CBC) with differential to be resulted and could be used as a secondary screen.

Although virtually every patient with suspected sepsis has their CBC analyzed, the goal of this blood test is traditionally to determine absolute white blood cell count and percentage of bands, as these are existing criteria within SIRS. The NLR has not been posited as being useful in the determination to initiate antibiotics or as a potential screen for sepsis. For a computer-generated alert, using a NLR is easy to implement and could provide useful guidance in prescreened high-risk patients.

In our study, patients—all of whom were prospectively being evaluated for sepsis—a NLR >3 gave an odds ratio of 6.9 of sepsis, with a sensitivity of 96.8%. This suggests that it may be reasonable to initiate broad-spectrum antibiotics in high-risk patients with an elevated NLR. Since a CBC has a rapid lab turnaround time, this may hasten treatment in

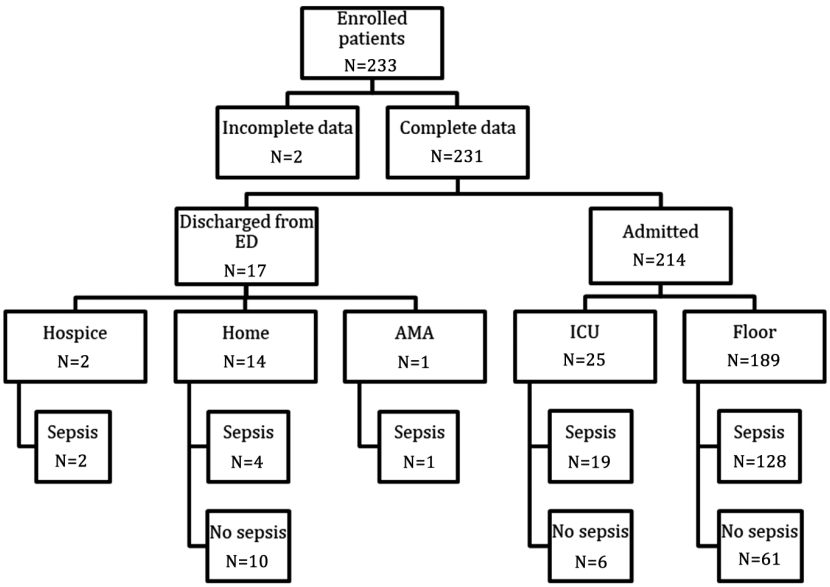


Figure 1. Patient flow diagram.
ED, emergency department; *AMA*, against medical advice; *ICU*, intensive care unit.

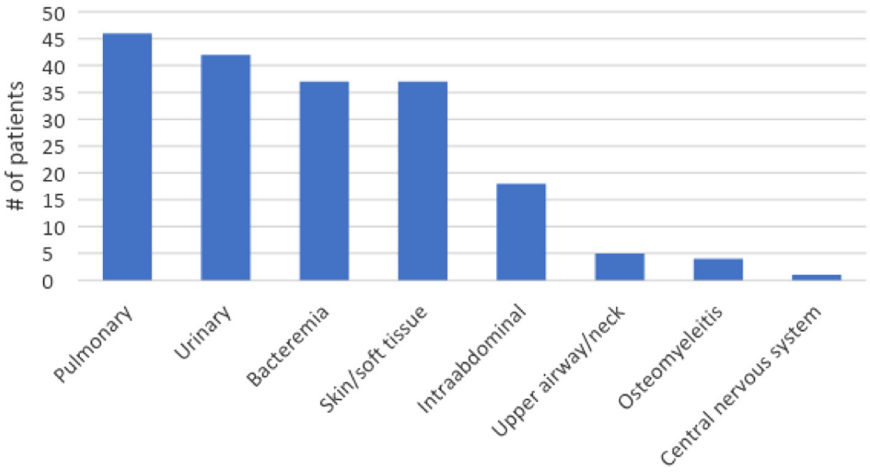


Figure 2. Sources of sepsis.

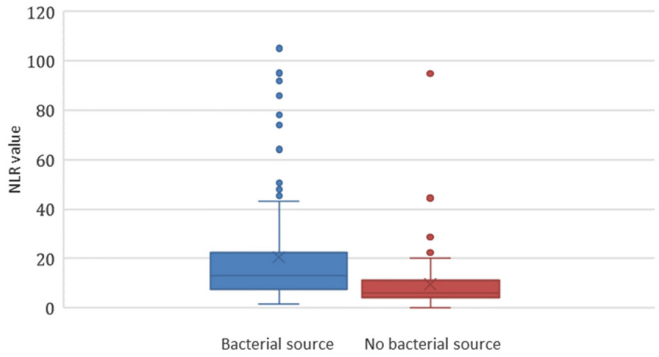


Figure 3. Neutrophil-to-lymphocyte ratio in patients with ≥2 SIRS* criteria.
**SIRS*, systemic inflammatory response syndrome; *NLR*, neutrophil-to-lymphocyte ratio.

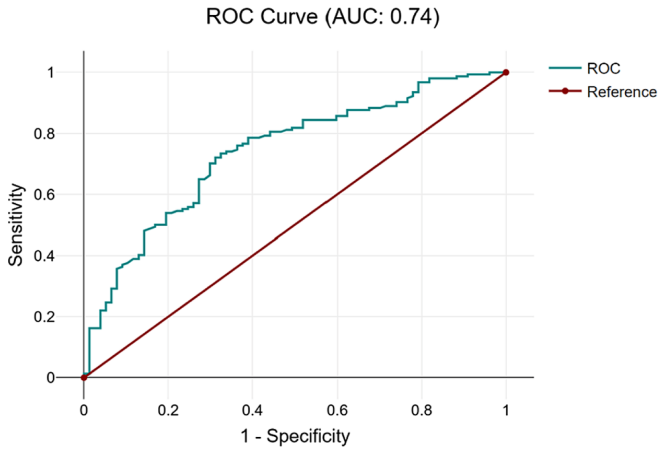


Figure 4. Receiver operating curve for test characteristics of neutrophil-to-lymphocyte ratio in predicting bacterial source in patients meeting ≥2 SIRS* criteria.
ROC, receiver operator curve; **SIRS*, systemic inflammatory response syndrome.

patients for whom the physician is "on the fence" regarding antibiotic administration.

Whether NLR would be useful in acute presentations of sepsis with negative SIRS and qSOFA screens is difficult to assess. We chose to include only patients with positive clinical exam features for sepsis, which represents workup bias within our study. This was done so that we could have a standardized protocol by which to enroll patients, rather than simply enrolling every patient who had a CBC drawn. There are many clinical presentations in which patients "screen negative" for sepsis using qSOFA and SIRS criteria, but the physician has a high index of suspicion for other reasons that are less easily quantified, or in whom sepsis is still on the differential diagnosis. These "screen negative" patients with sepsis are by definition the hardest to recognize, and NLR may have the potential to risk-stratify them. Further study may help to identify the role that NLR could have in screening patients.

It is important to acknowledge the performance of qSOFA and SIRS within the context of our study. Very few of our enrolled patients who went on to have a diagnoses of sepsis with bacterial sources had positive qSOFA screens, which is not in keeping with the existing literature on qSOFA scores. Only 11% of our bacterial sepsis patients had positive qSOFA scores, and 29% of our positive qSOFA screens were not septic. Because of this, it is difficult to speak to NLR's benefit in patients with positive qSOFA screens, as this represented the minority of our patient population, most of whom were enrolled on the basis of vital sign abnormalities consistent with SIRS. This would be an area for further study.

LIMITATIONS

Because this was a relatively small study performed at a single institution and we enrolled patients as a convenience sample, its generalizability is limited. The incidence of disease was very high in our cohort, which is important to

consider when interpreting our results. We enrolled a relatively high-risk cohort, which means that our data may not be applicable to patients with negative qSOFA/SIRS screens. To effectively mirror real-world application of the NLR in patients, we attempted to identify patients in a prospective manner to include patients with physiologic processes that cause vital sign abnormalities where infection might have been a consideration in the differential diagnosis, but ultimately the diagnosis was not sepsis. Further, this study is also limited by the study protocol inclusion criteria. Since this was a prospective study with written consent and patients with altered mental status could not consent, and surrogate consent was not always available, this could have affected the yield of NLR as a screening tool, either positively or negatively.

Since our study required qSOFA and SIRS screening for study entry, it is limited by the accuracy with which those screens were performed. At our institution, these values are input by a triage nurse and may be subject to individual variability and skillset. Examples of how this could have affected the study include inaccuracies in temperature measurements based on method or inaccuracies in counting respiratory rates. Additionally, our qSOFA data likely was affected by the lack of emphasis on it; historically, and currently, our institution stresses the importance of consideration for SIRS with suspicion of source of infection, with qSOFA of secondary import. It is possible that we may not have emphasized the documentation of it as much as SIRS given somewhat less familiarity, resulting in missed opportunities for enrollment in patients who were SIRS negative but qSOFA positive.

Additional limitations include the lack of inclusion of patients who were excluded from enrollment by study design. Non-English speakers were excluded because of inability to appropriately translate the informed consent for all comers. Although the drawing of blood is of minimal risk to the fetus, pregnant patients were excluded from the current study because during pregnancy the neutrophil count naturally increases during the second and third trimesters. Additionally, physiologic changes of pregnancy including increased heart rate and respiratory rate might make the patient SIRS positive, despite the absence of a severe infection. Patients triaged to the trauma bay were excluded because of difficulties with consenting patients and dictating diagnostic testing during their trauma evaluation.

This study was performed in a period prior to the COVID-19 pandemic. Because of issues with quarantining patients early in the pandemic, patient enrollment was stopped at the beginning of the pandemic. The utility of NLR as a screening test may not be applicable in a post-pandemic environment.

CONCLUSION

The neutrophil-to-lymphocyte ratio is a sensitive tool to help identify patients who may have a bacterial source for sepsis. It is fast to use and without additional cost to the patient. In our study, acceptable performance was demonstrated with a cutoff of 3. Further studies should focus on validation of these findings in broader populations.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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The Nonlinear Relationship Between Temperature and Prognosis in Sepsis-induced Coagulopathy Patients: A Retrospective Cohort Study from MIMIC-IV Database

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Section Editor: Quincy K. Tran, MD, PhD
Submission history: Submitted November 19, 2023; Revision received April 24, 2024; Accepted April 26, 2023
Electronically published August 16, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18589

Background: The prognostic value of body temperature in sepsis-induced coagulopathy (SIC) remains unclear. In this study we aimed to investigate the association between temperature and mortality among SIC patients.

Methods: We analyzed data for 9,860 SIC patients from an intensive care database. Patients were categorized by maximum temperature in the first 24 hours into the following: ≤36.0°C; 36.0–37.0°C; 37.0–38.0°C; 38.0–39.0°C; and ≥39.0°C. The primary outcome was 28-day mortality. We used multivariate regression to analyze the temperature-mortality association.

Results: The 37.0–38.0°C, 38.0–39.0°C and ≥39.0°C groups correlated with lower 28-day mortality (adjusted HR 0.70, 0.76 and 0.72, respectively), while the <36.0°C group correlated with higher mortality compared to the 36.0–37.0°C group (adjusted HR 2.60). A nonlinear relationship was observed between temperature and mortality. Subgroup analysis found no effect modification except in cerebrovascular disease.

Conclusion: A body temperature in the range of 37.0–38.0°C was associated with a significantly lower mortality compared to the normal temperature (36.0–37.0°C) group. Additionally, a gradual but statistically insignificant increase in mortality risk was observed when body temperature exceeded 38.0°C. Further research should validate these findings and elucidate involved mechanisms, especially in cerebrovascular disease subgroups. [West J Emerg Med. 2024;25(5)697–707.]

INTRODUCTION

Sepsis, defined as life-threatening organ dysfunction due to dysregulated host response to infection,[1] frequently leads to derangements in coagulation ranging from subtle activation to overt, disseminated intravascular coagulation (DIC).[2,3] This condition in sepsis is associated with multiple organ failure and high mortality.[4,5] In 2017 the International Society on Thrombosis and Haemostasis (ISTH) proposed "sepsis-induced coagulopathy" (SIC) criteria to identify early coagulopathy in sepsis, defined by sepsis plus thrombocytopenia and prolonged prothrombin time.[4] Several studies have validated SIC as an early identifier of impending overt DIC in sepsis.[6,7] Sepsis-induced coagulopathy correlates with mortality, with rates exceeding 30% at a score ≥4.[4] Compared to overt DIC criteria, SIC demonstrates greater sensitivity in predicting mortality.[7]

In summary, SIC represents an early phase of coagulation dysfunction in sepsis that often progresses to overt DIC. The

high morbidity and mortality associated with SIC highlights the need for early identification using simple criteria such as the SIC score, allowing rapid initiation of interventions that may improve outcomes in this high-risk population. Monitoring body temperature changes is vital in evaluating septic patient prognosis, as fever is a common symptom.[8] Both hypothermia and hyperthermia in sepsis reflect immune response to infection. However, their implications for prognosis remain debated.[9–13]

Previous studies have associated hypothermia with poor outcomes.[14–19] The prognostic value of hyperthermia is less clear, with conflicting reports.[11,13,20] This highlights the need to clarify the role of body temperature in sepsis.

Considering that SIC significantly influences sepsis prognosis by altering coagulation,[4,21,22] an exploration of the relationship between temperature and SIC will enhance our comprehension of sepsis pathophysiology and facilitate more precise prognostication and management strategies. Nonetheless, the prognostic value of body temperature abnormalities specifically within SIC has not been comprehensively established. Therefore, we aimed to investigate the association between body temperature and the short term mortality of septic patients with coagulopathy. The findings are expected to bridge a critical knowledge gap concerning the intricate interplay between temperature regulation and coagulation in sepsis.

Population Health Research Capsule

What do we already know about this issue?
Body temperature is a critical vital sign, but its prognostic value in sepsis-induced coagulopathy (SIC) remains unclear, with conflicting evidence on ideal temperature ranges.

What was the research question?
We aimed to investigate the association between body temperature and 28-day mortality among SIC patients.

What was the major finding of the study?
Compared to 36.0–37.0°C, 37.0–38.0°C was associated with lower mortality (adjusted HR 0.70, 95% CI 0.62–0.79, $P < 0.001$).

How does this improve population health?
Identifying the optimal temperature range in SIC could guide better thermoregulation management, potentially reducing mortality and improving outcomes in this high-risk population.

MATERIALS AND METHODS

Data Source

The data utilized in this study was extracted from the Medical Information Mart for Intensive Care-IV (MIMIC-IV) database through the employment of Navicat Premium 15 software. MIMIC-IV, a collaborative effort between Beth Israel Deaconess Medical Center (BIDMC) and Massachusetts Institute of Technology (MIT), is a comprehensive repository encompassing data from over 60,000 adult intensive care unit (ICU) admissions at Beth Israel Deaconess Medical Center spanning from 2008 to 2019.[23] The data, collected during routine clinical care at BIDMC, were de-identified, transformed, and made accessible to researchers who have completed requisite training in human research ethics and entered into a data use agreement. Access to the database was secured by our corresponding author, bearing certification No. 46450588. The Institutional Review Board at BIDMC granted an exemption from obtaining informed consent and approved the sharing of the research resource.

Study Population

Patient data conforming to sepsis-induced coagulopathy criteria were extracted from the MIMIC-IV database's ICU records. The patient selection process for this study adhered to the following inclusion criteria: (1) hospital stay duration of ≥24 hours; (2) age ≥18 years. Exclusion criteria encompassed: (1) presence of greater than 10% missing individual data; (2) outliers, indicated by values exceeding the mean ± 3 Standard Deviation (SD). In cases of multiple ICU admissions, solely data from the first ICU admission of the initial hospital stay were considered.

Data Extraction

Structured Query Language (SQL) was harnessed to extract data recorded on the first day of admission. Extracted data included demographic details, fundamental vital signs, comorbidities, basic laboratory parameters, and pre-treatment scoring systems. Demographic data encompassed race, gender, and age. Vital signs incorporated heart rate, respiratory rate, and body temperature. Body temperature was routinely measured by nurses at bedside, primarily through the axillary and oral route, at 4–8 hour intervals. For some ICU patients, occasional core temperatures from esophageal and rectal probes were also available. We extracted the maximum temperature on day one for each patient. Comorbidities were categorized as myocardial infarction, congestive heart failure, cerebrovascular disease, chronic pulmonary disease, renal disease, and diabetes. Laboratory parameters encompassed hemoglobin, platelet count, white blood cell count, bicarbonate, creatinine, urea nitrogen, glucose, Prothrombin Time (PT), Partial

Thromboplastin Time (PTT), and International Normalized Ratio (INR). Additionally, the Charlson Comorbidity Index (CMI), Sequential Organ Failure Assessment (SOFA) score, Simplified Acute Physiology Score II (SAPSII), Renal Replacement Therapy (RRT), first-day ventilation use, and vasopressor use were included. Variables with missing values ≥40% were excluded during variable selection. For some of the continuous variables included with missing data (see the Supplementary Table S1 for missing data), we use the simple substitution method to deal with them. Missing values are replaced with means if they follow a normal or approximately normal distribution, and with medians if they follow a skewed distribution.

Primary and Secondary Outcomes

The primary outcome measure was 28-day mortality, while secondary outcomes included 90-day mortality, length of stay (LOS) in both the Intensive Care Unit (ICU), and hospital.

Statistical Analysis

All participants were categorized into five groups based on their maximum body temperature within the first 24 hours of hospital admission: ≤36.0°C, 36.0–37.0°C, 37.0–38.0°C, 38.0–39.0°C, and ≥39.0°C. The reference group was defined as the temperature category of 36.0–37.0°C. Normally distributed continuous variables were presented as mean ± standard deviation, while non-normally distributed data were displayed as median [interquartile range (IQR)]. Normality distribution was assessed using the Shapiro-Wilk test. Categorical data were presented as counts (percentages). To compare the differences across groups, one-way analyses of variance (normal distribution), Kruskal–Wallis tests (skewed distribution), and chi-square tests (categorical variables) were undertaken.

Univariate logistic regression analyses were performed to explore the associations between each variable and the risks of 28-day and 90-day mortality, with the results presented in Supplementary Tables S2 and S3, respectively.

The association between body temperature and 28-day mortality was examined via Cox proportional hazard regression, with results expressed as Hazard Ratios (HR) along with 95% Confidence Intervals (CI). For each endpoint, four multivariate analytic models were developed: Model 1, unadjusted covariates; Model 2, covariates including gender, age, race, heart rate, and respiratory rate; Model 3, further adjusted for hemoglobin, platelet count, INR, white blood cell count, anion gap, bicarbonate, blood urea nitrogen, creatinine, glucose, PT, and PTT; and Model 4, encompassing all covariates. Linear trend tests across temperature categories were performed using the median temperature value in each group.

We also examined the linearity of the body temperature-mortality association using curve fitting. For this analysis, we modeled temperature as a continuous variable, rather than using the pre-defined temperature categories. A two-piecewise Cox model with smoothing spline was used to determine the threshold relationship between body temperature and mortality, with the threshold point identified through likelihood ratio testing and bootstrap resampling.

Furthermore, potential modifications of the relationship between body temperature and mortality were assessed, including the following variables: age (<70 vs. ≥70 years), gender, SOFA score (<4 vs. ≥4), SAPSII (<42 vs. ≥42), myocardial infarct (yes vs. no), cerebrovascular disease (yes vs. no), chronic pulmonary disease (yes vs. no), diabetes mellitus (yes vs. no) and renal disease (yes vs. no). Heterogeneity among subgroups was assessed by multivariate cox regression, and interactions between subgroups and body temperature were examined by likelihood ratio testing. To adjust for multiple comparisons in these subgroup analyses, we applied the Bonferroni correction. Specifically, we divided the predetermined significance level of $\alpha = 0.05$ by the number of subgroup comparisons (9), resulting in a Bonferroni-adjusted significance level of 0.0056. We then evaluated whether the association between temperature and SIC mortality differed significantly in each subgroup, using this corrected significance threshold.

Finally, Kaplan-Meier curves were constructed to visually examine the association between temperature categories and mortality.

Analyses were conducted using R software (http://www.R-project.org, The R Foundation) and Free Statistics software (version1.7), with two-sided $p < 0.05$ considered statistically significant.

We used Claude AI, an artificial intelligence writing assistant developed by Anthropic, to aid in final polishing of the manuscript. Claude AI provided suggestive content which we then reviewed, edited, and approved before inclusion. We take full responsibility for the content and conclusions of the manuscript.

RESULT

Baseline Characteristics and Patient Outcome

A total of 9,860 patients diagnosed with sepsis-induced coagulopathy (SIC) were included in this comprehensive study (Figure 1). The demographic details, vital signs, laboratory parameters, and comorbidities of these patients at baseline are meticulously presented in Table 1. Notably, compared to patients with a body temperature between 38.0–39.0°C, the mortality rate was slightly higher in the group with body temperatures above 39°C. However, the highest mortality rate was observed in the group with body temperatures below 36.0°C, suggesting a bimodal relationship between body temperature and mortality in SIC patients.

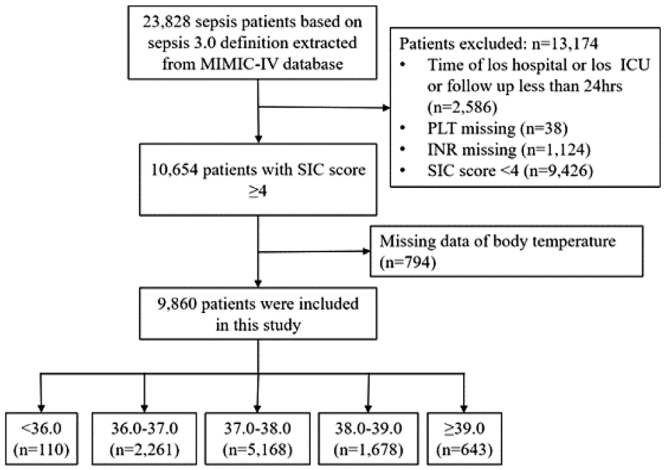


Figure 1. Flowchart of the screening and enrollment of study participants. MIMIC: Medical Information Mart for Intensive Care. *ICU*, Intensive Care Unit; *LOS*, length of stay; *PLT*, platelet; *INR*, International Normalized Ratio; *SIC*, sepsis-induced coagulopathy.

Relationships Between Body Temperature and Outcomes

Table 2 offers a comprehensive overview of the outcomes' association with varying body temperatures. In the unadjusted model (Model 1), the hazard ratios (HRs) and 95% confidence intervals (CIs) for 28-day all-cause mortality were 2.82 (2.17, 3.66) for temperatures <36.0;°C, 0.62 (0.56, 0.69) for 37.0–38.0°C, 0.63 (0.55, 0.72) for 38.0–39.0°C, and 0.75 (0.62, 0.90) for ≥39.0°C, all compared to the reference group of 36.0–37.0°C.

In the fully adjusted Model 4, which accounted for gender, age, race, vital signs, laboratory parameters, comorbidities, and severity scores, the association between temperature and 28-day mortality remained statistically significant. This suggests a robust inverse relationship between body temperature and short-term mortality risk in this patient population.

The results from the additional regression models (Models 2 and 3) were provided in Supplementary Table S4. These models showed consistent findings, with higher temperatures being associated with lower mortality risk.

When temperature was examined as a continuous variable, the fully adjusted Model 4 showed that for every 1°C increase in body temperature, there was an 18% (HR 0.82, 95% CI 0.78–0.87) reduction in the risk of 28-day mortality.

The non-linear relationship between temperature and 28-day all-cause mortality was further demonstrated by the smooth curve fitting analysis depicted in Figure 2 (p for non-linearity <0.001). A similar protective association was also observed for 90-day all-cause mortality (Supplementary Figure S1).

Furthermore, our multivariate linear regression models revealed that for every 1°C increase in body temperature, there was a corresponding increase in ICU length of stay by 0.40 days (95% CI: 0.24–0.55 days) and total hospital length of stay by 0.82 days (95% CI: 0.48–1.15 days) in the fully adjusted analysis.

Threshold Effect Analysis of Body Temperature on SIC Patients' Mortality

We conducted a smoothing function analysis to assess the potential non-linear relationship between body temperature and 28-day mortality in SIC patients. After adjusting for potential confounders including age, gender, laboratory results and comorbidities, we observed a non-linear association between body temperature and risk of 28-day mortality (Figure 2). This non-linear relationship was also observed when analyzing 90-day mortality (Supplementary Figure S1).

Further spline analysis revealed a threshold effect, with risk decreasing as body temperature increased up to 38.0°C (adjusted HR 0.640; 95% CI 0.589–0.696), after which risk slightly increased but was no longer statistically significant (adjusted HR 1.192; 95% CI 0.984–1.444). (Table 3)

The threshold effect at 38.0°C is illustrated by the spline curve in Figure 2, which depicts the estimated adjusted hazard ratios (solid line) and pointwise 95% confidence intervals (shaded area) for the relationship between body temperature and 28-day mortality risk. Our analyses indicate a complex non-linear association between body temperature and mortality risk in SIC patients, with hypothermia conferring the highest risk.

Subgroup Analysis

To identify factors impacting the effect of body temperature on 28-day mortality, comprehensive subgroup analyses were conducted, as depicted in Figure 3. Interaction p-values were largely non-significant across age, gender, severity scores, comorbidities, and other subgroups. Notably, an exception was observed for the cerebrovascular disease subgroup ($p < 0.001$), where patients without cerebrovascular disease exhibited a lower 28-day mortality risk (adjusted HR: 0.78, 95% CI 0.73~0.83). Analogous findings are discernible in the 90-day subgroup analysis (Supplementary Figure S2).

Survival Analysis

The Kaplan–Meier survival analysis in Figure 4 highlights the impact of varying body temperatures on 28-day survival. Mortality rates were notably higher in the <36.0 group and comparatively lower in the 37.0–38.0 group when contrasted with the reference group (36.0–37.0). This trend is reaffirmed with adjusted HRs of 2.6 (95% CI 1.99 ~ 3.42) and 0.7 (95% CI 0.63 ~ 0.78), respectively (Table 2). Consistent outcomes are observed in the 90-day survival analysis (Supplementary Figure S3).

Table 1. Baseline clinical and laboratory characteristics of the study patients.

Characteristic	Total n = 9,860	Temperature (°C) <36.0 n = 110	36.0 ~ < 37.0 n = 2,261	37.0 ~ < 38.0 n = 5,168	38.0 ~ < 39.0 n = 1,678	≥39.0 n = 643	*P*-value
Age, mean ± SD	66.9 ± 15.9	65.3 ± 18.2	70.7 ± 14.7	67.5 ± 15.2	63.5 ± 16.8	57.7 ± 17.9	< 0.001
Race, n (%)							< 0.001
White	6,730 (68.3)	62 (56.4)	1,605 (71)	3,546 (68.6)	1,149 (68.5)	368 (57.2)	
Other	3,130 (31.7)	48 (43.6)	656 (29)	1,622 (31.4)	529 (31.5)	275 (42.8)	
Gender, n (%)							< 0.001
Male	6,049 (61.3)	66 (60)	1,291 (57.1)	3,192 (61.8)	1,089 (64.9)	411 (63.9)	
Female	3,811 (38.7)	44 (40)	970 (42.9)	1,976 (38.2)	589 (35.1)	232 (36.1)	
Vital sign							
HR, mean ± SD	107.4 ± 21.6	99.0 ± 19.1	102.6 ± 21.2	105.4 ± 20.4	114.2 ± 20.7	124.4 ± 22.9	< 0.001
RR, mean ± SD	28.7 ± 6.7	27.3 ± 5.4	27.6 ± 5.9	28.4 ± 6.6	29.8 ± 6.7	32.8 ± 7.6	< 0.001
Laboratory data							
WBC ($\times 10^9$/L), mean ± SD	16.0 ± 14.5	18.0 ± 8.9	15.2 ± 10.6	16.0 ± 13.9	16.3 ± 12.8	18.4 ± 29.2	< 0.001
HGB (g/dL), median (IQR)	9.2 (7.9, 10.7)	9.2 (8.2, 11.5)	9.1 (7.8, 10.5)	9.1 (7.9, 10.6)	9.4 (8.0, 10.9)	9.6 (8.0, 11.1)	< 0.001
AG (mEq/L), mean ± SD	12.9 ± 3.8	15.2 ± 4.6	13.4 ± 4.1	12.8 ± 3.8	12.6 ± 3.6	13.1 ± 3.6	< 0.001
CO_2 (mmol/L), mean ± SD	20.4 ± 4.8	16.7 ± 5.3	20.4 ± 5.0	20.6 ± 4.7	20.6 ± 4.6	19.4 ± 4.8	< 0.001
PLT ($\times 10^9$/L), median (IQR)	117.0 (80.0, 164.0)	133.0 (100.0, 181.0)	118.0 (81.0, 175.0)	115.0 (80.0, 159.0)	118.0 (83.0, 165.0)	116.0 (67.0, 164.0)	0.001
Glucose (mg/dL), median (IQR)	143.0 (117.0, 190.0)	203.0 (141.0, 323.8)	142.0 (115.0, 188.0)	141.0 (116.0, 187.0)	147.5 (120.0, 194.0)	154.0 (122.0, 199.0)	< 0.001
BUN (mg/dL), median (IQR)	24.0 (16.0, 41.0)	29.5 (19.2, 55.2)	29.0 (18.0, 51.0)	24.0 (16.0, 39.0)	22.0 (15.0, 35.0)	22.0 (14.5, 37.0)	< 0.001
Scr (mg/dL), median (IQR)	1.2 (0.9, 2.0)	1.6 (1.1, 3.4)	1.3 (0.9, 2.2)	1.2 (0.8, 1.8)	1.2 (0.9, 1.8)	1.2 (0.9, 2.0)	< 0.001
INR, median (IQR)	1.6 (1.4, 2.0)	1.7 (1.5, 2.6)	1.7 (1.4, 2.3)	1.6 (1.4, 2.0)	1.6 (1.4, 2.0)	1.6 (1.4, 1.9)	< 0.001
PT (s), median (IQR)	17.5 (15.5, 22.1)	18.9 (16.1, 27.6)	18.1 (15.8, 24.3)	17.3 (15.4, 21.7)	17.2 (15.3, 21.1)	17.5 (15.6, 20.9)	< 0.001
PTT (s), median (IQR)	36.7 (31.1, 49.9)	47.8 (36.8, 85.4)	38.7 (32.1, 54.5)	36.2 (30.9, 48.8)	36.0 (30.9, 47.4)	35.9 (30.8, 48.0)	< 0.001
Medical history							
Myocardial infarct, n (%)	1,712 (17.4)	31 (28.2)	456 (20.2)	865 (16.7)	274 (16.3)	86 (13.4)	< 0.001
Congestive heart failure, n (%)	2,994 (30.4)	43 (39.1)	842 (37.2)	1,510 (29.2)	444 (26.5)	155 (24.1)	< 0.001
Cerebrovascular disease, n (%)	1,138 (11.5)	13 (11.8)	221 (9.8)	598 (11.6)	223 (13.3)	83 (12.9)	0.011
Chronic pulmonary disease, n (%)	2,379 (24.1)	30 (27.3)	578 (25.6)	1,269 (24.6)	373 (22.2)	129 (20.1)	0.012
Diabetes, n (%)	2,901 (29.4)	22 (20)	705 (31.2)	1,533 (29.7)	469 (27.9)	172 (26.7)	0.016
Renal disease, n (%)	2,161 (21.9)	31 (28.2)	647 (28.6)	1,093 (21.1)	297 (17.7)	93 (14.5)	< 0.001
Disease severity score							
Charlson comorbidity index, mean ± SD	6.0 ± 2.9	5.7 ± 2.9	6.6 ± 2.7	6.1 ± 2.8	5.4 ± 2.9	4.9 ± 3.0	< 0.001
SOFA score, mean ± SD	4.1 ± 2.3	4.8 ± 2.4	4.2 ± 2.3	4.1 ± 2.3	3.9 ± 2.1	4.1 ± 2.2	< 0.001
SAPSII, mean ± SD	41.7 ± 14.5	51.6 ± 16.6	43.2 ± 13.8	40.8 ± 14.2	40.7 ± 15.0	43.9 ± 15.9	< 0.001
Procedure							
RRT use, n (%)	605 (6.1)	19 (17.3)	157 (6.9)	292 (5.7)	88 (5.2)	49 (7.6)	< 0.001

(*Continued on next page*)

Table 1. Continued.

Characteristic	Total n = 9,860	Temperature (°C)				*P*-value
		<36.0 n = 110	36.0 ~ < 37.0 n = 2,261	37.0 ~ < 38.0 n = 5,168	38.0 ~ < 39.0 n = 1,678	≥39.0 n = 643	
Ventilator use, n (%)	5,065 (51.4)	87 (79.1)	879 (38.9)	2,667 (51.6)	1,063 (63.3)	369 (57.4)	< 0.001
Vasopressor use, n (%)	5,341 (54.2)	78 (70.9)	1,193 (52.8)	2,796 (54.1)	917 (54.6)	357 (55.5)	0.005
Outcomes							
Los hospital (days), median (IQR) days	9.0 (5.6, 16.0)	6.8 (3.9, 14.2)	8.5 (5.3, 15.1)	8.7 (5.4, 15.0)	10.0 (6.0, 18.2)	11.2 (6.8, 21.4)	< 0.001
Los ICU (days), median (IQR) days	3.1 (1.8, 6.2)	4.4 (2.6, 7.4)	2.9 (1.7, 5.3)	2.9 (1.7, 5.6)	3.8 (2.0, 7.7)	4.8 (2.5, 9.3)	< 0.001
28-day mortality, n (%)	2,062 (20.9)	61 (55.5)	622 (27.5)	938 (18.2)	305 (18.2)	136 (21.2)	< 0.001
90-day mortality, n (%)	2,754 (27.9)	68 (61.8)	811 (35.9)	1,292 (25)	408 (24.3)	175 (27.2)	< 0.001

HR, heart rate; *RR*, respiratory rate; *WBC*, white blood cell; *HGB*, hemoglobin; *PLT*, platelets; *AG*, anion gap; CO_2, bicarbonate; *BUN*, blood urea nitrogen; *Scr*, serum creatinine; *INR*, International Normalized Ratio; *PT*, prothrombin time; *PTT*, partial thromboplastin time; *SOFA*, sequential organ failure assessment; *SAPSII*, simplified acute physiology score II; *RRT*, renal replacement therapy; *LOS*, length of stay.

DISCUSSION

In our study, a significant revelation emerges from the analysis. Specifically, SIC patients within the 37.0–38°C temperature range exhibited the most favorable prognosis, characterized by the lowest mortality. Conversely, low body temperature (<36.0°C) was associated with higher mortality in the SIC population similar to that observed in other septic cohorts. Subgroup analyses, aside from cerebrovascular disease, demonstrated no substantial effect modification by age, gender, or comorbidities.

Our results contribute novel insights into the implications of body temperature in SIC, marking a pioneering attempt at investigating this association. Sepsis-induced coagulopathy holds a pivotal place in the spectrum of sepsis-related coagulation disorders, intimately connected with disseminated intravascular coagulation (DIC).[24] Recognized for its role in the pathogenesis of sepsis, SIC acts as a bridge between early systemic inflammation and full-blown DIC. By highlighting the potential value of SIC as a marker and a possible therapeutic target, our study underscores its significance in guiding clinical decisions and furthering our understanding of sepsis pathogenesis.

The observed differences in mortality and hospital stay duration based on temperature groups underscore the clinical significance of temperature management in SIC. Patients in the hypothermic group (<36.0°C) displayed the highest 28-day mortality risk, suggestive of severe physiological distress and compromised organ function.[25] Correspondingly, maintaining a normothermic range (37.0–38.0°C) was associated with improved survival outcomes, highlighting the potential importance of normothermia in enhancing patient prognosis.[26] Our study echoes previous reports associating lower temperatures with heightened mortality risk in septic patients.[13,19] Notably, our definition of hypothermia (<36.0°C) within the SIC cohort yielded a 2.6-fold increase in mortality after adjusting for confounding factors, reaffirming the significance of this observation.

The underlying mechanisms linking temperature with mortality in sepsis are multifaceted. Hypothermia can contribute to immune suppression, impaired thermoregulation, and disrupted coagulation pathways by causing platelet dysfunction and a mild decrease in platelet count or other steps in the coagulation cascade, thereby exacerbating mortality risk.[27] Conversely, fever has been linked to improved survival due to enhanced bacterial clearance, optimized antibiotic efficacy, and controlled inflammatory responses.[11,28] In contrast to prior studies in sepsis populations, our findings in the sepsis-induced coagulopathy (SIC) cohort did not indicate that an early peak temperature above 39.5°C was associated with worse outcomes.[11,29] In fact, patients with temperatures in the 37.0–38.0°C range exhibited the

Table 2. Results of multivariate regression analysis between temperature and outcomes.

	Model I		Model IV	
Variable	**HR (95% CI)**	***P*-value**	**HR (95% CI)**	***P*-value**
Primary outcomes				
28-day mortality[a]				
Temperature	0.78 (0.74 ~ 0.83)	<0.001	0.82 (0.78 ~ 0.87)	0.001
Body temperature				
<36.0	2.82 (2.17 ~ 3.66)	<0.001	2.6 (1.99 ~ 3.42)	<0.001
36.0–37.0	1 (Ref)		1 (Ref)	
37.0–38.0	0.62 (0.56 ~ 0.69)	<0.001	0.7 (0.63 ~ 0.78)	<0.001
38.0 ~ –39.0	0.63 (0.55 ~ 0.72)	<0.001	0.76 (0.66 ~ 0.88)	0.001
≥39.0	0.75 (0.62 ~ 0.9)	0.002	0.72 (0.59 ~ 0.87)	0.001
Trend		<0.001		<0.001
Secondary outcomes				
90-day mortality				
Temperature	0.79 (0.75 ~ 0.83)	<0.001	0.84 (0.8 ~ 0.89)	<0.001
Body temperature				
<36.0	2.52 (1.97 ~ 3.23)	<0.001	2.48 (1.92 ~ 3.2)	<0.001
36.0–37.0	1 (Ref)		1 (Ref)	
37.0–38.0	0.64 (0.59 ~ 0.7)	<0.001	0.73 (0.67 ~ 0.8)	<0.001
38.0–39.0	0.63 (0.56 ~ 0.71)	<0.001	0.79 (0.69 ~ 0.89)	<0.001
≥39.0	0.72 (0.61 ~ 0.85)	<0.001	0.73 (0.62 ~ 0.87)	0.001
Trend		<0.001		<0.001
LOS ICU[b]	0.77* (0.61 ~ 0.92)	<0.001	0.4* (0.24 ~ 0.55)	<0.001
LOS hospital[b]	1.33* (1.01 ~ 1.66)	<0.001	0.82* (0.48 ~ 1.15)	<0.001

Note: Model I adjusted for nothing. Model IV adjusted for gender, age, race, HR, RR, hemoglobin, platelets, INR, WBC, anion gap, bicarbonate, bun, creatinine, glucose, PT, PTT, myocardial infarction, congestive heart failure, cerebrovascular disease, chronic pulmonary disease, renal disease, Charlson comorbidity index, SOFA score, SAPSII, RRT, first day ventilation use and vasopressor use.
[a]Logistic regression analysis.
[b]Linear regression analysis.
*Regression coefficient (β).
HR, hazard ratio; *CI*, confidence interval; *LOS*, length of stay.

lowest mortality, similar to those with temperatures above 39.0°C.

We found that normothermia (37.0–38.0°C, defined as a mild fever in some countries) was associated with reduced mortality compared to 36.0–37.0°C. This is consistent with previous findings. A multicenter RCT by Schortgen et al. reported external cooling to achieve normothermia (36.5–37.0°C) could reduce 14-day mortality compared to external heating to achieve fever control.[8] However, a RCT by Young et al. did not find a significant difference in 90-day mortality between fever control and no fever control.[30] The discrepancy may be explained by the different target temperature ranges. Overall, maintaining normothermia or mild fever appears to be beneficial based on current evidence.

Fever is common in sepsis patients. However, studies on the association between high fever (>39.0°C) and sepsis mortality remain controversial.[16,31] Our study showed slightly increased mortality in high fever patients with SIC than in mild fever patients, but did not reach statistically significance Future research is warranted to clarify this relationship in SIC patients.

Moreover, our results demonstrated a nonlinear relationship between body temperature and both 28-day and 90-day all-cause mortality. Each Celsius degree increase in temperature correlated with an 18% reduction in 28-day mortality, underscoring the potential benefits of maintaining normothermia during SIC treatment. However, the relationship shifted beyond a temperature threshold of 38.0°C, where consistently increased temperatures correlated

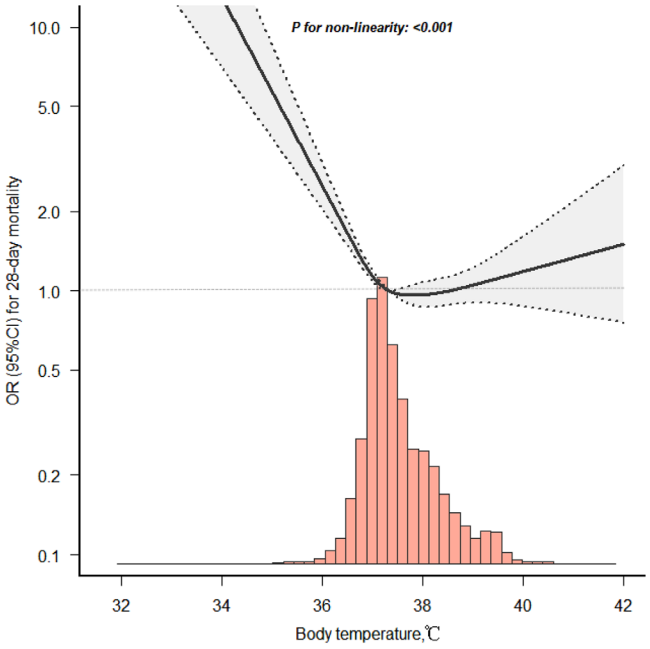


Figure 2. Smooth curve fitting for temperature and 28-day mortality in patients with sepsis-induced coagulopathy.

with gradual, albeit statistically insignificant, increases in mortality.

Notably, subgroup analysis revealed no significant interaction on 28-day mortality in most subgroups, suggesting that body temperature might independently influence the prognosis of SIC patients regardless of factors like age, gender, or other comorbidities. However, a significant interaction was observed in cerebrovascular disease patients, indicating that this specific subgroup may have unique thermoregulation characteristics warranting further investigation.[32] The phenomenon that patients with sepsis complicated by cerebrovascular disease displayed different patterns of fever and outcome associations merits closer investigation. Several possible mechanisms may underpin this interaction. First, thermoregulation in cerebrovascular disease is impaired. Central thermoregulation involves complex neural circuitry like the preoptic anterior hypothalamus.[33] Ischemic or hemorrhagic stroke can interrupt the involved pathways, compromising thermoregulatory capacity.[34] This may contribute to altered fever responses in our subgroup of patients. Second, cerebral inflammation is exacerbated by fever. Animal studies showed

Table 3. Threshold effect analysis of the association between the body temperature and the 28-day mortality in SIC patients.

Threshold of body temperature	HR (95%CI)
<38.095	0.640 (0.589, 0.696)
≥38.095	1.192 (0.984, 1.444)

Note: The data have been adjusted for all of the factors included in Model IV in Table 2.
HR, hazard ratio; *CI,* confidence interval; *SIC,* sepsis-induced coagulopathy.

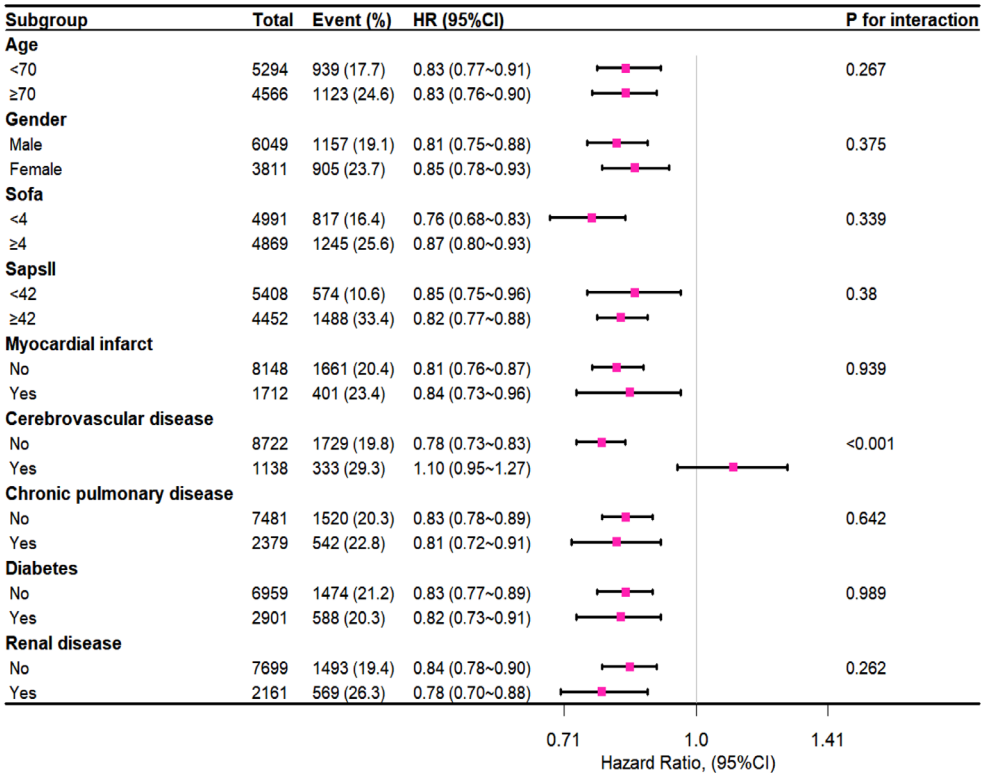


Figure 3. Subgroup analysis of association between temperature and 28-day mortality.

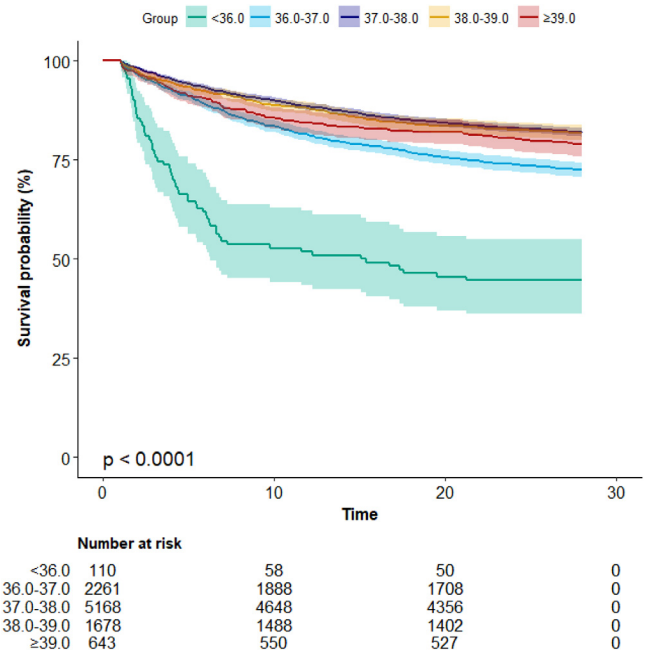


Figure 4. Kaplan–Meier curve of 28-day mortality for patients with sepsis-induced coagulopathy.

hyperthermia can worsen ischemic injuries via increased neutrophil infiltration, blood-brain barrier dysfunction, edema formation and neuronal loss.[35,36] Therefore, febrile responses in sepsis patients with preexisting cerebrovascular lesions may worsen secondary insults through neuroinflammation. Third, cerebral perfusion is impaired by fever. Fever escalates metabolic demands while septic shock reduces cerebral perfusion.[37–39] The combined effects may create mismatches in oxygen supply and demand, setting the stage for ischemic damage. Strict fever control might help conserve neuronal viability.

Our study holds several notable strengths. By exclusively focusing on SIC patients, we address a crucial gap in the literature. Our comprehensive analysis bolsters the reliability and generalizability of our findings, while also uncovering novel correlations and their implications. The observed non-linear temperature-mortality relationship adds a new layer of understanding to SIC management, highlighting potential harm at both temperature extremes.

However, certain limitations should be acknowledged. Our study's retrospective nature and reliance on data from a single center introduce potential biases and limit external validity. Inclusion of patients receiving antipyretics or temperature management could influence observed temperatures. Additionally, the use of the highest body temperature at ICU admission may not capture dynamic temperature changes. It is also important to note that our analysis was limited to 9,860 patients out of the initial cohort of 23,828 patients due to the lack of available SIC scores, which was our primary independent variable of interest. The exclusion of patients without SIC scores may have introduced potential selection bias, as these patients could have differed systematically from those included in the analysis. However, the large sample size of 9,860 patients with complete data still provides a robust basis for our findings. Future studies with more comprehensive data collection would be valuable to further validate and generalize our results.

CONCLUSION

In conclusion, our study identifies an association that merits attention in the context of SIC patient management in ICU settings. We found that among SIC patients on their first day in the ICU, a body temperature from 37.0–38.0°C was associated with a significantly improved prognosis, marked by the lowest overall mortality risk, while the group with low body temperature (<36.0°C) exhibited the highest mortality risk. Additionally, a gradual but statistically non-significant increase in mortality risk was observed when body temperature exceeded 38.0°C. Future research on the impact of rigorous temperature management on SIC patient outcomes, and prospective validation of our association between temperature and sepsis mortality, is needed to provide a more comprehensive understanding of this complex relationship.

AVAILABILITY OF DATA AND MATERIAL

All data in the article can be obtained from MIMIC-IV database (https://mimic.physionet.org/).

ETHICS DECLARATIONS

The research protocol for this retrospective study using a de-identified database was reviewed and approved by the Institutional Review Board (IRB) of the Massachusetts Institute of Technology and Beth Israel Deaconess Medical Center. The requirement for informed consent was waived in accordance with the US Code of Federal Regulations and institutional guidelines.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This work was supported by the

Guangdong Medical Science and Technology Research Fund Project (grant no. A2023178 to ZTE), the Basic and Applied Basic Research Fund of Guangdong (Regional Cooperation Fund Project, 2022) (grant no. 2022A1515140033 to JJ), the 14th Five-Year High-Level Medical Key Specialty Project of Foshan, and the Foshan Science and Technology Innovation Projects (2022) (grant no. 2220001004172 to GJC). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. There are no other conflicts of interest or sources of funding to declare.

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Scoping Review: Is Push-Dose Norepinephrine a Better Choice?

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Section Editor: David Page, MD
Submission history: Submitted November 16, 2023; Revision received April 11, 2024; Accepted April 16, 2024
Electronically published July 17, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18584

Introduction: The use of push-dose vasopressors to treat anesthesia-induced hypotension is a common evidence-based practice among anesthesiologists. In more recent years, the use of push-dose vasopressors has transitioned to the emergency department (ED) and critical care setting. There is debate on the best choice of a push-dose vasopressor, with push-dose epinephrine or phenylephrine being more commonly used. This scoping review evaluated publications regarding the clinical use of push-dose norepinephrine.

Methods: We queried research studies in both PubMed and Google Scholar on the use of push-dose norepinephrine in human subjects, with numerous randomized controlled trials that compare norepinephrine to other vasopressors including phenylephrine, ephedrine, and epinephrine.

Results: A large majority of the studies were performed in the setting of spinal anesthesia prior to cesarean section, while several involved the administration of general anesthesia, with limited-to-no literature in the emergency and critical care setting. Of the 27 studies that we included in the review, 17 were randomized controlled trials. These studies demonstrated that norepinephrine was safe and effective.

Conclusion: Prior research has demonstrated the superiority of norepinephrine as a pressor of choice for various shock states. In this review, the safety and efficacy of push-dose norepinephrine is demonstrated, and favorable hemodynamic markers are shown in comparison to other agents. In addition, there are some safety and efficiency benefits to using push-dose norepinephrine from an administration standpoint, as well as clinically in decreased need for repeat doses. Further high-quality studies in the emergency and critical care realm would be beneficial to confirm these findings. [West J Emerg Med. 2024;25(5)708–714.]

Keywords: *push-dose vasopressors; norepinephrine; anesthesia-induced hypotension; critical care.*

INTRODUCTION

The use of push-dose vasopressors to treat anesthesia induced-hypotension is a common, evidence-based practice among anesthesiologists,[1] which has transitioned to the emergency department (ED) and critical care setting. Push-dose vasopressors allow clinicians to urgently stabilize patients' hemodynamics and provide additional time for procedures (eg, intubations) and bridging to continuous infusions. Norepinephrine (NE) is the vasopressor of choice in most shock states due in part to a decreased incidence of side effects,[2] superior hemodynamic profile,[3] and better control of the shock state.[4] Our main purpose in this scoping review was to determine the evidence for push-dose NE compared to other vasopressors while addressing the safety, effectiveness, and efficiency of the drug.

METHODS

In this study we evaluated full-text publications in the English language regarding the clinical use of push-dose NE in human subjects in accordance with PRISA-ScR guidelines. Using PubMed and Google Scholar in October 2022, literature was reviewed based on the following keywords: "bolus norepinephrine," "push-dose norepinephrine," and various formulations of "norepinephrine/administration and dosage" [Mesh] AND (push bolus OR bolus dose) Filters: English, Humans. Using OR including various other names for norepinephrine including Droxidop, Nordefrin, Normetanephrine, Levonorepinephrine, Noradrenaline, Levarterenol, Levonor, Levophed, Levophed Bitartrate, or Noradrénaline tartrate renaudin.

We identified 88 articles using these search terms (Figure). These articles were reviewed to determine whether the administration of NE was studied as a push or bolus dose. We excluded those which only included NE infusions. One reviewer reviewed the studies for eligibility, which was then confirmed independently by a second reviewer. Non-human studies, case reports, and letters to the editors were excluded. We also excluded studies on circulating plasma levels of NE, as well as articles whose primary outcome was not hemodynamics. One excluded article focused on NE use to avoid post-reperfusion syndrome in liver transplant, and another focused on umbilical arterial pH in neonates after their mothers received NE during their cesarean section. Of these included articles, 27 studies that included push-dose NE were included in the following review. The articles obtained were published in or after 2015 except for one study.[5] Seventeen were randomized controlled trials (RCT), and four were dose-finding trials. There were three prospective observational studies and three literature reviews.

Population Health Research Capsule

What do we already know about this issue?
Push-dose vasopressors are commonly used in emergency and critical care settings. Norepinephrine infusions have been shown to be superior to other vasopressors.

What was the research question?
We sought to determine the evidence for push-dose norepinephrine compared to other vasopressors.

What was the major finding of the study?
The safety and efficacy of push-dose norepinephrine at 4–16 mcg is demonstrated compared to other agents.

How does this improve population health?
Push-dose vasopressors are a crucial part of emergency and critical care and are used for hemodynamic stabilization during time-sensitive patient emergencies.

RESULTS

There were seven RCTs that compared NE with phenylephrine, encompassing a total of 626 patients, all in the setting of maternal patients receiving spinal anesthesia for cesarean section.[6–12] Norepinephrine showed less risk of bradycardia compared to phenylephrine. The use of NE required fewer boluses than phenylephrine to correct hypotension and maintained higher cardiac output and stroke volume in comparison to phenylephrine. There were no safety concerns with NE used peripherally. The relative potency ratio used on average was norepinephrine: phenylephrine 1 microgram (μg):12.5 μg.

Two double-blinded RCTs compared NE with both phenylephrine and ephedrine.[13,14] These two studies involved a total of 211 patients receiving spinal anesthesia for cesarean section. Norepinephrine had fewer episodes of bradycardia compared to phenylephrine and fewer episodes of tachycardia compared to ephedrine. In one study[14] NE maintained a higher mean arterial pressure (MAP) compared to the other two agents.

Baraka et al looked at the hemodynamic effects in phenylephrine, NE, and epinephrine for intubated patients undergoing coronary artery bypass grafting[5]. Phenylephrine and NE had similar changes in systemic vascular resistance without significant change in cardiac output. All agents increased MAP similarly in this study. Of note, this was the only study we found that compared push-dose epinephrine with NE.

Three double-blinded RCTs compared NE with ephedrine with 276 total patients.[15–17] In each study, NE was found to be more efficacious than ephedrine in maintaining MAP and was also associated with less tachycardia and fewer total doses given. One study used radial artery catheters for monitoring both MAP and heart rate, while the others used non-invasive monitoring at standard intervals. These studies also included hypertensive patients undergoing spinal surgery and patients with coronary artery disease undergoing knee arthroscopy.

Four RCTs compared different NE boluses/infusions, two of which were double-blinded.[18–21] Each of these studies was related to spinal-induced hypotension during cesarean section, and primarily focused on prevention of hypotension by administration of prophylactic NE. Infusions were successful in preventing hypotension, and higher boluses

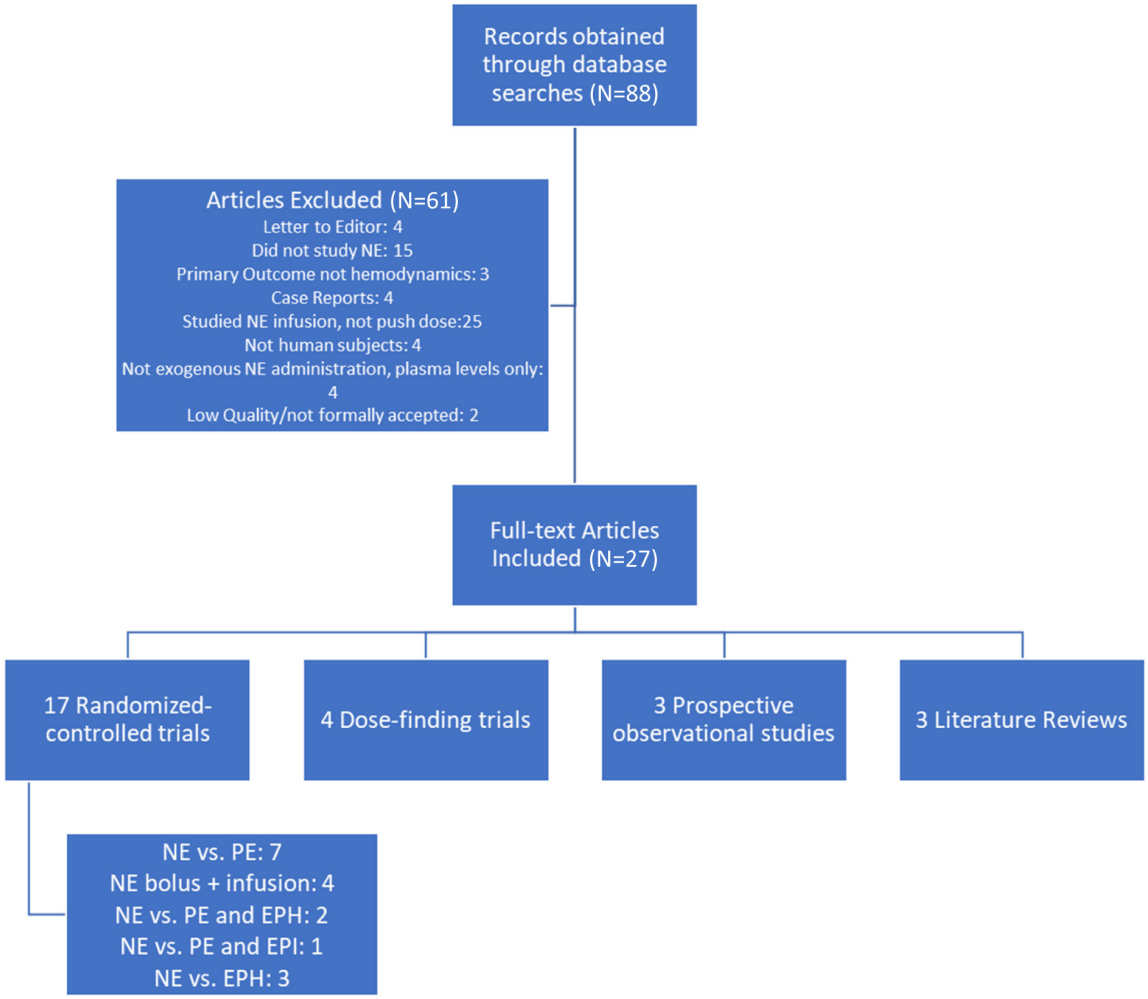


Figure. Search Strategy and Results. *NE*, norepinephrine; *PE*, phenylephrine; *EPH*, ephedrine; *EPI*, epinephrine.

(6 μg or 0.10 μg/kg) performed better compared to lower boluses (4 mcg or 0.05 μg/kg).

There were four dose-finding trials including a total of 342 patients undergoing spinal anesthesia during cesarean delivery.[22–25] Different methods were used to determine efficacy, with the primary goal of maintaining systolic blood pressure at 80% of the initial reading. For a double-blind sequential allocation study with biased coin up and down design, the ED_{90} was 5.8 μg. Using random allocation graded dose response, the ED_{50} for NE was 10 μg. Another study comparing prophylactic versus rescue bolus of NE has an ED_{90} of 10.85 μg for prophylactic dose and 12.3 μg for rescue dose.

There were three prospective, observational studies regarding push-dose NE, one during general anesthesia and two during spinal anesthesia for cesarean sections.[26–28] Two of these studies compared NE against phenylephrine.[27,29] Norepinephrine resulted in increased stroke volume compared to phenylephrine. Other hemodynamic effects were similar between the two agents. Another study reviewed the use of NE compared to ephedrine, with NE showing higher MAPs and less tachycardia compared to ephedrine, also lower number of boluses needed for treatment of hypotension.[28]

There were three prior literature reviews identified.[29–31] The first performed in 2018 identified nine full-text articles regarding the use of norepinephrine.[30] At that time, it was determined that the efficacy of NE is similar to phenylephrine without adverse outcomes, shows improvement in cardiac output and decreased risk of bradycardia. A second review focused on the pharmacology of various vasopressors and their diverse clinical scenarios for use (intraoperative, periprocedural, bridge to vasopressor infusions, post-cardiac arrest, and anaphylaxis).[31] This article also covered the safety and compounding concerns with the bedside mixing of vasopressors. Diluted concentrations have been shown to be safe peripherally, although central access is preferred. A third review focused on anesthesia use of vasopressors and addressing the pharmacology of common agents in detail.[32]

DISCUSSION

Push-dose epinephrine or phenylephrine are commonly used vasopressors in the critical care setting for the treatment of hypotension.[32] Epinephrine has both alpha and beta effects, thus acting as an inopressor. At lower doses (0.01 to 0.1 μg/kg/min), epinephrine stimulates beta-1 and beta-2 receptors and functions as an inotrope, and at higher doses (>0.1 μg/kg/min) it also stimulates alpha-1 causing vasoconstriction, thus increasing blood pressure. Phenylephrine is a pure alpha-1 agonist that increases arterial and venous tone, thus increasing blood pressure. Ephedrine has both alpha-1 and beta-1 receptor activity. It is a popular choice in the operating room due to its rapid onset (one minute) and longer duration of action (60 minutes).

Norepinephrine is an alpha-1 receptor agonist with moderate beta-1 activity and minimal beta-2 activity. It is an attractive agent because its hemodynamic effects are dominated by its alpha-1 activity, while its beta-1 activity provides just enough inotropy to maintain cardiac output. There are advantages to using push-dose NE compared to other vasopressors including safety, effectiveness, efficiency, and cost.

Safety

The preparation of push-dose vasopressors is associated with a high risk for medication errors because these medications are usually mixed at the patient's bedside for immediate use in stressful situations.[33,34] Because of this high risk, it is recommended that these preparations be double checked by another healthcare professional prior to administration. Immediately after preparation, all syringes and bags that are used in the process should be labeled with the appropriate concentration and medication name to further prevent any medication errors.

Compared to compounding other push-dose vasopressors, an advantage to push-dose NE is that it can allow for limited preparation depending on premixed bag availability. If using a premixed bag 4 milligrams (mg)/250 milliliters (mL) to make push-dose NE, it would require no mixing, and theoretically less chance for compounding errors. For institutions that do not have premix NE 4 mg/250 mL, the preparation of push-dose NE can be mixed by withdrawing the 4 mL of NE from the 4mg/4 mL vial and injecting it into a 250 mL bag of normal saline. From the bag, withdraw 10 mL of NE-containing fluid into a 10 mL syringe. The final concentration would be 16 μg/mL of norepinephrine.

All the dose-finding studies reviewed are in pregnant women undergoing elective cesarean sections receiving spinal anesthesia. However, this data could be extrapolated to the critical care setting with the understanding that patients might require higher empiric doses. Based on several studies assessing push-dose NE, doses ranging from 4–16 μg were reported to be safe and effective in treating or preventing hypotension due to spinal anesthesia. An initial push-dose of NE 4–16 μg (0.25–1 mL) seems to be reasonable in the critical care setting.

Effectiveness

Norepinephrine is the first-line vasopressor for almost all forms of shock, including undifferentiated shock, vasodilatory/septic shock, and cardiogenic shock. The 2021 Surviving Sepsis Campaign recommends NE as the first choice in patients with septic shock (Evans 2021).[35] In the CENSER trial, patients who received early NE had better control of their shock state by the six-hour mark.[4] Not only does NE improve blood pressure, but it also improves cardiac output.[36] It was previously thought that NE might worsen organ hypoperfusion compared to other vasopressors. However, it has since been shown that in patients with severe septic shock, those who received NE had higher splanchnic circulation compared to those who received epinephrine.[37]

A study done by Martin et al showed that patients treated with NE had significantly lower hospital mortality compared to those treated with high-dose dopamine and/or epinephrine.[38] For cardiogenic shock, one study showed that NE has a lower incidence of refractory shock compared to epinephrine.[39] Norepinephrine has also been shown to have a decreased risk of causing arrhythmias compared to dopamine, which makes it preferred over other vasopressors, especially in a cardiogenic shock state.[40] In the setting of hypovolemic or hemorrhage shock, there is a concern that vasopressors may compromise microcirculation and cause tissue ischemia due to excessive arteriolar vasoconstriction. However, a recent study by Harrois et al observed that NE preserved intestinal microcirculation during hemorrhagic shock in mice.[41] Additionally, there was a study completed by Poloujadoff et al in rats, which showed that when using either a hypotensive or normotensive target for fluid resuscitation in hemorrhagic shock, rats that received NE infusions had improved survival compared to those who received fluids only.[42]

The use of push-dose NE can be extended to settings beyond that of shock states, such as prior to or during procedures that require hemodynamic optimization, such as endotracheal intubation or the induction of general anesthesia. Baraka et al compared the effects of NE, phenylephrine, and epinephrine on patients who were endotracheally intubated before undergoing elective coronary artery bypass grafting.[5] They found that the NE group had the highest increase in MAP (42.9% vs 35% and 32.6%). In addition, the PrePARE trial has shown that a fluid bolus may not be enough to prevent cardiovascular collapse.[43] Push-dose epinephrine has gained popularity in the emergency and critical care realm for this purpose. However, randomized trials comparing epinephrine to NE in this setting have not been performed.

Efficiency and Cost

Using a single agent for both push-dose and continuous infusion requires overall less medications/materials than compounding two different agents, which in turn improves efficiency in critical care settings where every minute matters. Compared to phenylephrine 10 mg vials and epinephrine 1 mg vials, the average wholesale price of NE 4 mg vials is slightly more expensive for the required dose needed to prepare push-dose NE.[44] However, in critical care settings push-dose vasopressors are commonly used as a bridge to an infusion; therefore, the NE cost would be negated, as the same bag used to make up the push-dose NE can be used for the infusion.

LIMITATIONS

This review of push-dose NE demonstrated a significant number of double-blinded RCTs. However, nearly all the studies were performed in the operating theater, with limited data in the ED or critical care setting. Patients may be less optimized, and likely would be considerably older and have more comorbidities, than the populations of pregnant females primarily studied in this review undergoing spinal anesthesia. In addition, the optimal dosing of NE may not be accurately reflected for the critical care setting. However, the lack of adverse events is reassuring for its safety profile. It is unclear whether the shorter half-life of NE would impact its utility for periprocedural use; however, the effect of push-dose NE remained either equivalent or better than other vasopressors in the studies reviewed. Norepinephrine appears to be the vasopressor of choice compared to phenylephrine and ephedrine. Comparisons to push-dose epinephrine, which is more commonly used in the critical care setting, are also lacking.

CONCLUSION

Prior research has demonstrated the superiority of norepinephrine as a pressor of choice for various shock states, although it is recognized that the clinical situation may dictate which vasopressor is used. In this review, the safety and efficacy of push-dose NE are demonstrated, and favorable hemodynamic markers are shown in comparison to other agents. In addition, there are some safety and efficiency benefits to using push-dose NE, from both an administration standpoint and clinically in a decreased need for repeat doses. Further high-quality studies in the emergency and critical care realm would be beneficial to confirm these findings.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Program Signaling in Emergency Medicine: The 2022–2023 Program Director Experience

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Section Editors: Paul Logan Weygandt, MD, and Chris Merritt, MD
Submission history: Submitted February 2, 2024; Revision received April 22, 2024; Accepted June 3, 2024
Electronically published August 27, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.19392

Introduction: Program signaling (PS), which enables residency applicants to signal their preference for a specific program, was introduced in emergency medicine (EM) in the 2022–2023 residency application cycle. In this study we evaluated EM program directors' (PD) utilization of PS in application review and ranking. This study also explores the relationship between program characteristics and number of signals received as well as the relative importance and utilization of signals related to the number of signals received.

Methods: This is an institutional review board-approved, cross-sectional study of PDs at Accreditation Council for Graduate Medical Education-accredited EM residency programs. We used descriptive statistics to describe the characteristics of residency programs and practices around PS. Measures of central tendency and dispersion summarized continuous variables. We used chi-square analysis or the Fisher exact test for comparisons between groups for categorical variables. Comparisons for continuous variables were made using the *t*-test for independent samples or analysis of variance.

Results: The response rate was 41% (n = 113/277 EM programs). Most programs participated in PS (n = 261/277 EM programs, 94.2%). Mean number of signals received was 60 (range 2–203). Signals received varied based on program characteristics including geographic location and program type, duration, environment, and longevity. Most used PS in holistic review (52.2%), but other uses varied by proportion of applications that were signaled. The importance of PS in application review (mean 2.9; 1–5 scale, 1 = not important, 5 = extremely important) and rank list preparation (2.1) was relatively low compared to other application elements such as standardized letters of evaluation (4.97 for review, 4.90 for ranking).

Conclusion: The study provides insights into PS utilization in EM's inaugural year. We have identified patterns of signal use based on program characteristics and number of signals received that can inform signal allocation and utilization on an individual applicant and program level. A more nuanced understanding of signal use can provide valuable insight as the specialty of EM grapples with fluctuations in its applicant numbers and shifting demographics of its applicant pool. [West J Emerg Med. 2024;25(5)715–724.]

INTRODUCTION

Program signaling (PS) was introduced into the residency application process in response to the increasing number of applications received by programs, exacerbating the challenge of comprehensive holistic review.[1] Subsequently, EM has experienced drastic fluctuations in the number of applicants pursuing EM and specialty Match rates, as well as unprecedented changes to the demographics of its application pool over the last several years.[2] Even with variability in the number of applications to emergency medicine (EM) in recent years, EM application numbers remain significantly above what they were 10 years ago.[2,3] Program signaling allows applicants to assign signals to their most desired training programs, so that programs may focus their holistic efforts toward high-yield interview candidates, potentially benefiting both applicants and programs.

Program signaling was implemented in EM via the Electronic Residency Application Service (ERAS) in the 2022–2023 residency application cycle, allowing applicants to send five signals at the time of their residency application submission with instruction to not signal their home or away-rotation institutions.[4] The Association of American Medical Colleges (AAMC) published generic guidance for programs regarding the use of PS only during the interview-offer phase and programs attested to a code of conduct regarding signal usage when opting into the process, including guidance not to use PS in rank order list (ROL) decisions.[5] While data was evaluated by ERAS across all participating specialties, and other specialties have reported their own specialty-specific data, opportunities remained to further investigate questions specific to PS within EM.[6–18] The unique challenges facing EM created an appetite and underscored the need for specialty-specific guidance.

To provide evidence-based guidance, the ERAS Application Working Group, a subset of the Council of Residency Directors in EM (CORD EM) Application Process Improvement Committee, created a survey to address more nuanced EM-specific questions not asked or answered by the AAMC survey. Our objective in this study was to determine how EM program directors (PD) used PS in their application review and ranking practices during the 2022–2023 application cycle, particularly in relation to the proportion of signaled applications received. To our knowledge, no other specialties participating in PS have reported PS utilization data in this manner. We also explored the relationship between program characteristics and the number of signals received, including characteristics not previously studied by the AAMC such as geographic location, program length of training, program environment, and program longevity. Lastly, we investigated the relative importance and utilization of signals in comparison to other residency application elements and in relation to the number of signals received.

Population Health Research Capsule

What do we already know about this issue?
Program signaling (PS) was introduced into the emergency medicine (EM) residency application process in 2022–2023 via the Electronic Residency Application Service.

What was the research question?
How did EM program directors use PS in application review and ranking?

What was the major finding of the study?
52.2% of program directors used PS in holistic review. Other uses varied by proportion of signaled applications.

How does this improve population health?
Understanding PS usage patterns helps inform PS allocation and usage on an individual applicant and program level.

METHODS

Study Design

We used a cross-sectional study design. Participants were PDs in Accreditation Council for Graduation Medical Education (ACGME)-accredited EM residency programs participating in the 2023 National Resident Matching Program Match. The CORD member directory, cross-referenced with the ACGME Accreditation Data System public search website, was used to compile the email distribution list. We edited the list to reflect new PDs when possible (277). The survey was created following a thorough literature review and synthesis of background information. Questions were iteratively reviewed by experts in EM medical education. The survey was further refined after conducting two cognitive interviews with EM residency program leaders and then piloted by several EM educators to assess for clarity of the questions. Data was primarily quantitative. No identifying information was collected. The study was designed to take about 10 minutes to complete. Our survey tool is included in Appendix 1. This study was approved by the institutional review board at the institution of authors TF and TS.

Data Collection

The survey link was distributed via email. We collected data using a confidential and secure web-based (Qualtrics, Provo, UT) survey of EM residency PDs or their designees. Anonymous links were created for each potential respondent and distributed via Qualtrics. As described by Dillman and

colleagues, one week prior to distribution of the survey link, PDs received a brief email introducing the study and informing them that they would receive the study link in the coming week.[19] Participants then received a message containing the survey link. Non-responders received up to three reminder messages over five weeks.

Data Analysis

Data was downloaded from REDCap, hosted at Maine Medical Center, directly into SPSS for Windows v 27 (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY) statistical software for analysis. We used descriptive statistics to describe the characteristics of study participants' residency training programs. Program practices and experiences around PS were described using numbers and percentages for each categorical variable. We summarized continuous variables using measures of central tendency (mean or median) and dispersion (standard deviation, interquartile range [IQR]). Comparisons between groups for categorical variables were made using chi-square analysis or the Fisher exact test. Comparisons for continuous variables were made using the *t*-test for independent samples or analysis of variance. We accepted a *P*-value of <0.05 as significant. We also computed differences between groups and their associated 95% confidence intervals (CI) and created visual data displays to aid in interpretation.

RESULTS

Program Characteristics

We received 113/277 surveys (response rate 41%). Participants represented diverse geographic regions, with the largest numbers from the Middle Atlantic, East North Central Midwest, and South Atlantic regions (Table 1). Programs represented were most commonly urban, university-based, and three years length of residency training. Faculty at participating programs were largely university or hospital employees, and most programs reporting being founded more than 15 years.

Program Signaling Participation and Applications Received

The majority of respondents participated in the PS component of the ERAS supplemental application during the 2022–2023 residency application cycle (106, 94%). Reasons for non-participation included not signing up in time (three, 2.7%), feeling that it would not contribute to applicant review or interview offer decisions (two, 1.8%), and being a newly approved program (1, 0.9%). Programs interviewed to fill a mean and median of 12 postgraduate year (PGY)-1 spots (range 6–26 spots, IQR 8–15). The number of signals received by participating programs ranged from 2–203, with a mean of 60 and median of 50 (IQR 23–86). Programs reported receipt of between 283–1,400 applications (mean 768, median 772, IQR 600–926). The proportion of applications that were signaled ranged from 0.7% to 26.5% (mean 7.3%, median 6.5%, IQR 3.9–10.1%).

There was a moderate, positive correlation between the number of signals and the number of applications received ($r = 0.581$, $P < 0.001$) and the proportion of signals received increased based upon the number of applications received ($P < 0.001$) as well as the proportion of applications that were signaled ($P < 0.001$). The number of signals received increased as the number of PGY-1 positions increased ($P < 0.001$). Four quartiles were determined for the number of program signals received, the number of applications received, and the proportion of applications signaled (Supplemental Table 1) to allow for further comparison of data as subsequently detailed.

Signals Received by Program Characteristics

The number of signals received differed significantly based on several key characteristics: geographic location, with greater numbers of signals received in coastal regions ($P < 0.01$); program duration, with four-year receiving more than three-year programs ($P < 0.01$); program type, with urban programs receiving the most ($P < 0.01$); program environment, with university-based programs receiving the most ($P < 0.01$); and longevity of programs with programs in existence >15 years receiving the most ($P < 0.01$). Additional detail is provided in Figures 1 and 2 and Supplemental Figure 1.

Signal Utilization

Programs most commonly endorsed using PS as one component of holistic review (59, 52.2%). Additional specific ways that signals were used include the following: as a tiebreaker between two equally qualified candidates (45, 39.8%); as a screening tool (44, 38.9%); to help prioritize the program's wait list or wait list order (31, 27.4%); and to send an interview invitation to every applicant who signaled the program (19, 16.8%). The proportion of applications that were signaled appeared to affect the frequency with which programs endorsed using signals to prioritize the wait list ($P < 0.001$), serve as a tiebreaker ($P < 0.001$), and to send interview invitations to every signaling applicant ($P = 0.03$) (Figure 3). Participants anticipated using PS in the 2023–2024 cycle similarly to their reported use in the 2022–2023 cycle, and similar differences were also noted for anticipated use based on the proportion of applications that were signaled.

Signal Importance

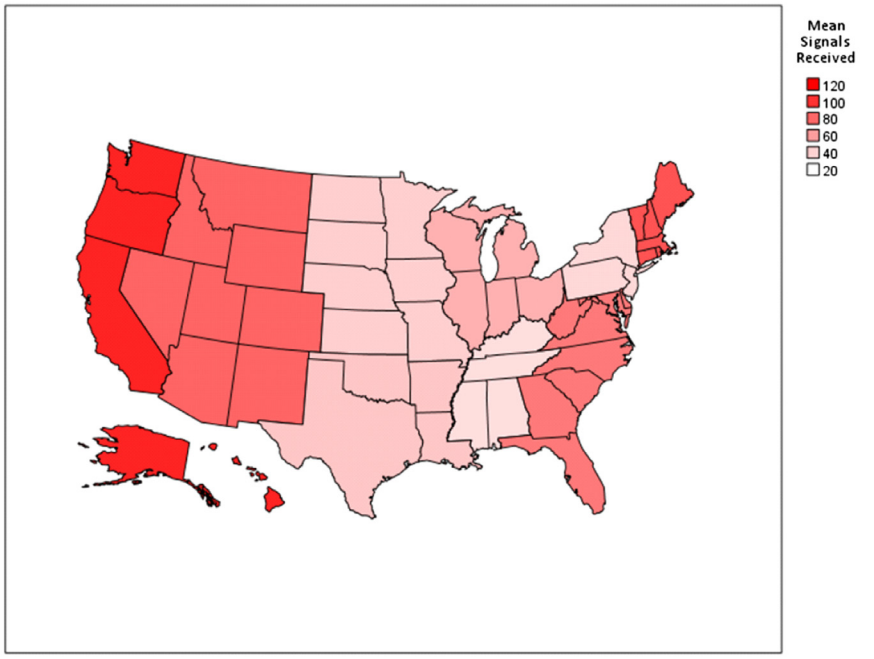
Participants rated the importance of various application elements when considering interview invitations and preparing their program's rank order list (ROL) using a 5-point scale (1 = not important at all, 5 = extremely important) (Table 2). Participants rated the standardized letter of evaluation (SLOE) as the most important element

Table 1. Characteristics of participating residency programs and survey respondents.

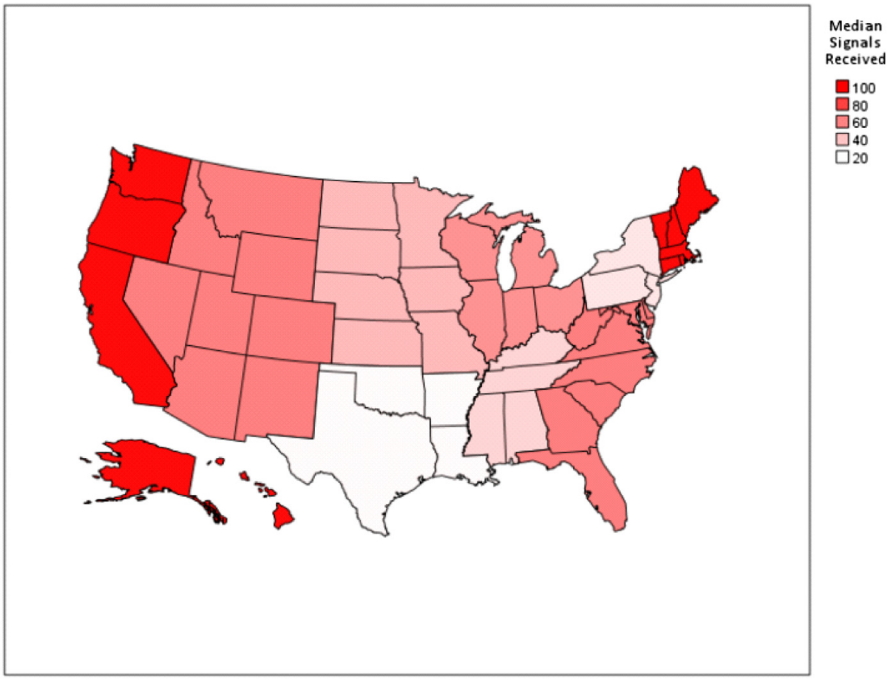
Characteristic	% (*n*)	Comparison to existing program data (percentage of programs)
Professional role		
*Program director	100 (113)	
Geographic region		
Middle Atlantic	24.8 (28)	23.7[a]
East North Central Midwest	20.4 (23)	20.5[a]
South Atlantic	17.7 (20)	19.1[a]
Pacific West	11.5 (13)	10.6[a]
West South Central	11.5 (13)	9.9[a]
New England	5.3 (6)	4.2[a]
Mountain West	4.4 (5)	3.9[a]
West North Central Midwest	2.7 (3)	3.9[a]
East South Central	1.8 (2)	4.2[a]
Program length		
Three years	77.0 (87)	80.6[b]
Four years	23.0 (26)	19.4[b]
Program environment		
Urban	63.7 (72)	Not available
Suburban	30.1 (34)	Not available
Rural	6.2 (7)	Not available
Program type		
University-based	47.8 (54)	35.4[a]
Community-based, university-affiliated	36.3 (41)	46.2[a]
Community-based	15.9 (18)	18.4[a]
Faculty employment model		
University or hospital	73.5 (83)	Not available
Contract management group	18.6 (21)	Not available
Democratic physician-led group	8.0 (9)	Not available
Program longevity		
<5 years	17.7 (20)	Not available
5–10 years	8.0 (9)	Not available
10–15 years	10.6 (12)	Not available
>15 years	63.7 (72)	Not available

**261/277 EM programs participated in PS for 2022–2023. All 277 programs surveyed.*
Middle Atlantic = NJ, NY, PA; East North Central Midwest = IL, IN, MI, OH, WI; South Atlantic = DC, DE, GA, FL, MD, NC, SC, VA, WV, PR; Pacific West = AK, CA, HI, OR, WA; West South Central = AR, LA, OK, TX; New England = CT, MA, ME, NH, RI, VT; Mountain West = AZ, CO, ID, MT, NM, NV, UT, WY; West North Central Midwest = IA, KS, MN, MO, ND, NE, SD; East South Central = AL, MS, KY, TN.
[a]Fellowship and Residency Electronic Interactive Database (FREIDA), https://freida.ama-assn.org
[b]Emergency Medicine Residents' Association (EMRA) Match Database, https://match.emra.org/

when reviewing applications (mean 4.97, 95% CI 4.93–5.00). The SLOEs (mean 4.90, 95% CI 4.83–4.97) and interview day performance (mean 4.81, 95% CI 4.72–4.89) were most important when preparing the ROL. Importance of the presence or absence of a program signal when reviewing applications was a mean of 2.9 (95% CI 2.67–3.13) and median of 3 (2,4). Importance of the presence or absence of a program signal when preparing a ROL was a mean of 2.1 (95% CI 1.87–2.32) and median of 2 (1–3). About 30% of participants (28) endorsed the presence or absence of a program signal as very or extremely important when reviewing applications while 11% (10) rated program signals as being equally important to ROL development.



(A)



(B)

Figure 1. (A) Mean number of signals received by geographic region. (B) Median number of signals received by geographic region. Geographic regions include: East North Central Midwest (IL, IN, MI, OH, WI), East South Central (AL, MS, KY, TN), Middle Atlantic (NJ, NY, PA), Mountain West (AZ, CO, ID, MT, NM, NV, UT, WY), New England (CT, MA, ME, NH, RI, VT), Pacific West (AK, CA, HI, OR, WA), South Atlantic (DC, DE, GA, FL, MD, NC, SC, VA, WV, PR), West North Central Midwest (IA, KS, MN, MO, ND, NE, SD), and West South Central (AR, LA, OK, TX).

We assessed for differences in PDs' relative assessments of various application elements based on the proportion of applications that were signaled (Supplemental Figure 2). As the proportion of applications signaled increased, the proportion of programs endorsing board scores as "extremely important" decreased ($P < 0.01$). As the proportion of applications signaled increased, the proportion of programs endorsing communication before the interview

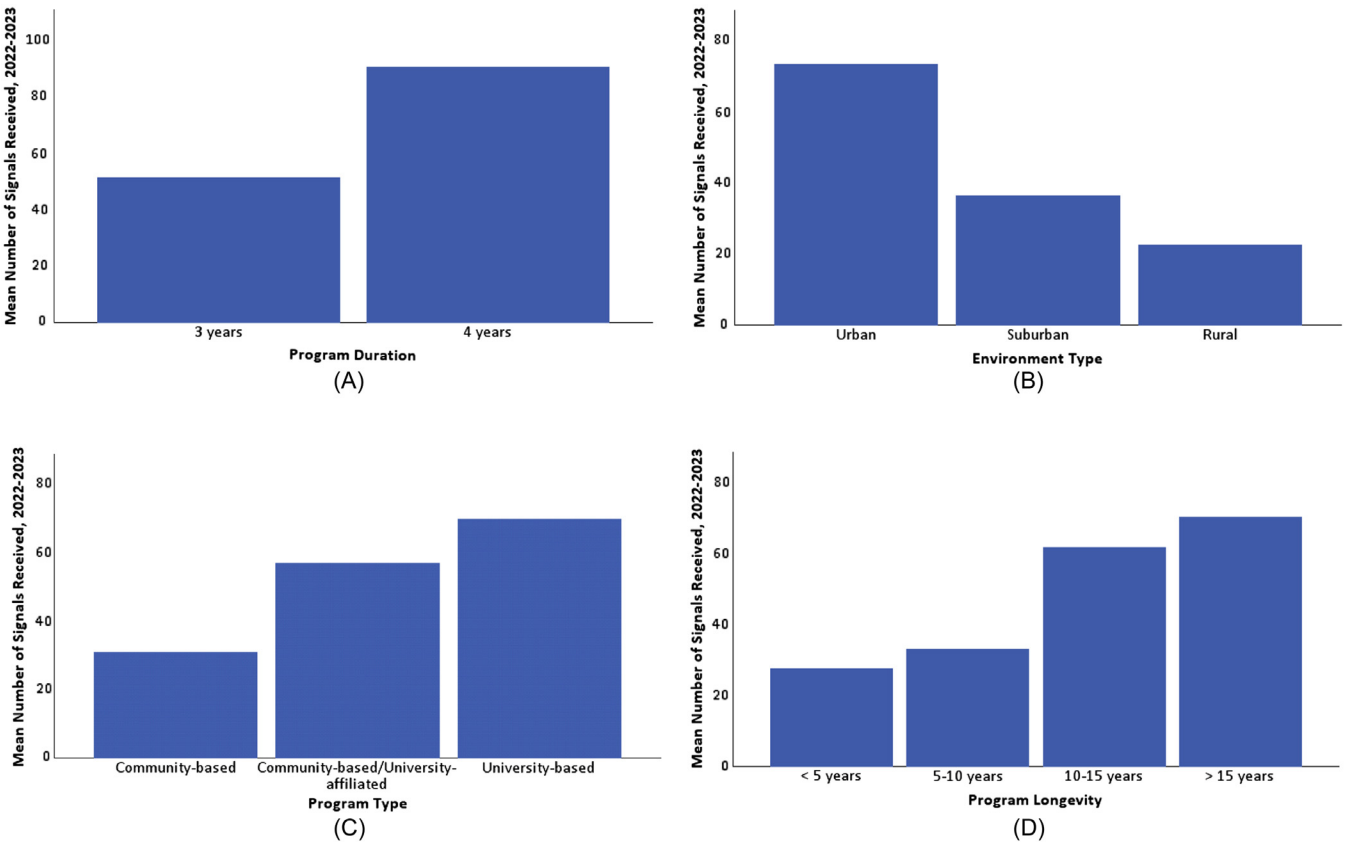
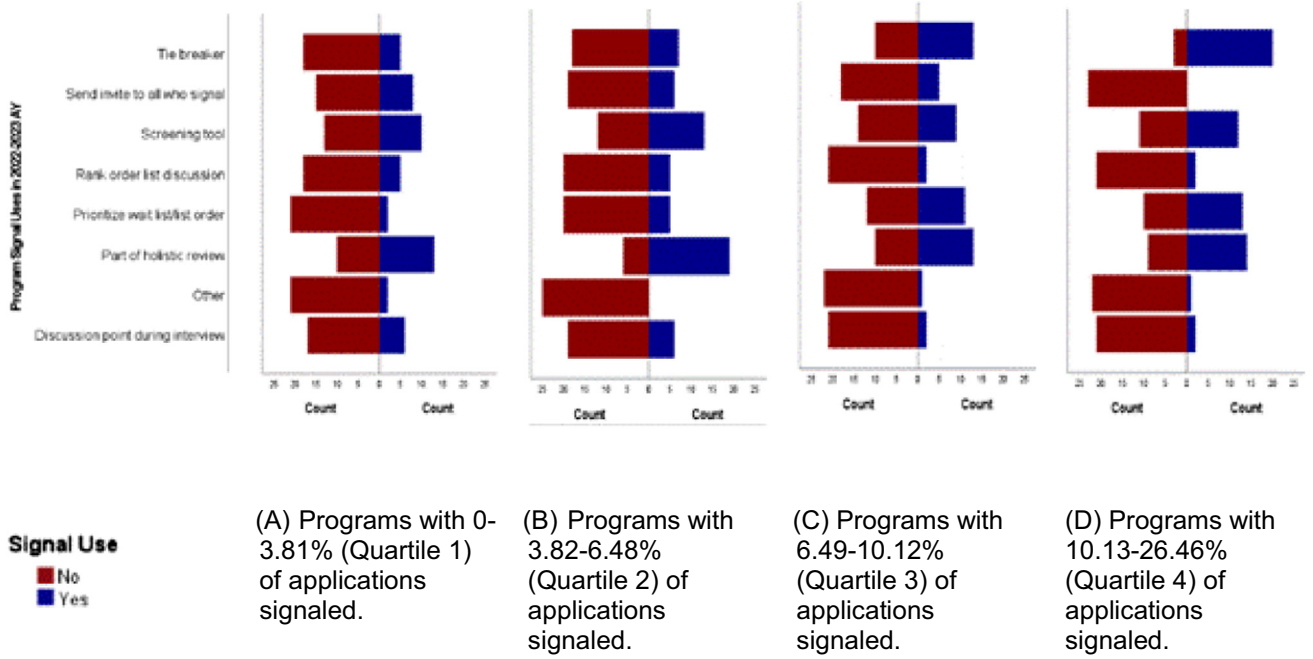


Figure 2. Mean number of signals received by program characteristics. (A) Mean number of signals received by program duration. (B) Mean number of signals received by environment type. (C) Mean number of signals received by program type. (D) Mean number of signals received by program longevity.



(A) Programs with 0-3.81% (Quartile 1) of applications signaled.

(B) Programs with 3.82-6.48% (Quartile 2) of applications signaled.

(C) Programs with 6.49-10.12% (Quartile 3) of applications signaled.

(D) Programs with 10.13-26.46% (Quartile 4) of applications signaled.

Figure 3. Program signal use in the 2022–2023 academic year by the proportion of applicants signaled.*
*The AAMC Code of Conduct, which programs attest to when signing up to participate in program signaling (PS), specifically prohibits the use of PS in rank-order list discussion and preparation.

Table 2. Importance of application elements.

Application element	Importance when reviewing applications	Importance when preparing rank order list
	Mean (95% CI)	Mean (95% CI)
SLOEs	4.97 (4.93–5.00)	4.90 (4.83–4.97)
Interview day interactions	N/A	4.81 (4.72–4.89)
Prior work or life experiences	3.61 (3.42–3.80)	3.52 (3.32–3.72)
Board scores	3.47 (3.27–3.66)	3.14 (2.93–3.35)
MSPE	3.44 (3.24–3.65)	3.32 (3.12–3.53)
Extracurricular involvement	3.36 (3.17–3.54)	3.25 (3.05–3.45)
Presence or absence of a program signal	2.90 (2.67–3.13)	2.10 (1.87–2.32)
Communication before interview	2.64 (2.42–2.87)	2.89 (2.65–3.13)
Research experience	2.46 (2.27–2.64)	2.43 (2.24–2.62)
Letters of recommendation	2.40 (2.22–2.58)	2.33 (2.15–2.52)

*5 point scale where 5 = extremely important and 1 = not important at all.
CI, confidence interval; *SLOE*, standardized letter of evaluation; *MSPE*, medical student performance evaluation.

as "not important at all" increased while the proportion rating this factor "very important" decreased ($P < 0.01$). Extracurricular involvement increased in importance as the number of applications signaled increased, with a larger proportion of participants rating this aspect of the application "extremely important" as the proportion of applications signaled increased ($P = 0.04$). Programs with the lowest proportion of signaling applicants were more likely to rate research experience as "not important at all" than those who had a larger proportion of applications signaled ($P = 0.02$).

DISCUSSION

Responses to our survey appear to be appropriately representative of programs nationwide with regard to geographic distribution, program length, and program type (Table 1).[20,21] Ranges and median numbers for applications and PS data are similar to ERAS data, again demonstrating that our survey respondents reflected a representative sample of EM programs that participated in PS during the studied application cycle.[6]

For data analysis, we used quartiles based on the percentage of signaling applications a program received to correct for the differences in raw numbers based on program size. With the number of signals allocated to each EM applicant increasing from five to seven for the 2023–2024 academic year, it is reasonable to presume that the raw number and percentage of signaling applicants programs receive will also proportionally increase. This discrepancy may make it more difficult for a program to accurately identify with a given quartile based on this year's application data, but these data should still serve as a rough guide by which programs can assess themselves.

Understanding the relationship between program characteristics and the number of received program signals can be helpful for both programs and applicants. Programs can determine their competitiveness within the context of similar programs, which can be particularly helpful in the current EM match environment with a changing applicant demographic pool and many programs going unmatched over the past few years.[2] Providing programs with a barometer against which to measure their own demographics and proportion of signaled applicants early in the application cycle can help guide how they incorporate program signals into their approach and more effectively select applicants who will be highest yield for their programs. By understanding signaling trends as related to program characteristics, advisors and applicants may be able to strategically determine the best approach for allocating signals to maximize each signal's impact.

In our study, we noted that the Pacific West and New England regions demonstrated the highest mean and median signal numbers. In contrast, programs in the East South Central, Mid-Atlantic, West South Central, and West North Central Midwest received fewer signals. It is reasonable to speculate that many of these patterns reflect overall population density patterns, suggesting local preferences that mirror the US population. This hypothesis aligns with our data, which showed that more urban (likely more population-dense) programs received a higher proportion of signals. The only region that does not fit this hypothesis is the Mid-Atlantic region, which is the most densely populated in the country, but we suspect the very high EM program density in this region likely contributed to program signal dilution, leading to lower signals per program.

On average, four-year programs received a higher proportion of signaling applicants than three-year programs. While program length itself may be a driver of this, it may also be due to other confounding features more commonly associated with four-year programs, including urban location, university affiliation, and program duration and stability. Ultimately, our data was unable to discern this difference. Programs with the lowest proportion of signaling applicants were more likely to be smaller, rural, and not academically affiliated. These programs were more likely to rate research experience as "not important at all." We suspect that these smaller, more community-oriented programs may be less research-focused in their missions and, therefore, emphasize research less in their applicant selection. Applicants may be able to use this information to target their signals depending on their interests.

It seems intuitive that the proportion of signaling applicants a program receives would affect how that program values and uses the signal, but to our knowledge this is the first data to demonstrate that effect. When examining signaling use among programs separated into quartiles based on the proportion of signaling applicants, significant differences emerged. Programs that received lower proportions of signaling applicants were more likely to report offering interviews to all signaling applicants while those with the highest proportion of signaling applicants were more likely to incorporate signals as a screening tool or to help prioritize the program's wait list or wait-list order.

By asking programs to rate the importance of various application elements, we hoped to gain an understanding of the relative importance of PS in relation to interview offers and ROL creation. Receiving a program signal in orthopedics was ranked among the most important factors in resident selection for interview.[13] While a successful sub-internship at the PD's institution and letters of recommendation were the highest-ranked criteria for resident selection for interview at urology programs, 81% of urology PDs reported that a lack of a signal would negatively impact interview offer chances for an applicant.[18] In our study, program signals were not shown to hold as much weight as in orthopedics or urology. Program signals were only rated as more important than narrative letters of recommendation, pre-interview communication, and research experience.

How an applicant performs clinically (SLOEs, Medical Student Performance Evaluation) is understandably most important, with PS intended to be only one small part of the holistic application review.[22] Students can be reassured that the traditionally valued portions of the EM application retain their importance well above the value of a program signal, and programs across all quartiles are interviewing and ranking students who did not send them a signal.

Analyzing this data in a more granular fashion, we did observe some significant differences in the relative importance of residency application elements between quartiles. As the proportion of signaling applicants increased, the proportion of participants endorsing board scores as "extremely important" decreased. This discrepancy may speak to the intended ability of PS to mitigate the use of filtering behavior. Programs with smaller proportions of signaling applicants may continue to seek out strategies to stratify their applicant pool to better allocate their holistic review efforts, such as using board score filters. Programs with a higher proportion of signaling applicants, on the other hand, may not feel this same pressure. Alternatively, it is possible that having been prompted by the introduction of PS to investigate programs before applying, applicants may strategically have chosen to target their signals to programs that advertised a lack of board score cutoffs because their score fell below stated cutoffs at other programs or because they valued programs that do not emphasize standardized test scores.

Our data also demonstrates that as the proportion of signaling applicants increased, the proportion of respondents rating pre-interview communication as "extremely important" decreased and the proportion of respondents rating pre-interview communication as "not important at all" increased. This trend suggests that the signal is serving its intended purpose of allowing the applicant to meaningfully express interest, obviating the need for additional, extra-application communication, lessening the burden for both applicants and programs. It also suggests that PS reduces the impact of other communication from applicants.

The AAMC guidance was consistent in its messaging that program signals were only to be used during the application review and interview-offer portion of the application cycle. It is worth noting that despite all programs having attested in the code of conduct not to use PS in the consideration of ROL placement, 11% of programs reported program signals to be very important to the ROL development process. The 2022–23 AAMC PD survey found similar results among PD respondents from all specialties.[6] Program directors may be extrapolating that a student who signaled is likely to be a higher probability match than a student who did not send a signal. This use presumes that student preference will not be significantly affected by their experiences engaging with programs throughout the interview season and is at risk of being flawed logic. However, it is important that applicants be aware that signals may be used by PDs in this manner and should take this into consideration when choosing where to signal.

Participation of EM programs in PS remained robust for the 2023–2024 cycle, with 278 of 279 programs participating and 97.5% of applicants participating (email communication from AAMC ERAS Pilot Administration Director, Jayme Bograd, January 2024).[24] We hope that

this data helps inform programs and applicants on a more nuanced approach to PS in the EM residency application process.

LIMITATIONS

Respondents (113) compared to the total number of ACGME-accredited EM residency programs (277) was limited. The PDs who chose to respond may differ from those who did not concerning their PS experience. Forty-six percent of EM programs did not fill in the 2023 Main Residency Match.[25] Our survey was distributed in the weeks that followed. The PDs experiencing a difficult Match cycle may have been more or less inclined to fill out a survey regarding the residency application process. University-based programs were over-represented. Community-based, university-affiliated programs were under-represented. The 11% of programs that reported using signals as part of their ROL discussions may be an underestimate as other programs may not have been comfortable disclosing behavior that was knowingly in violation of the code of conduct.

CONCLUSION

This study provides detailed data and patterns of signal use yielding insights into program signaling in EM's inaugural year for both programs and applicants. Our data provides a more nuanced understanding of signal utilization across a spectrum of EM programs in a way that allows individual programs to go beyond the general AAMC recommendations and compare their approach to that of programs with similar characteristics. Identifying patterns of signal use based on program characteristics can also inform advising for students deciding on how to best allocate their signals. As EM continues to navigate fluctuations in its applicant numbers and shifting demographics of its applicant pool, providing insight to guide signal use and utilization can help pave a path forward for the specialty toward the goal of more efficiently finding the right applicant for the right program.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Emergency Department Slit Lamp Interdisciplinary Training Via Longitudinal Assessment in Medical Practice

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Section Editors: Jules Jung, MD and Andrew Ketterer, MD
Submission history: Submitted October 20, 2023; Revision received March 21, 2024; Accepted June 7, 2024
Electronically published August 16, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18514

Introduction: Eye emergencies make up nearly 3% of US emergency department (ED) visits. While emergency physicians (EP) should diagnose and treat these ophthalmologic emergencies, many trainees report limited ocular exposure and insufficient training throughout their residency to confidently conduct a thorough slit-lamp exam.

Methods: We created an interdisciplinary, simulation-based mastery learning (SBML) curriculum to teach emergency attending physicians how to operate the slit lamp with multimodal learning methodology at a tertiary academic center. The EPs first demonstrate their initial slit-lamp competency with a 20-item checklist, and they then review the necessary curricular content to pass their independent readiness test before completing their in-person teaching and demonstration session with an ophthalmology attending to demonstrate procedural mastery (minimal passing score >90%).

Results: Fifteen EPs were enrolled; all completed the final exam of the curriculum. The pre- and post-curriculum checklist scores increased by an average of seven points ($P = .002$); 86.7% of EPs felt confident in completing a slit-lamp exam after the curriculum, compared to 20% at the beginning. Five of 15 reported teaching learners within the two-month post-curricular period, ranging from 5–30 students. The hands-on teaching was the most positively reviewed element of the curriculum.

Conclusion: The SBML program successfully trained EPs on performing a comprehensive slit-lamp exam with promising results of downstream education to junior learners. We encourage other institutions to leverage SBML as a teaching modality for procedural-based training and advocate cross-discipline education initiatives. [West J Emerg Med. 2024;25(5)725–734.]

INTRODUCTION

The slit-lamp[1] (Figure 1A) is a microscope that allows for a detailed examination of the anterior eye segment using light beam manipulation. The slit-lamp enables physicians to diagnose anterior ophthalmic pathologies such as corneal injuries, iritis, hyphema, hypopyon, and foreign bodies[2]; furthermore, it is essential for performing detailed ophthalmologic exam techniques such as lid eversion, fluorescein examination, and foreign body removal.[3] The Wood's lamp[4] (Figure 1B), in contrast, is a handheld device often used to characterize skin pigmentation, dermal infections, and macroscopic infections with a built-in magnifying lens and ultraviolet (UV) light. The UV capabilities can highlight fluorescein staining during external ocular exams to assess corneal pathologies at lower magnification. While the Wood's lamp offers a less detailed examination than the slit lamp, it is a more portable diagnostic tool for larger ocular lesions, foreign bodies, or

specific reaction to fluorescein staining and meets the needs of the emergency physician (EP) under certain situations.

Eye emergencies make up nearly 3% of US emergency department (ED) visits, the most common of which are traumatic.[5,6] The most common eye injury evaluated in the ED is corneal abrasion (superficial injury to the cornea) and eyelid laceration. Such injuries are best viewed under high-field magnified viewing using the slit lamp to assess for concomitant injuries or co-infections such as corneal ulcers, hypopyon/endophthalmitis, retained foreign body, full thickness corneal laceration, globe ruptures, and seidel testing.[7] Ocular emergencies such as traumatic globe rupture, ocular foreign body, closed-angle glaucoma, and endophthalmitis are visible only using the slit lamp, and fall within the EP's scope of practice for diagnosis, triaging, and management.[8] Mismanaged ophthalmic emergencies can result in inappropriate consultation, excessive testing, financial burden, and even irreversible vision loss.[9] Despite the significance and frequency of ocular emergencies across the US, many EPs are not confident performing a detailed ophthalmic exam.[10]

Previous literature has found EPs receive fewer than 10 hours of ophthalmic education during residency with low confidence in performing a comprehensive ophthalmic slit-lamp exam.[11] Ophthalmic education through clerkships and didactics in medical school is also in decline, leading to the unpreparedness of incoming residents before any formal residency training.[11,12] However, it is important that EPs be confident in using the slit lamp to appropriately triage and manage ocular emergencies as part of the Accreditation Council for Graduate Medical Education (ACGME) Emergency Medicine (EM) Milestones Patient Care domain (PC8) – General Approach to Procedures, which designates a set of sequential milestones for overall procedural competency, not focusing on a specific list of procedures.[13]

The optimal learning environment for adult learners to perform a technically challenging procedure should incorporate elements from both the mastery learning model and rapid cycle deliberate practice (RCDP). The mastery learning model ensures that students can master a topic if they receive unlimited time and support in learning and reviewing material until mastery proficiency is reached. Meanwhile, the RCDP model ensures learners can practice skills repetitively while receiving brief, interspersed feedback to achieve a designated proficiency level before proceeding to the next task.[14,15–17] Within medical education, simulation-based mastery learning (SBML) models have been successfully implemented across various specialties, such as emergency medicine, general surgery, critical care, and gastroenterology.[18,19,20] In light of successful, smaller scaled studies on the effectiveness of slit-lamp training within undergraduate medical education, we propose a SBML procedural training curriculum that can enable adult learners to conduct deliberate performances of intended cognitive or psychomotor skills in sequential order with a repetitive skills assessment.[15,21,22] Specific, informative feedback will enable sustained performance improvement to achieve slit-lamp mastery.[23] Our goal was to design a pilot interdisciplinary course that could teach EPs to complete a comprehensive slit-lamp exam in diagnosing common anterior eye pathology.

METHODS

Our study, Emergency Department Slit Lamp Interdisciplinary Training via Longitudinal Assessment in Medical Practice (ED SLIT LAMP), is a multicentered, collaborative project that leverages the conceptual frameworks of the mastery learning model and RCDP to ensure proficiency in conducting a comprehensive slit lamp exam. It also serves as a scaffold for deconstructing barriers in traditional siloed medical practices and leads to improved patient care, knowledge synthesis, and resource utilization of our consulting services. The study was conducted at Thomas Jefferson University (TJUH) and the Wills Eye Hospital (WEH) from 2021– 2023. The hospitals with their respective EDs, are 0.2 miles apart, with staff from each institution working as consultants at the other; WEH residents function as ophthalmology consultation for the TJUH ED, while TJUH EPs function as overnight medical emergency

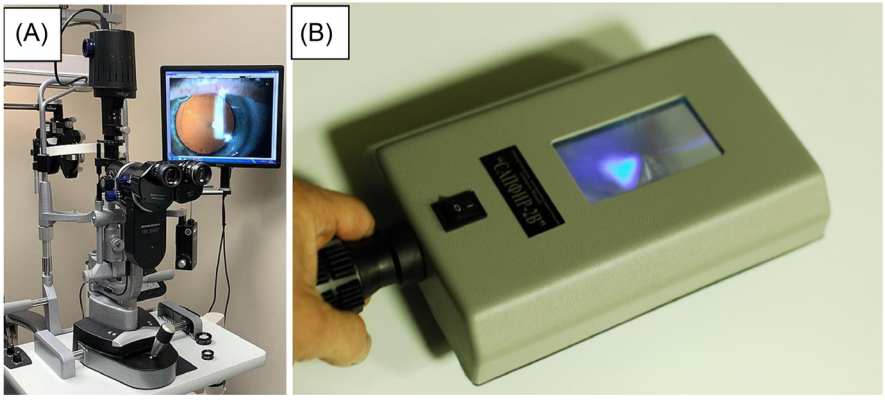


Figure 1. Slit lamp (A) and Wood's lamp (B).

consultants at the WEH ED. The geographic and relationship proximity created ideal conditions to develop and pilot a procedural skill competence SBML curriculum.

Emergency physicians were selected as ideal learners due to their level of training and unique teaching responsibilities. Using the TJUH ED listserv we recruited eligible participants and offered staggered financial incentives. For this pilot study, we required a minimum of 12 participants to meet 5% type 1 error and 80% power based on score improvement from baseline testing to post-testing, as referenced by Miller at al.[24] The ED SLIT LAMP study leveraged talents from content and education experts from both institutions to create an interdisciplinary procedural teaching curriculum. The success of a traditional SBML curriculum is linked to the learners' skill acquisition. Our study expands this measure to include interdisciplinary collaboration, demonstrating the successful alignment between educational and patient-centered goals that benefit both departments. To evaluate the curriculum, we employed all four levels of the Kirkpatrick model. Using pre- and post-test Likert scale questionnaires, our measurement of success included improved learner confidence (level 1), knowledge acquisition (level 2), willingness of learners to incorporate their skillset in clinical practice (level 3), and dissemination of this knowledge to junior learners (level 4). Any curricular feedback and improvements were extracted for future curricular iterations.

A needs-based analysis conducted at TJUH ED revealed EPs desired hands-on slit-lamp education and training on identifying anterior segment ophthalmic complaints. Since ophthalmology is a recognized component of the American Board of Emergency Medicine exam content, we constructed the pre-test clinical content based on critical and common ocular diagnoses, the most common WEH ED ophthalmology discharge diagnoses, and clinical identifications deemed "can't miss" by the ED and ophthalmology department.

All curricular contents (lecture materials, video recording, pre-post-post assessments, study surveys, mastery learning checklist) were created by the principal investigator [XCZ] with ophthalmology co-investigators consultation [CC, MEL] based on targeted needs assessment. These materials underwent sequential review by select experts at WEH and were modified sequentially until a consensus was reached. The minimal passing checklist score was determined to be 90%, based on combined determination from ophthalmologist experts at WEH and similar threshold determined by Miller et al.[24] Each curriculum assessment (Appendix A) was constructed to mirror the natural knowledge, skills, and attitude progression from the ACGME EM Milestones Patient Care Domain (PC8). Due to the multifaceted nature of EM, there is no specific procedural milestone for performing a slit-lamp exam, as described in detail in the ACGME Ophthalmology PC1: Data Acquisition - Basic Ophthalmology Exam and Testing (Level 1).[13] However, the EM PC8 milestones provide structured language applicable to many ED procedures and advanced device-assisted medical examinations (ie, slit-lamp exam). Please see Table 1 for the correlation between the EM milestone and ED SLIT LAMP assessments.

The longitudinal curriculum included four unique time points (Time 0–3) of intervention staggered over six months (Appendix A, Appendix B). At Time 0, participants completed an in-person baseline slit-lamp exam that was video-recorded and reviewed by two independent investigators [XCZ] [MEL]. At Time 1, the participants gained access to an asynchronous learning packet that consisted of a PowerPoint presentation on common ED eye complaints, digital library links to the WEH Manual, slit-lamp checklist, and a video recording of a comprehensive slit-lamp examination.[25] The participants also gained access to an independent readiness assessment (IRAT), which was required to be completed within 30 days with a minimum score of 90% before proceeding to the next in-person phase of the study (Appendix A).

Upon achieving the passing IRAT score, they were invited to participate in the Time 2 (in-person) SBML portion of the study where they were to complete an in-person demonstration of a comprehensive slit-lamp exam by a board-certified ophthalmologist [CC] on a standardized patient volunteer. Following the demonstration, participants were given unlimited time for RCDP with brief, interspersed feedback under the observation and teaching from the ophthalmologist. Participants were required to complete a minimum 18 of 20 checklist items to achieve mastery (Appendix B). Upon completing the final checklist, the participants were asked to complete a course evaluation and learner confidence survey (Appendix C) with Likert scaling, subjective commentary, and a validated 5-item Critical Incidence Questionnaire (CIQ) for curricular improvement. Given the unpredictability nature of the "unlimited attempts" at Time 2, all participants were scheduled at two-hour intervals to allow for device preparation, one to two re-attempts, debriefing, survey completion, and general troubleshooting. At Time 3, participants completed a 60-day post-examination survey, assessing their ocular knowledge, slit-lamp confidence, clinical teaching opportunities, and relevant interprofessional relationships.

We used a Wilcoxon signed-rank test to differentiate the checklist scores between the curricular intervention by incorporating collected paired data before and after the training, median and interquartile range values of subtotal scores at two-time points.[26] We used McNemar's test to comparing each categorical sub-score (Yes/No) by time points and corresponding *P*-value within the same population.[27] The descriptive summaries of survey questions at Time 0, Time 2, and three-month follow-up were analyzed using Bonferroni adjusted *P*-values (multiplying *P*-value

Table 1. Corresponding emergency department slit-lamp assessments to ACGME EM* milestone general approach to procedures.

ACGME EM milestone PC8	Bolded PC8 elements relatable to performing a slit lamp exam	Correlating ED SLIT LAMP assessments
Level 1	Identifies indications for a procedure and pertinent anatomy and physiology. Performs basic therapeutic procedures (eg, suturing, splinting)	Appendix A–Part II (clinical image examination)
Level 2	Assesses indications, risks, benefits, and alternatives and obtains informed consent in low- to moderate-risk situations. Performs and interprets basic procedures, with assistance. Recognizes common complications	Appendix B–Part I (slit lamp technical) Appendix B (final checklist)
Level 3	Assesses indications, risks, and benefits and weighs alternatives in high-risk situations. Performs and interprets advanced procedures, with guidance. Manages common complications	Appendix A–Part III (ophthalmology exam mix-n-match
Level 4	Acts to mitigate modifiable risk factors in high-risk situations. Independently performs and interprets advanced procedures. Independently recognizes and manages complex and uncommon complications	Appendix B (final checklist)
Level 5	Teaches advanced procedures and independently performs rare, time-sensitive procedures. Performs procedural peer review	Appendix C–ED SLIT LAMP surveys

**ACGME EM*, Accreditation Council for Graduate Medical Education Emergency Medicine; *PC*, patient care; *ED SLIT LAMP*, Emergency Department Slit Lamp Interdisciplinary Training.

from Wilcoxon signed-rank test by the number of multiple tests, doubling the *P*-values), which was directly compared to the pre-specified 5% significance level. All statistical analyses were performed using R 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria).[28]

This study was approved by the institutional review board at Thomas Jefferson University Hospital (TJUH) in Philadelphia, PA. Informed consent was obtained from participating physicians. This study was funded by the Center for Faculty Development and Nexus Learning Pedagogy Grant at Thomas Jefferson University.

RESULTS

Fifteen EPs (six females and nine males) were enrolled in ED SLIT LAMP during the two-year period; none were lost to follow-up. All participants were board-certified EPs with an average clinical experience of 7.8 years post-residency graduation. All EPs completed the final exam of the curriculum in one attempt and all under 60 minutes.

Table 2 lists the 20 steps of the slit-lamp exam curriculum checklist, comparing participant results from recorded slit-lamp attempts (Time 0) to the final in-person assessment (Time 2). The intra-class correlation in test scores between EPs and ophthalmologists at Time 0 (2 raters) was 0.98. We found a significant increase between the checklist scores before and after the education initiative, 12.0 to 19.0, $P = 0.002$.

The most notable differences between the pre- and post-curricular intervention were as follows: 1) instructing the patient to close their eyes while powering up and positioning the patient in the slit lamp with the forehead touching the horizontal bar and chin in the chinrest ($P < 0.001$); 2) adjusting the microscope 90 degrees to facial plane with illumination set at a 45-degree angle ($P = 0.008$); 3) performing an anterior chamber evaluation ($P = 0.002$); 4) looking for cells and flare ($P = 0.021$); and 5) placing fluorescein in the inferior fornix of the eye ($P = 0.031$). The most missed steps at the baseline exam were: 1) applying a transparent face shield (26.7%); 2) instructing patients to close their eyes when the machine was turned on (26.7%); 3) looking for cells and flare (26.7%).

Figures 2 and 3 illustrate learners' confidence in performing and teaching the slit-lamp exam at the beginning of the study (Time 0), immediately after achieving procedural mastery (Time 2), and two months later (Time 3). Figure 4 illustrates the learners' likelihood in teaching the slit-lamp exam at Time 0 and Time 2. Before participating in the slit-lamp curriculum, 73% of EPs also reported rarely or never performing a slit-lamp exam, while 80% of EPs reported sometimes or often using a Wood's lamp for ocular complaints. Only 20% of EPs reported feeling confident in performing and teaching a comprehensive slit-lamp exam, while 67% of EPs reported feeling confident in using and teaching Wood's lamp for ocular examination.

After completing the slit-lamp curriculum (Time 2), 86.7% of EPs reported feeling confident performing a comprehensive slit-lamp exam for ocular complaints, and 73.3% were more confident in teaching residents how to perform a slit-lamp exam. Most EPs strongly agreed that the ED SLIT LAMP curriculum helped them perform an

Table 2. Descriptive summary of checklist evaluation at pre- and post-curricular and comparison between time points.

Checklist item	Performed	Time 0, N(%) (N = 15)	Time 2, N(%) (N = 15)	*P*-value from exact McNemar's test
1 - Identify slit lamp anatomy.	Yes	13 (86.7%)	15 (100%)	0.50
2 - Apply transparent face shield over the slit lamp (COVID).	Yes	4 (26.7%)	15 (100%)	<0.001
3 - Sanitize forehead and chin rest for the patient.	Yes	5 (33.3%)	14 (93.3%)	0.004
4 - Apply topical tetracaine/proparacaine on patient's eyes.	Yes	8 (53.3%)	12 (80.0%)	0.22
5 - Unlock instrument base and shift by pulling toward you.	Yes	15 (100%)	15 (100%)	NA
6 - Adjust eye pieces for your interpupillary distance and refractive error.	Yes	10 (66.7%)	14 (93.3%)	0.22
7 - Adjust table height and/or chair(s) - neither patient nor examiner should be hunched over.	Yes	12 (80.0%)	14 (93.3%)	0.50
8 - Instruct patient to close eyes while you power up by turning on the light source at low voltage setting and focus on right eyelid. Position patient in slit lamp with forehead touching the horizontal bar and chin in the chin rest.	Yes	4 (26.7%)	15 (100%)	<0.001
9 - Set magnification on lowest settings (10x to 12x), illumination at largest aperture and widest slit beam.	Yes	12 (80.0%)	15 (100%)	0.25
10 - Adjust chin rest so the patient is sitting comfortably with their chin on the chinrest and their forehead against the headrest.	Yes	12 (80.0%)	15 (100%)	0.25
11 - Practice macro and micro adjustments of the sliding base with joystick.	Yes	14 (93.3%)	15 (100%)	1.00
12 - Adjust microscope 90° to facial plane with illumination set at 45° angle (angle left for patient's right eye, and right for left eye).	Yes	7 (46.7%)	15 (100%)	0.008
13 - Perform outer structure evaluation.	Yes	14 (93.3%)	15 (100%)	1.00
14 - Perform anterior chamber evaluation.	Yes	5 (33.3%)	15 (100%)	0.002
15 - Look for cells and flare.	Yes	4 (26.7%)	12 (80.0%)	0.02
16 - Place a drop of tetracaine/proparacaine on a sterile fluorescein strip.	Yes	15 (100%)	15 (100%)	NA
17 - Place the fluorescein in the inferior fornix of the eye by pulling down on the lower lid and gently touching the bulbar conjunctiva with the fluorescein strip.	Yes	9 (60.0%)	15 (100%)	0.03
18 - Adjust cobalt blue filter on diaphragm wheel at maximum beam height and medium width slit setting for fluorescein evaluation.	Yes	14 (93.3%)	15 (100%)	1.00
19 - Focus the slit beam at 9:00 position on limbus. Move across the cornea to the 3:00 position by tilting joystick laterally.	Yes	12 (80.0%)	15 (100%)	0.25
20 - Pull instrument base toward you when finished and lock in position. Turn off.	Yes	4 (26.7%)	13 (86.7%)	0.004
		Time 0, median [IQR]	Time 2, median [IQR]	*P*-value from Wilcoxon signed rank test
Subtotal score		12.0 [10, 16]	19.0 [19, 20]	0.002

IQR, interquartile range.

independent slit-lamp exam and identify critical findings for common ocular complaints (80%), enhancing their learning more than traditional lectures and reading alone (86.7%). Of the asynchronous materials, the video demonstration was the most used (53% used it "a lot" or a "great deal"); the PowerPoint lecture and WEH Manual were the least used. At two months post-ED SLIT LAMP (Time 3), 73% and 67% of participants expressed extreme confidence in performing and teaching a resident how to perform a slit-lamp exam. Five t of 15 EPs reported teaching learners within the two-month

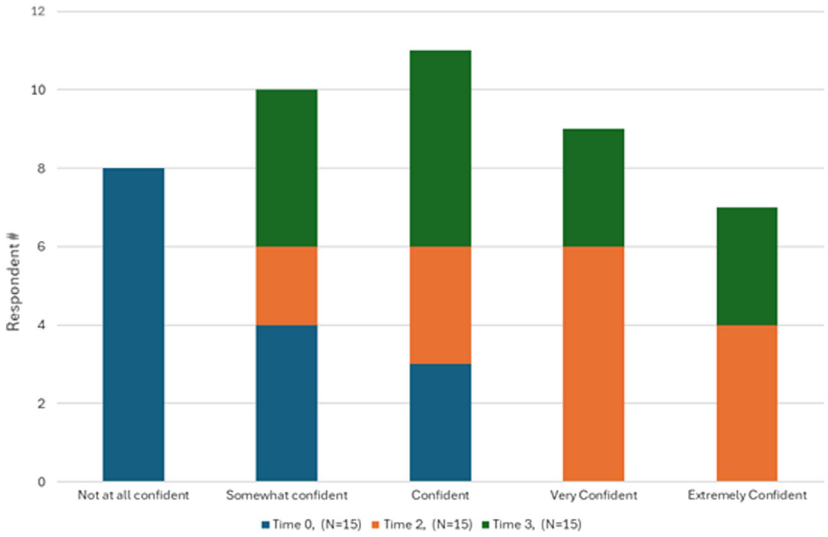


Figure 2. Learner confidence in performing the slit-lamp exam at Time 0 (pre-curricular), Time 2 (immediate post-SBML curriculum), and Time 3 (2-month post-SBML curriculum).

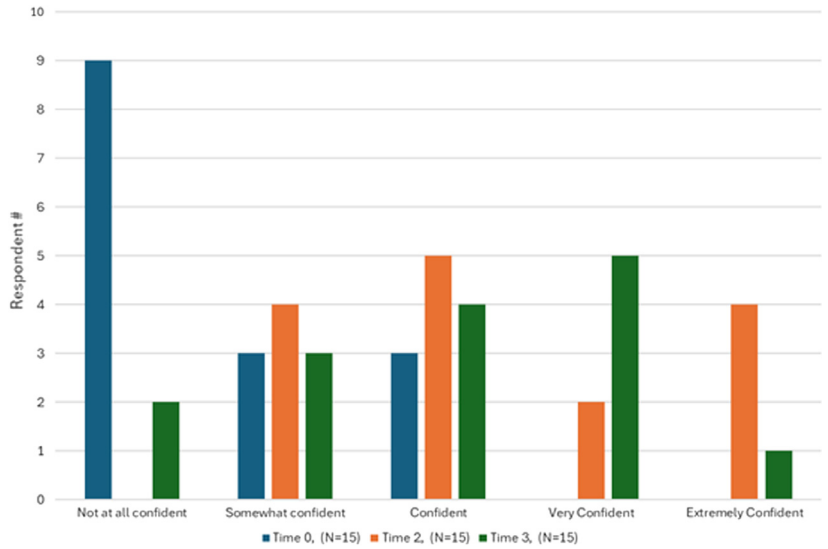


Figure 3. Learner confidence in teaching the slit-lamp exam at Time 0 (pre-curricular), Time 2 (immediate post-SBML curriculum), Time 3 (2-months post-SBML curriculum).

post-curricular period, ranging from 5–30 students per EP participant.

Table 4 summarizes the statistically significant findings from the survey responses based on the three timeframes. There was a statistically significant increase in self-reported confidence in 1) performing a comprehensive slit lamp exam and 2) teaching residents to perform this exam between Time 0 to Time 2 and Time 0 to Time 3 ($P < 0.001$). There was no difference in reliance on ophthalmology consultation to modify or reinforce a treatment plan for ocular complaints when comparing Time 0 to Time 3 ($P = 0.70$, $P = 0.814$). There was also no statistical difference in the number of patients with ocular complaints evaluated by the study participants at the TJUH ED and WEH ED throughout the study ($P = 0.14$, $P = 1.00$).

DISCUSSION

The ED SLIT LAMP curriculum allowed EPs to increase their use and confidence in performing slit-lamp exams in the ED. The impetus for the project arose from EPs' intrinsic motivation to provide better patient care. Our participant population consisted primarily of junior faculty who were initially uncomfortable performing or teaching slit-lamp exams and preferred using the Wood's lamp. Upon completing the curriculum, the EPs noted a significant increase in self-reported confidence in using slit-lamps

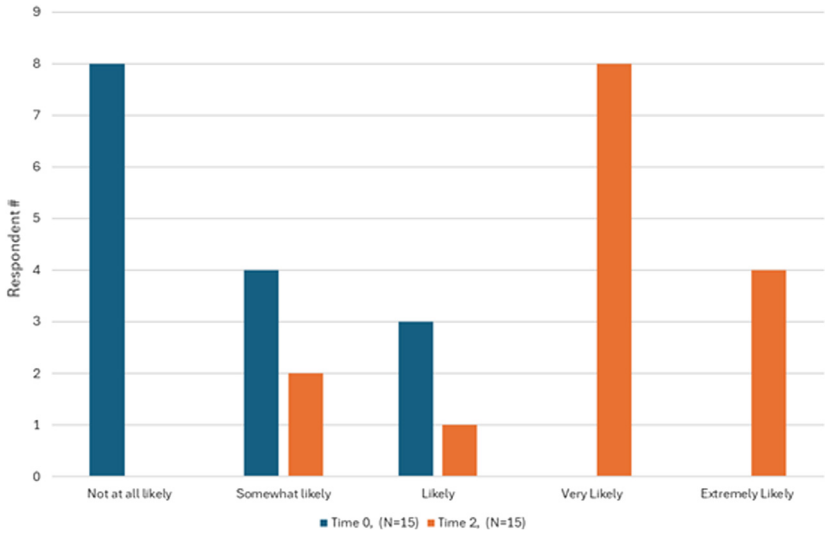


Figure 4. Learner likelihood in teaching the slit-lamp exam at Time 0 (pre-curriculuar) and Time 2 (immediate post-SBML curriculum).

and were teaching multiple junior learners during their study enrollment.

The improvement between the pre-and post-curricular procedural competency also demonstrates the importance of understanding the technical nuances of the slit-lamp exam and practicing critical device movement, such as careful patient positioning, adjusting of the chin straps, changing the microscope angulation, and adjusting varying slit-lamp beam lengths and widths for diagnosing a wide range of anterior ophthalmic pathologies. These skills are drastically different than those required to operate a Wood's lamp, which acts primarily as a magnifying glass with UV capabilities.

Our curriculum achieved three of the four Kirkpatrick goals. The majority of the participants (over 80%) reported positive reaction to the curriculum (the curriculum helped them perform a slit-lamp exam, evaluate for common pathologies, and offered more than traditional lectures) (Level 1); all of the participants demonstrated procedural mastery at Time 2 (Level 2); upwards of 50 learners received instructions from the study participants on how to use the slit lamp at Time 3 (Level 3). While the reliance on ophthalmology consultation did not reveal statistically significant changes, we posit that improved procedural acumen resulted in more targeted consultation questioning and improved rapport between the medical disciplines.

Since our participants were board-certified EPs with limited availabilities, the most valued component of the curriculum was the in-person RCDP session with the ophthalmologist (Time 2). This was reflected in almost every CIQ item, with specific mention of direct guidance in positioning the beam to look for cells and flare. The most surprising element to many participants was how many ocular diagnoses required the slit-lamp exam and that learning the procedure was not as complicated as they had initially anticipated. In contrast, many of the participants felt most distanced or removed from the curriculum in reviewing the asynchronous learning materials.

We were unsurprised to see the confidence levels in using Wood's lamp unchanged between the three different time frames. While the slit lamp offers a superior and in-depth evaluation of the anterior segment of the eye, we acknowledge that a comprehensive slit-lamp exam is time- and resource-consuming and may not affect the clinician's management if the suspected pathology involves larger lesions, foreign bodies, or specific reaction to fluorescein staining. The Wood's lamp remains an easier and more portable diagnostic tool for some ocular pathologies, and its use in the clinical arena is still acceptable in certain situations.

LIMITATIONS

This study was conducted at a single, large, tertiary academic center with an affiliated ophthalmology hospital and supported with internal grant funding. While the results were positive, multiple factors ciykd prevent this study from being replicated, especially at community sites without a close relationship with ophthalmology. One of the most significant challenges is scheduling in-person evaluations in the pre-curricular session, as well as the final in-person training and examination. We encountered significant logistical challenges in creating a schedule that was amenable to the ophthalmologists, EPs (with unpredictable shift schedules), and research investigators, as well as finding a consistent space in the WEH and WEH ED that had access to an attached-observer scope to ensure the participants were focusing on the correct anatomic structure during their procedural demonstration. This was further exacerbated when accounting for the "unlimited attempts" for RCDP. As this was our pilot study with advanced learners, we

Table 3. Statistical analysis of survey questions between the three different study timeframes.

Survey question	Time 0 median [IQR][a]	Time 2 median [IQR][b]	Time 3 median [IQR][c]	Bonferroni adjusted *P*-value from Wilcoxon signed rank test time 0 vs. time 2	Bonferroni adjusted *P*-value from Wilcoxon signed rank test time 0 vs. time 3
Slit lamp					
Based on your current practice patterns: how confident are you in: performing a comprehensive slit lamp exam for ocular complaints?	1 [1, 2]	4 [3, 4.5]	3 [2.5, 4]	<0.001	<0.001
Based on your current practice patterns, how confident are you in: teaching residents to perform a comprehensive slit lamp exam for ocular complaints	1 [1, 2]	3 [2.5, 4.5]	3 [2, 4]	<0.001	0.004
How often do you: perform an independent slit lamp exam for ocular complaints?	2 [1, 2.5]	n/a*	3 [3, 3]	n/a*	0.064
Wood's lamp					
Based on your current practice patterns, how confident are you in: performing a comprehensive Wood's lamp exam for ocular complaints?	4 [2, 4]	4 [4, 5]	4 [3, 5]	0.016	0.03
Based on your current practice patterns, how confident are you in: teaching residents to perform a comprehensive Wood's lamp exam (with access to a slit lamp) for ocular complaints?	4 [2, 4]	4 [4, 5]	4 [3, 5]	0.03	0.08
How often do you: use a wood lamp (with access to a slit lamp) for ocular complaints?	3 [3, 4]	n/a*	3 [3, 3]	n/a*	1.00
Ophthalmology consultation habits					
How confident are you in identifying common ocular pathology seen in your main work site (CC, MHD, Urgent Care)?	2 [2, 3]	n/a*	3 [3, 4]	n/a*	0.018
On average, how many eye pathologies do you see at the main work site?	10 [4, 15]	n/a*	5 [3, 12.5]	n/a*	0.14
On average, how many eye pathologies do you see at other facilities?	12 [0, 40]	n/a*	37.5 [13.5, 50]	n/a*	1.00
How often do you rely on ophthalmology consultation to: help modify your treatment plan for ocular complaints?	3 [3, 3]	n/a*	3 [2.5, 3]	n/a*	0.70
How often do you rely on ophthalmology consultation to: reinforce your treatment and plan for ocular complaints?	3 [2, 3]	n/a*	3 [2, 3]	n/a*	0.814
How often do you rely on ophthalmology consultation to: provide additional information and guidance to your treatment and plan for ocular complaints?	3 [3, 4]	n/a*	3 [3, 3.5]	n/a*	1.00

Confidence levels: 1 = Not at all confident, 5 = Extremely confident
Frequency levels: 1 = Never, 5 = Always
[a]Time 0 = pre-curricular evaluation.
[b]Time 2 = immediate post SBML exam. Frequency of slit lamp and Wood's lamp use were intentionally omitted for Time 2 due to the close proximity between Time 0 and Time 2, thus resulting in 'n/a' for some calculations.
[c]Time 3 = three months after SBML exam.
CC, Jefferson Hospital in Center City Philadelphia; *MHD*, Jefferson Methodist Hospital; *IQR*, interquartile range.

over-budgeted a two-hour template for each learner, which drastically limited the number of participants we could schedule for the final in-person exam.

Due to the longitudinal nature of this study and several in-person components, maintaining participant recruitment and engagement was also difficult. Of the 50 eligible board-certified TJUH EPs, only 15 EPs volunteered to participate. The primary deterrence, when discussed with non-participants, was time restraints and commuting into the city for in-person evaluations and examinations. We suggest implementing dedicated teaching days (ie, conference days or faculty meetings) for larger participant recruitment and subsequent follow-up and examination.

This study was funded by an internal grant that provided minor financial incentives for the participants and standardized patient volunteers. While our needs-based analysis revealed participants were more focused on promoting better patient care, many of the participants expressed appreciation for the staggered gift cards, which also incentivized them to complete each timeline-specific survey. All other investigators' efforts, in contrast, were in-kind and required dedicated non-academic and non-clinical time to enroll participants, record all the interactions, and provide unrestricted time availabilities for the final mastery assessment. This study was also unanimously supported by both departmental leaderships to promote a better collegial relationship and interdisciplinary education opportunity between organizations with the two principal investigators holding unique leadership positions, ophthalmology consulting director [CC] and EM clerkship director [XCZ]. We suspect that also positively affected our recruitment process and the success of this interdisciplinary training curriculum. As this study was conducted at an academic hospital in an urban setting, it has been suggested that academic centers likely overestimate EP comfort and confidence in the diagnosis and management of ophthalmic emergencies.[9] Furthermore, the proximity between both EDs may skew the data, as these EPs are likely exposed to fewer ophthalmic emergencies than hospitals without a nearby eye-focused ED.

Ultimately, the biggest limitation to this pilot study was the lack of in-person skill assessment at the 60-day follow-up due to limited staffing and scheduling challenges. In lieu of an objective competency score, we leveraged self-reported confidence at the 60-day mark as an approximate measurement of the skill retention. We recognize that learners are poor at gauging their own abilities, both over- and underestimating their skills based on a variety of factors. It is notable that 80% of our learners were initially "not confident" in completing a comprehensive slit-lamp exam prior to the SBML curriculum and scored an average checklist score of 60%. At Time 2, almost 87% of responders were "confident" in completing a comprehensive slit-lamp exam after receiving an average checklist score of 95%. Unfortunately, there is no association between learners' confidence and passing rate (score >18) at Time 0 (Pearson chi-square 3.46, $P = 0.17$) and Time 2 (Pearson chi-square 0.833, $P = 0.66$), respectively. While we are unable to predict how these learners would have performed on their slit-lamp exam test at day 60, we are encouraged to see the number of study participants who continued to teach slit-lamp exam for junior learners. We posit these participants will likely have improved sustained competence and decreased skill decay by actively teaching others. Future studies should be considered to add a final examination (procedure or multiple-choice question) to validate our results.

CONCLUSION

Emergency physicians are expected to diagnose and manage ocular complaints as part of their training and clinical practice. Our primary focus was to create a rigorous methodologic training curriculum (slit-lamp exam) for a specialty-focused skillset that could result in downstream teaching. This project highlighted a significant need for slit-lamp exam training within our institution that led to a successful transdisciplinary simulation-based mastery learning curriculum and improved our EPs' confidence in performing and teaching slit-lamp exams to future clinicians. Furthermore, this study demonstrates that adult learners, especially attending physician value direct interaction with clinical instructors when learning a new skillset and are intrinsically motivated to hone their skillset and teach it to future learners when they have achieved this mastery. We encourage other institutions to leverage SBML as a teaching modality for procedural-based training and advocate cross-discipline education initiatives. Future investigation could include creating a multicenter study to implement this curriculum at other academic institutions and potentially include it in EM residency training.

ACKNOWLEDGMENTS

We want to thank the Thomas Jefferson University Center for Faculty Development and Nexus Learning (CFDNL) for their generous support and grant funding in completing this study.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This study received grant funding from the Center for Faculty Development and Nexus Learning (CFDNL) Pedagogy, Thomas Jefferson University. There are no other conflicts of interest or sources of funding to declare.

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Emergency Medicine Milestones Final Ratings Are Often Subpar

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Submission history: Submitted January 16, 2024; Revision received June 14, 2024; Accepted July 8, 2024
Electronically published August 16, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18703

Background: The emergency medicine (EM) milestones are objective behaviors that are categorized into thematic domains called "subcompetencies" (eg, emergency stabilization). The scale for rating milestones is predicated on the assumption that a rating (level) of 1.0 corresponds to an incoming EM-1 resident and a rating of 4.0 is the "target rating" (albeit not an expectation) for a graduating resident. Our aim in this study was to determine the frequency with which graduating residents received the target milestone ratings.

Methods: This retrospective, cross-sectional study was a secondary analysis of a dataset used in a prior study but was not reported previously. We analyzed milestone subcompetency ratings from April 25–June 24, 2022 for categorical EM residents in their final year of training. Ratings were dichotomized as meeting the expected level at the time of program completion (ratings of ≥3.5) and not meeting the expected level at the time of program completion (ratings of ≤3.0). We calculated the number of residents who did not achieve target ratings for each of the subcompetencies.

Results: In Spring 2022, of the 2,637 residents in the spring of their last year of training, 1,613 (61.2%) achieved a rating of ≥3.5 on every subcompetency and 1,024 (38.8%) failed to achieve that rating on at least one subcompetency. There were 250 residents (9.5%) who failed to achieve half of their expected subcompetency ratings and 105 (4.0%) who failed to achieve the expected rating (ie, rating was ≤3.0) on every subcompetency.

Conclusion: When using an EM milestone rating threshold of 3.5, only 61.2% of physicians achieved the target ratings for program graduation; 4.0% of physicians failed to achieve target ratings for any milestone subcompetency; and 9.5% of physicians failed to achieve the target ratings for graduating residents in half of the subcompetencies. [West J Emerg Med. 2024;25(5)735–738.]

INTRODUCTION

With the advent of the Next Accreditation System (NAS), the Accreditation Council for Graduate Medical Education (ACGME) introduced a new assessment process called the "milestones."[1] The milestones are objective behaviors that reflect elements of the major competencies (eg, patient care, systems-based practice) in thematic domains called "subcompetencies" (eg, emergency stabilization, patient- and family-centered communication). The milestone scale uses nine ratings from 1.0, 1.5, 2.0, 2.5, etc, to 5.0. The scale is predicated on the assumption that a rating (level) of 1.0 corresponds to an incoming emergency medicine (EM)-1 resident and a rating of 4.0 is the graduation "target," albeit not a graduation expectation or requirement. According to the ACGME: "Level 4 is designed as a graduation *goal* but *does not* represent a graduation *requirement*."[2] The EM milestones have been used exclusively as a formative assessment by the ACGME. Likewise, a physician's EM

milestone ratings are not considered when determining the eligibility of a physician to take the American Board of Emergency Medicine (ABEM) written qualifying examination.

The EM milestones were introduced in 2012, and the first ratings were reported in 2013.[3] The EM milestones were revised in 2021, resulting in 22 subcompetencies. Since 2012, substantial validity evidence for the EM milestones has been accumulated.[4–10] A resident's milestone ratings are usually assigned by clinical competency committees (CCCs). Some subcompetency ratings are below target levels. Often, the subcompetency ratings assigned by the CCCs are lower than the ratings that residents give themselves.[11] The milestones were initially designed to have a rating of 4.0 as the target for a resident completing an EM residency.[9] Aggregate EM milestones are reported annually by the ACGME.[12] These data and other reports suggest that a substantial number of graduating residents are not achieving a level 4 rating in many milestone subcompetencies.

We undertook this study to determine the frequency with which graduating residents received the target milestone rating.

METHODS

Study Design

This retrospective cross-sectional study was a secondary analysis of an already de-identified dataset used in a prior study.[13] Our current study was deemed exempt from human subject research by the Western-Copernicus Group Institutional Review Board. The dataset available to the investigators did not include physician or program characteristics that would allow a more detailed analysis.

Study Setting and Population

We analyzed milestone subcompetency ratings from Spring 2022 for categorical EM residents in their final year of training. These milestone ratings were submitted between April 25–June 24. This ratings report used EM Milestones 2.0, which included 22 subcompetencies. The dataset had been provided earlier to ABEM by the ACGME as part of the routine EM milestones secure data-sharing process.

Measurements or Key Outcome Measures

The primary measure was the number of subcompetencies for which physicians failed to achieve a target rating of 3.5 at the time that the Spring milestone ratings were submitted to the ACGME. Because the ratings were submitted between April and June prior to residency completion, and the CCC could have determined the ratings even earlier than that, an expected rating for purposes of the study was modified to be 3.5 rather than 4.0. Doing so assumed that the resident would achieve a rating of 4.0 over the remaining weeks to months of residency training. We determined the number of physicians who did not achieve the target rating for the subcompetencies (from 0 subcompetencies to all 22 subcompetencies).

Data Analysis

Ratings were dichotomized as meeting the target level at the time of program completion (≥3.5) and not meeting the target level at the time of program completion (≤3.0). We calculated the number of competencies for which a target rating was not achieved.

RESULTS

In Spring 2022, there were milestone ratings for 2,637 residents in the Spring of their last year of training in 279 EM residencies. There were 1,613 residents (61.2%) who achieved a rating of ≥3.5 on every subcompetency and 1,024 residents (38.8%) who failed to achieve a rating of ≥ 3.5 on at least one subcompetency. There were 250 physicians (9.5%) who failed to meet half of their target subcompetency ratings. There were 105 residents (4.0%) who failed to meet the target rating (ie, rating was ≤3.0) on every subcompetency (Table).

Table. The frequency of emergency medicine residents receiving target milestones ratings lower that 3.5 in Spring 2022 (n = 2,637).

Number of ratings lower than 3.5	Number of terminal-year residents	Percent of total
0	1613	61.2
1	235	8.9
2	155	5.9
3	97	3.7
4	77	2.9
5	68	2.6
6	39	1.5
7	35	1.3
8	21	0.8
9	22	0.8
10	15	0.6
11	10	0.4
12	15	0.6
13	16	0.6
14	19	0.7
15	12	0.5
16	9	0.3
17	15	0.6
18	11	0.4
19	19	0.7
20	14	0.5
21	15	0.6
22	105	4.0

LIMITATIONS

First, the actual level of subcompetency achievement at graduation was imprecisely known. We chose a rating of ≥3.5 to represent the performance target, given that the milestone ratings were provided prior to the completion of the program. Using a rating of 4.0 to be assigned two months prior to graduation would likely underestimate subcompetency achievement and a score of 3.5 at two months prior to program completion would likely overestimate subcompetency achievement. Anticipating that all residents with a rating of 3.5 would achieve a rating of 4.0 within weeks was a benevolent assumption. Second, demographic data on residents (eg, gender) and program characteristics (eg, duration of training) were unavailable to the investigators. Although this lack of additional information limited our ability to determine factors associated with the ratings, we believe that the findings are sufficiently significant on their merit and warrant additional investigation.

Third, we did not correlate poor subcompetency ratings with program extension or remediation, thus limiting the opportunity to gather any evidence of predictive or consequential validity. It is possible that nearly every physician who did not achieve a rating of ≥3.5 on nearly half of the milestone subcompetencies underwent remediation. Fourth, the ratings are assigned by CCCs. The structures of, and information used by CCCs, vary by EM residency.[14,15] We did not attempt to determine the reliability or accuracy of the individual ratings. Moreover, we did not examine the potential impact of bias in the ratings. Prior studies suggested that women were assigned lower performance ratings.[16,17] Sixth, the ratings used for this study were from the first year of the EM Milestones 2.0. Although there was a degree of acclimation in developing facility with the EM Milestones 1.0, it is likely that the same degree of unfamiliarity would be less with the most recent version. The degree to which the continued use of EM Milestones 2.0 will change rating trends is unknown.

DISCUSSION

This study is the first in EM to demonstrate the degree to which physicians completing EM residencies are not achieving target subcompetency ratings. These data showed that of the 2,637 residents in their last year of training, nearly one in ten failed to meet target ratings for half of the EM subcompetencies. A similar finding was reported for physicians completing pediatric EM fellowships.[18] However, that report used a target rating of 4.0, not 3.5 as in our study. Consequently, 67% of pediatric EM fellows did not attain a rating of at least 4.0 for at least one subcompetency.

A physician should be able to graduate from residency without scoring 4.0 on all 22 subcompetencies. In fact, all 4.0 ratings (a straight-line score) would be highly improbable.[19] Consider the hypothetical situation that would result from the milestones being used in a summative manner to determine ABEM board eligibility. If residents were required to have no more than six subpar (ie, <3.5) milestone ratings (more than one-fourth of the subcompetencies), then 353 residents (13.4%) in their final year of training would not be eligible to take the ABEM written qualifying examination. Given the intent of the milestones as a formative instrument, ABEM maintains the position that the milestones should not be used as a summative determinant of board eligibility.

The rate of program extension by physicians beyond a scheduled graduation date has been reported to be approximately 8.5%.[13] These extensions include physicians undergoing academic remediation, as well as program extensions due to a personal leave of absence. The prevalence of physicians not meeting half of the target subcompetency ratings was 9.5%. Based on these findings, there were physicians who failed to meet at least half of the EM milestone subcompetencies yet were deemed competent to practice autonomously as attested by the program director. This likelihood does not challenge the construct validity of the milestones, nor does it suggest that the target is too high. In a fact, a prior validity study by Korte et al used program director survey data to verify the appropriateness of the target ratings.[9]

In this study we did not analyze the impact of training length (EM1-3 vs EM1-4). However, a review of mean scores was undertaken in a prior investigation that used the same study period.[13] The scores suggest that residents in EM1-3 programs tended to have higher scores through the postgraduate years (PGY) 1–3. For example, in the PGY-3 year, residents from EM1-3 programs had a mean rating of 3.51 (95% confidence interval [CI] 3.50–3.53) and residents from EM1-4 programs had a mean rating of 3.07 (95% CI 3.05–3.09), while EM4 residents had a mean rating of 3.67 (95% CI 3.65–3.69).

This analysis is an initial exploration into a more thorough investigation of the final milestones rating that an EM resident receives. The current study does not identify variable impact within demographic groups, nor does it provide any indices of predictive validity. Given the findings of this analysis, a more thorough analysis of the milestones should be undertaken to determine their psychometric qualities and subsequent utility in the field. Given the use of the milestones as a formative evaluation system, it should not be used to make summative decisions such as the determination of ABEM board eligibility. A more structured, valid, and reliable process for making the summative determination that a physician has demonstrated the necessary competencies to practice safely and independently is advisable. Moreover, such a detailed summative process could also be used to make a confident determination that a physician is eligible for board certification. This process would be easily accommodated in a model of competency-based medical education.

CONCLUSIONS

Many physicians complete an EM residency without meeting a target rating for a graduating resident in up to half of the EM milestones. Some residents (4%) did not meet a target rating in any milestone. These findings support the continued use of the milestones as a formative instrument, rather than a tool to determine board eligibility.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Drs. Gorgas, Ankel, and Carter are members of the American Board of Emergency Medicine (ABEM), Board of Directors. Drs. Joldersma, Barton, and Reisdorff are employees of ABEM. ABEM receives no revenue from Emergency Medicine Milestones reporting. There are no other conflicts of interest or sources of funding to declare.

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Making A Difference: Launching a Multimodal, Resident-Run Social Emergency Medicine Program

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Section Editor: Paul Logan Weygandt, MD
Submission history: Submitted October 17, 2023; Revision received April 28, 2024; Accepted May 30, 2024
Electronically published August 16, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18509

Introduction: Social medicine seeks to incorporate patients' social contexts into their medical care. Emergency physicians are uniquely positioned to address social determinants of health (SDoH) on the frontlines of the healthcare system. Miami-Dade County (MDC) is a diverse and socially vulnerable area. In 2020, the University of Miami-Jackson Health System (UM-JHS) emergency medicine (EM) residency program launched a multimodal, resident-led Social EM program to identify and address SDoH in the emergency department (ED).

Methods: We use a four-pillar approach to SDoH in the ED: Curriculum Integration; Community Outreach; Access to Care; and Social Justice. Residents graduate with a knowledge of Social EM principles through an 18-month curriculum, an elective, and a longitudinal track. We developed sustainable initiatives through interdepartmental and community-based partnerships, including a Narcan distribution initiative, an ED-based program linking uninsured patients to follow-up care, a human trafficking education initiative, and a quality improvement initiative for incarcerated patients.

Results: Given that the 18-month curriculum was launched in 2022, a full rotation of the curriculum had not been completed as of this writing, and data collection and analysis is an ongoing process. The initial pretest and post-test survey data show improvement in knowledge and confidence in managing Social EM topics. The Narcan initiative has screened 1,188 patients, of whom 144 have received Narcan. The ED-based patient navigation program has enrolled 31 patients to date, 18 of whom obtained outpatient care. Analysis of the impact/effectiveness of the program's other initiatives is ongoing.

Conclusion: To our knowledge, this is one of the most robust social EM programs to date, as many other programs primarily focus on service opportunities. Rooted in the revised principles of Bloom's taxonomy of cognitive learning, this program moves beyond understanding Social EM tenets to generating solutions to address SDoH in and outside the ED. [West J Emerg Med. 2024;25(5)739–747.]

BACKGROUND

Social medicine, or the incorporation of patients' social contexts into their medical care, has become a vibrant, interdisciplinary movement that has gained traction in medical schools, residencies, and at the national level. Social medicine emphasizes the importance of social determinants of health (SDoH), or "the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks."[1] The US Department of Health and Human Services lists five core SDoH to consider during patient care: economic stability; education access and quality; healthcare access and quality; neighborhood and built environment; and social and community context.[1]

Although SDoH can be applied to all specialties, they are perhaps most relevant to emergency medicine (EM). Passage of the Emergency Medical Treatment and Labor Act (EMTALA) in 1986[2] was acknowledgment that emergency

physicians are often the only link to the healthcare system for patients with financial limitations. Emergency physicians are estimated to provide two-thirds of acute care for all uninsured patients and half of acute care for all Medicaid patients.[3] Whether they are rushing a patient to CT, leading their team during a resuscitation, or evaluating patients in a crowded hallway, emergency physicians are immersed in longstanding, complex social issues: trauma; poverty; homelessness; mental health disorders; etc. Therefore, recognizing the effects of SDoH on patient care is critical in the ED.

Jackson Memorial Hospital (JMH) is the primary training site for the University of Miami-Jackson Health System (UM-JHS) EM residency program. It is also the third largest public hospital in the country. The UM-JH Social EM program was launched in 2020 to improve the incorporation of patients' social contexts into their care.

Needs Assessment

When designing a Social EM program, keeping the residency's location and patient population in mind is important. Like most EDs across the nation, the JMH ED is a place of refuge for patients whose SDoH may prevent them from obtaining care elsewhere. As a safety-net hospital in the seventh most populous county in the nation,[4] JMH serves a particularly diverse patient population with striking socioeconomic needs. The UM health system conducted formal needs assessments of Miami-Dade County (MDC) from 2019–2022, and the UM-JHS Social EM program was designed to reflect these needs.[4,5]

The UM-JHS Social EM program was designed to ensure that all residents graduate with the ability to incorporate their patients' SDoH into ED care regardless of their ultimate practice locations. However, certain aspects of this program were designed to address the unique needs of MDC—a "minority-majority" community that experiences challenges with English proficiency, and in which 20% of the population lives below the poverty level.[4,5]

PROGRAM GOALS

Bloom's taxonomy of cognitive learning objectives outlines six levels in the cognitive domain: knowledge; comprehension; application; analysis; synthesis; and evaluation.[6] Over time, scholars have sought to revise this framework and, when taken as a whole, these revisions place less emphasis on a linear progression through each level.[6] Instead, there is an increased focus on generating new hypotheses and developing projects that use and expand upon the acquired knowledge.[6] Therefore, the UM-JHS Social EM program seeks to shift its participants from purely understanding SDoH as they pertain to EM, to generating effective solutions for addressing these SDoH in and outside the ED. The Social EM program outlines six goals for its residents, who are then tasked with generating effective solutions and designing their own measurable outcomes for each goal. Upon successful completion of this program, residents should be able to:

1. Define and identify SDoH in the ED and apply these principles to bedside care.
2. Engage with MDC outside the ED and address its social and medical needs through longitudinal involvement in local outreach initiatives.
3. Solidify and share acquired knowledge through an 18-month, multimodal curriculum.
4. Identify and seek to address barriers to medical care experienced by patients who use the ED as their main source of healthcare.
5. Identify and seek to address recurrent social justice issues encountered in the ED.
6. Enact positive change through advocacy and quality improvement initiatives at hospital-wide, local, and/or national levels.

PROGRAM PARTICIPATION

Since its launch in 2020, the program has been divided into four pillars that address core areas within Social EM: Curriculum Integration; Community Outreach; Access to Care; and Social Justice (Figure 1). Initiatives within each pillar will be discussed in a separate section. Anyone affiliated with the UM-JHS ED can participate in initiatives across all four pillars. Many of these initiatives are longitudinal, allowing for varying levels of participation throughout residency. Additionally, this program also offers leadership, peer teaching, and scholarly opportunities that may count toward existing residency requirements.

The UM-JHS has a three-year EM residency program, and each of its classes (postgraduate years [PGY] 1–3) is comprised of 14–15 residents. EM residents are not required to participate in the Social EM program but are encouraged to do so. They may choose to serve as program leaders (Figure 1), participate in the longitudinal track and/or two-week elective (discussed in detail in subsequent sections below), or to participate in individual initiatives as their schedules allow. However, Social EM program leadership developed a formal curriculum to ensure that all residents graduate with a solid understanding of core Social EM principles, regardless of their level of involvement with the program; this will be discussed in a separate section.

CORE LEADERSHIP HIERARCHY

This program was designed to be executed by residents in collaboration with faculty, medical students, and staff. The program was structured into a core leadership hierarchy to appropriately divide the labor of designing and launching initiatives that pertain to each pillar, while ensuring that residents complete their existing clinical and academic

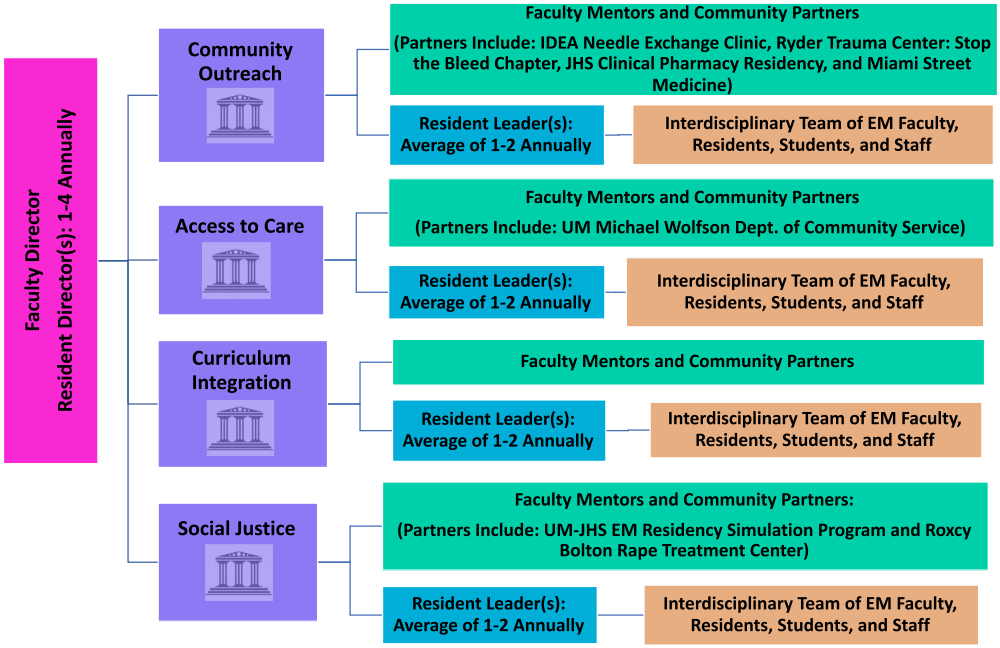


Figure 1. Social emergency medicine program organization and division of labor. Program directors consist of one faculty director and 1–4 resident directors (EM residents selected via a formal application process). Program directors oversee initiatives across all four pillars but spend additional time leading Curriculum Integration initiatives to ensure a seamless incorporation of Social EM principles into residency training. Pillar leaders are EM residents who are selected by program directors via a formal application process; they design and oversee initiatives in their assigned pillars. Faculty mentors are generally core faculty in the EM department with expertise in their assigned pillar. However, faculty in other specialties at UM-JHS may also serve as mentors if they currently oversee a community or hospital-based initiative that collaborates with the Social EM program. (For example, a faculty mentor from the family medicine department oversees the IDEA Needle Exchange Clinic.) Anyone affiliated with the EM department may serve as a team member. Team members work directly with their assigned resident leaders and divide the tasks required to launch and publicize initiatives.

requirements (Figure 1). This leadership hierarchy organizes, executes, and publicizes the program and its initiatives.

Directors

A faculty director and at least one resident director oversee the program together (Figure 1). The original directors, Patricia Panakos, MD, and Naomi Newton, MD, authored this paper and conceptualized the program together in Fall 2020. The collaboration between Drs. Panakos and Newton was borne from a shared passion for social medicine and a desire to implement an EM residency-based program to address the SDoH of patients in MDC. Dr. Panakos is the associate program director for the UM-JHS EM residency and has undergone formal training in curriculum development. She has also developed ED-based public health initiatives at JHS, such as a universal screening program for communicable diseases, including HIV, hepatitis C, and syphilis. Dr. Panakos continues her role as faculty director for the social EM program. Dr. Newton is an alumna of the UM-JHS EM residency and served as chief resident during her final year of training. She assumed the role of the social EM program's resident director as a PGY-1 and transitioned her position upon her graduation in 2023. She has also collaborated with Dr. Panakos on public health initiatives, including a universal HIV screening initiative in JHS's pediatric ED. Dr. Newton is currently pursuing a two-year fellowship in health policy and advocacy at Emory University.

Given that there was no precedence for such a program at UM-JHS, Drs. Panakos and Newton worked almost daily to create the program and maintain its sustainability, while also completing their existing clinical and academic responsibilities. Drs. Panakos and Newton designed the program's overall structure, created a formal selection process for pillar leaders, and identified community partners and faculty mentors with expertise in Social EM. They presented a formal proposal that was approved by both the chair of the ED at JMH and the UM-JHS EM residency program director in October 2020. They also designed and launched the 18-month curriculum, two-week elective, and longitudinal track, which are described in subsequent sections of this paper. To account for continued program growth, the original directors selected four new resident directors for the 2023–2024 academic year via a formal application process (Figure 1).

Directors approve proposed initiatives across all pillars and work directly with pillar leaders to track progress and troubleshoot challenges. They check in remotely with pillar

leaders at least bi-monthly to ensure timely project completion. They also promote the program at a departmental and hospital-wide level and help pillar leaders identify faculty and community partners (Figure 1). Resident directors are recognized with a Social EM leadership award upon their graduation.

Resident Leaders

An average of two PGY-1 or PGY-2 EM residents lead each pillar. Interested residents apply for this position via a brief electronic application (Google Survey) at the start of the academic year and are selected by the directors. Residents generally do not serve as leaders of more than one pillar, as this position must be balanced with existing residency obligations. Resident leaders report directly to the directors and dedicate an average of two to four hours per week to their roles. As leaders progress through training, they may either remain in their leadership roles or transition their roles to incoming PGY-1s and PGY-2s. All resident leaders who have served for at least one year are recognized with a special award upon graduation from residency.

Leaders focus on designing initiatives that pertain to the goals of their assigned pillar. They identify appropriate partners within JHS and MDC to aid in developing and launching these initiatives (Figure 1). Partners include JHS faculty (including those in non-EM specialties), local outreach organizations (many of which already had established relationships with UM-JHS through medical student involvement), and other JHS-affiliated residency programs (eg, pediatrics, internal medicine, family medicine). Interdisciplinary collaboration prevents the Social EM program from "re-inventing the wheel" and helps initiatives achieve success with fewer funding, resource, and logistical restrictions. Resident leaders delegate day-to-day tasks to an interdisciplinary team to divide the labor of executing these initiatives. Leaders are required to check in remotely with their team members at least monthly to discuss progress on pillar initiatives.

Interdisciplinary Teams

Team members divide the tasks required to launch initiatives within their assigned pillar. They are required to dedicate a minimum of one to two hours per week on these tasks and check in regularly with their pillar leaders as previously discussed. Those who desire to do so may participate in more than one pillar team. Participation in a pillar team is open to anyone in the UM-JHS ED. However, during the first three years of the program, teams were primarily comprised of EM-bound UM medical and pharmacy students, JHS clinical pharmacy residents, and hospital staff (eg, nurses and social workers).

PROGRAM DESIGN: THE 4-PILLAR APPROACH

In the following section, we provide a broad overview of each pillar's objectives and highlight several key initiatives within each pillar. When relevant, please see the corresponding appendices for additional details.

Curriculum Integration

This pillar incorporates the tenets of Social EM into residency training to empower future generations of emergency physicians to apply Social EM principles to their care. This is the only pillar that requires all EM residents to participate because its initiatives have been incorporated into the existing residency curriculum. Doing so ensures that all EM residents graduate with an understanding of SDoH and the principles of Social EM, regardless of their level of involvement in other pillars. Of note, approval from the institutional review board was not required for the development of this curriculum.

We developed and launched a multimodal, 18-month Social EM curriculum that has been incorporated into the existing 18-month residency didactic schedule (Appendix A). The curriculum covers 18 core social EM topics (Table 1) and includes journal clubs, simulation cases, lectures, problem-based learning, and interactive group discussions. The curriculum is led by faculty and residents with expertise or

Table 1. 18 core areas of study were chosen to be covered monthly during the 18-month Social EM curriculum. This curriculum is integrated into standard residency didactic schedule, which repeats every 18 months. Using a multimodal learning format, topics can be presented as traditional lectures, case-based discussions and journal clubs ("Cases"), or simulations. The initial modalities for each topic are listed below; the modalities used for each topic will change every 18 months (eg, the pediatric health lecture would be presented as either a case or simulation 18 months later). Additional details regarding logistics and implementation can be found in Appendix A.

Lectures	Cases	Simulations
1. Social determinants of health	7. Implicit bias/racism	13. Human trafficking and domestic violence
2. Healthcare coverage and access	8. Homelessness	14. Substance abuse and harm reduction
3. Financial stability	9. Health literacy	15. Caring for incarcerated patients
4. Frequent ED utilizers	10. Immigration	16. Highly communicable diseases/STI epidemics
5. Women's health	11. Resource insecurity	17. Language and cultural barriers to healthcare
6. Pediatric health	12. Trauma-informed care	18. Gender identity

ED, emergency department; *STI*, sexually transmitted infection.

interest in the core topics. Social EM leadership assists presenters in identifying learning objectives for each session, selecting topics, and developing content. All conference attendees participate in pre- and post-surveys to assess their baseline knowledge and the effectiveness of each didactic session. Residents are also asked to evaluate the Social EM curriculum during the annual residency program evaluation. Surveys and results are discussed further in the Impact/ Effectiveness section of this manuscript.

In 2022, we launched the two-week Social EM elective for residents who desire a more in-depth experience with the program (Appendix B). This elective is open to PGY-2 EM residents during their elective block and is comprised of service opportunities, self-directed study, peer teaching, and initiative participation across all pillars. The PGY-2 rotation schedule is designed so that only one resident completes an elective in any given month. Therefore, the experience is personalized for each participating resident. Social EM directors work with the resident ahead of time to design an elective schedule that ensures participation across all pillars but allows them to engage more deeply within their pillar(s) of interest (Appendix B).

We also designed a longitudinal track that was launched the 2023–2024 academic year. Track participants engage in a set number of outreach events, quality improvement initiatives, peer teaching, and self-directed study over 18 months. The requirements are based on a point system that ensures engagement with all pillars but allows for deeper exploration in areas of individual interest. Residents must reach a minimum of 30 points to complete the track (Figure 2). Requirements include a longitudinal scholarly activity that culminates in a presentation at the local, regional, or national levels (eg, developing a project to address food insecurity). They must also participate in the Social EM didactic curriculum through peer teaching, developing new elements to the curriculum, and mentoring medical students. Participants log their progress via an online form and must attend a minimum of nine monthly track meetings with the Social EM directors over an 18-month period. Upon graduation, residents who complete the track will receive a Distinction in Social EM.

Community Outreach

This pillar was designed to establish a meaningful presence in MDC beyond bedside care and to address social issues through partnerships with local organizations. For example, through a partnership with Miami Street Medicine, participants join an interdisciplinary team in providing

Activity	Hours Spent	Personal investment value	Total Points
Caring with Compassion Module	4	0.5	2
Leadership of a Pillar	12	1.5	18
IDEA Clinic	4	0.5	2
Miami Street Medicine	3	0.5	1.5
DOCS Fair	5	0.5	2.5
Stop the Bleed Training Program	2	0.25	0.5
Stop the Bleed Lecturing	3	0.5	1.5
Coordinating care for 6 patients	4	0.25	1
Writing a high utilizers brief	2	0.5	1
Food Insecurity - Distribution Event	4	0.5	2
Human Trafficking Training Program	2	0.25	0.5
Human Trafficking Lecturing	1	0.5	0.5
Developing/Updating QI Protocol	4	1	4
Attending advocacy event	6	1	6
Developing a case/sim	4	0.75	3
Developing a lecture	6	1	6
Presenting article at JC	2	0.5	1
Peer-reviewed publishing in Social EM	8	1.5	12
Non-peer reviewed publishing in Social EM	4	1	4
Developing a new Social EM project	12	1.5	18
Social EM Elective	4	1	4
Attending track meetings	1	0.25	0.25
*Other pre-approved social EM activity	Varies	Varies	Varies
		Total	91.25
Legend:			
Community Outreach			
Access to Care			
Social Justice			
Curriculum Integration			
Social EM Leadership			

All residents must participate in the following actvities at a minimum

QTY	Activity	PTS
1	CC Module	2
1	Curriculum Development	3
2	Community Outreach	1.5
1	Access to Care	1
1	Social Justice	1
1	JC Presentation	1
9	Track Meetings	2.25
		11.75
	Minimum Points	30

Figure 2. Point system for the 18-month longitudinal track. Note that opportunities in each pillar may vary over time. This figure lists opportunities from the fall of 2023.

regular medical care at locations commonly occupied by Miami's homeless population. Through a partnership with the Stop the Bleed Campaign, participants undergo formal training to serve as local instructors. Participants then lead workshops that teach non-medical community members to perform bystander cardiopulmonary resuscitation and stabilize victims of violence until first responders arrive. Participants may serve as instructors for Stop the Bleed events throughout MDC, as their schedules allow.

This pillar launched a Narcan program in July 2022, in partnership with the UM IDEA (Infectious Disease Elimination Act) Needle Exchange Clinic and the UM Michael Wolfson Department of Community Service (DOCS). This program seeks to address South Florida's opioid epidemic and is in keeping with the statewide Emergency Treatment for Suspected Opioid Overdose Act.[7] At community health fairs, participants provide free opioid use disorder (OUD) screening, based on Diagnostic and Statistical Manual of Mental Disorders, 5th ed, criteria.[8] Narcan is subsequently distributed to those identified to be at high risk for life-threatening overdoses, and additional OUD counseling and training on safely administering Narcan are provided.[9]

Access to Care

This pillar links chronically ill patients, high ED utilizers, and the uninsured to outpatient care. It also seeks to centralize existing social support resources within UM-JHS and efficiently address SDoH at the bedside. Through a partnership with DOCS, uninsured patients presenting to the ED with chronic complaints are paired with long-term patient navigators, who help them secure affordable outpatient care upon discharge.

The High Utilizers Initiative aims to streamline the care of patients who frequently visit the ED. Participants conduct chart reviews of individuals flagged as frequent utilizers in the electronic health record and create patient care briefs that auto-populate in their charts. These patients often present to the ED numerous times a week and receive care from different clinicians each time. By consolidating their pertinent medical information, these briefs allow for better, more streamlined patient care with less repetition of tests and procedures. The briefs also lessen the cognitive load of the clinician, decreasing the time spent on chart reviews and helping guide future care.

Many patients present to the ED with conditions that are exacerbated by a lack of basic resources. It is challenging to address these complex SDoH amidst the time constraints of ED care, and EDs can no longer rely heavily on social workers for assistance, due to the nationwide social worker shortage.[10] This pillar partnered with Miami Street Medicine and the JMH Pharmacy Department to create resource guides for patients and clinicians in response to this need. Community resource guides (in English, Spanish, and Haitian Creole) provide information for affordable outpatient clinics, prescriptions, mental health services, temporary housing, meal programs, and substance use treatment centers, as well as resources for pregnant patients and victims of domestic violence. Clinician resources include referral information for resident-run subspecialty clinics, instructions for initiating buprenorphine in the ED and referring patients to medication-assisted treatment clinics, and algorithms for human trafficking screening.

Social Justice

This pillar tackles health inequity and injustice issues through interdisciplinary education and quality improvement initiatives. The Human Trafficking Education Ambassador program, in partnership with JMH's Rape Treatment Center, teaches clinicians to screen for and treat victims of human trafficking. Florida has the third highest number of human trafficking cases in the nation, and MDC is, sadly, a known trafficking hub.[11] Trained residents lead interactive seminars, sharing HIPAA-compliant trafficking cases and teaching clinicians to identify and address red flags for trafficking.

This pillar also seeks to improve care for incarcerated patients in the ED, particularly concerning patient privacy and examinations in the presence of law enforcement. Initiatives include a recently published review on the barriers to caring for this population and recommendations to improve their delivery of care.[12] We also implemented a simulation session on caring for incarcerated patients into residency didactics.

IMPACT/EFFECTIVENESS

Curriculum Integration

Social EM leadership is in the process of completing a formal impact assessment of the curriculum integration pillar of the program via a single-group, pretest-posttest design.[6] Brief pre- and post-didactic session surveys are designed for each Social EM topic in the 18-month curriculum. Surveys are designed to assess baseline knowledge of the topic and the changes in this baseline knowledge after the session. Survey questions also address relevant epidemiological statistics and useful community resources for addressing the topic in MDC. Each post-survey ends with a blank section for participants to write in any additional feedback, which Social EM program leadership uses for subsequent didactic sessions.

For convenience, these surveys are administered via electronic forms; conference attendees scan QR codes to the forms before and after the session. All residents, faculty, students, and staff in attendance are eligible for participation in the surveys. However, thus far, survey participation has generally been limited to resident attendees, as faculty, staff, and student attendance is less consistent. Hospital badge

numbers are used to compare individuals' changes in pre- and post-session responses.

Since the 18-month curriculum was launched in 2022, a full rotation of the curriculum has not been completed as of this writing, and data collection and analysis is ongoing. However, thus far, the curriculum topics have been well-received, with residents indicating an improved confidence in their ability to recognize and address these Social EM issues at the bedside. For example, Figure 3 shows key results from the pre- and post-surveys administered during the first session of the formal curriculum in 2022—a simulation session on highly communicable diseases/sexually-transmitted infection (STI) epidemics (Table 1). These results suggest efficacy in improving baseline knowledge and confidence with the topic of acute HIV in the ED, including epidemiology, community resources, and initiating either highly active antiretroviral therapy or pre-exposure prophylaxis when indicated.

An impact assessment of the two-week elective is pending, as only one PGY-2 resident had completed at the time of this manuscript's development.

Community Outreach

It is challenging to concretely assess the impact of the Community Outreach pillar, as its service-driven initiatives are generally qualitative in nature. However, initial data from the Narcan Initiative highlights its impact on MDC. As of May 2023, the program screened 1,188 patients across MDC, of whom 144 received Narcan. In recognition of the Narcan Initiative's current impact and continued growth, JMH's Department of Emergency Medicine received the 2023 University of Miami Mitchell Wolfson Sr. Department of Community Service award.

Access to Care

We are currently in the early stages of data collection to analyze the success of the Access to Care initiatives. Thus far, the patient navigation program has enrolled 31 ED patients. Of these patients, 18 were able to successfully complete their navigation goals and obtain outpatient care. This program has particularly benefitted non-English-speaking patients, whose language barriers can hinder their ability to navigate a complex system. For example, navigators were able to link a Spanish-speaking patient to outpatient oncologic care for her untreated gynecologic cancer. Recently, a homeless, uninsured patient living at the Miami Rescue Mission (MRM) was treated for an acute ulcerative colitis flare in the ED. After he was discharged, the navigators ensured that he obtained timely follow-up at an MRM-affiliated gastroenterology clinic, a student-run clinic staffed by UM faculty. We are continuing to publicize this program and encourage emergency clinicians

N = 30 residents	Pre-Acute HIV Sim	Post-Acute HIV Sim
% Correct	43%	92%

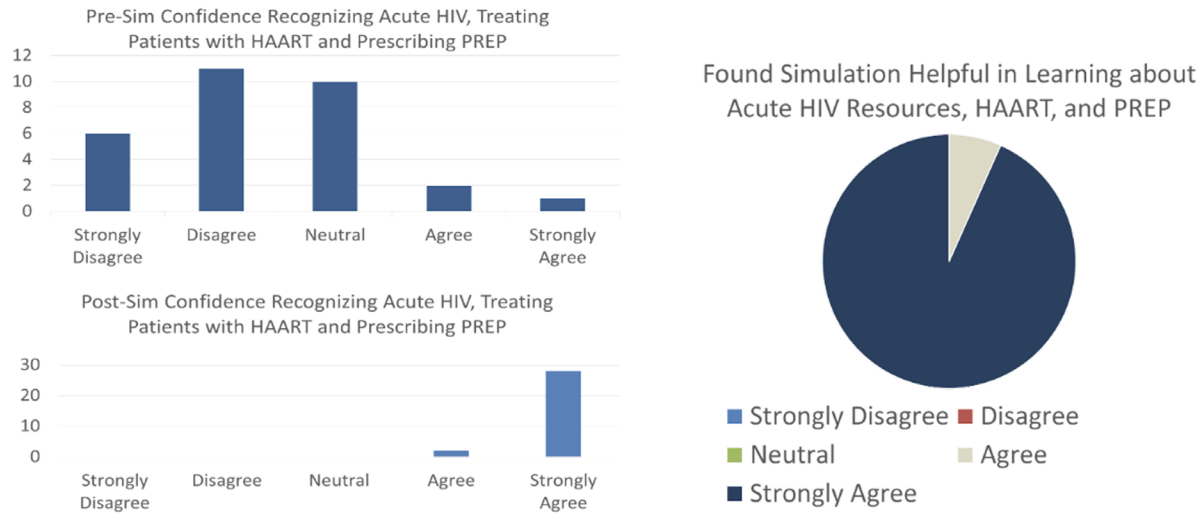


Figure 3. Comparison of key pre- and post-survey results after a simulation session on highly communicable diseases/STI epidemics; 30 residents completed the surveys. After the session, residents indicated an increased confidence in their ability to recognize acute HIV and initiate Highly Active Antiretroviral Therapy (HAART) or Pre-Exposure Prophylaxis (PrEP) treatment when indicated. Most residents found the session beneficial in learning about community resources for ED patients with HIV, as well as prescribing HAART and PrEP.

to enroll their patients during their shifts. We are still in the data collection phase of the High Utilizers initiative.

Social Justice

The Social Justice pillar initiatives experienced several launch delays due to COVID-19 pandemic restrictions and faculty turnover. Initiatives were officially launched in the 2022–2023 academic year, and data regarding their impact and effectiveness is pending. Thus far, human trafficking education ambassadors have given well-received lectures to JHS-affiliated clinics and to JMH's family medicine, pediatrics, and internal medicine residencies.

Overall Program Feedback and Support

Since the program is under the direct guidance of a current residency associate program director, there is continual communication between Social EM directors and EM residency leadership. Residency leadership actively engages with and provides insights into pillar initiatives, leading to timely changes to the program when deemed necessary. For example, previous feedback led to the development of the elective and longitudinal tracks. Residents in the core Social EM leadership team also obtain regular qualitative feedback from their peers and share this feedback with the Social EM directors. This program is also reviewed during the annual residency program evaluation committee meeting. This program has full EM departmental support.

Additional Recognition/Awards

Overall, this robust, multimodal, resident-led Social EM program has rapidly grown over the last three years, despite the COVID-19 pandemic. In 2023, six of the 14 PGY-3 residents graduated with a Social EM distinction. The program's interdisciplinary nature ensured its success, as multiple initiatives were launched without significant funding or administrative restrictions. The program is receiving increasing recognition. In addition to the previously mentioned community service award for the Narcan Initiative, the MDC chapter of the Stop the Bleed Campaign received a 2021 award from the mayor for its education initiatives in local high schools. In 2023, we were also honored to receive the 2023 ACEP Social EM Section Distinguished Program Award.

LIMITATIONS

Residents' availability often limits consistent participation in Social EM. Residents have multiple clinical and academic responsibilities, and as they progress through training, their time is further limited by searching for jobs and applying for fellowships. In response to this limitation, the elective and longitudinal track were developed to allow for flexible but regular participation, as many requirements can be completed during lighter rotations. The didactic curriculum also ensures that all residents will graduate with the same baseline knowledge of Social EM tenets. Additionally, the Social EM leadership will transition every two years, allowing junior residents with leadership roles to pass on their duties to incoming residents as they become senior residents.

Certain aspects of this program were designed to address some of the social issues that are particularly prevalent in MDC and may not be generalizable to other EM residency programs in the United States. Other residency programs seeking to develop their own Social EM initiatives should consider the unique needs of their patient populations when doing so.

The program's first three years were dedicated to overall development, garnering participants, finding community partners, and launching initiatives in each pillar. Therefore, data collection to formally assess the program's impact and effectiveness is still in process and is currently limited to initial data (unblinded pre- and post-tests completed by resident participants) from the launch of the 18-month didactic curriculum. This data may also be subject to selection bias, as most residents, faculty, students, and staff are excited about the Social EM program and want it to succeed.

CONCLUSION

The University of Miami-Jackson Health System Social EM program was launched in 2020 to address the SDoH of patients in Miami-Dade County—an area of significant medical and social need. It targets critical social issues through four pillars: Curriculum Integration; Community Outreach; Access to Care; and Social Justice. This multimodal, resident-run program achieved rapid success in three years by developing sustainable initiatives in partnership with local organizations and other UM-JHS departments. Rather than focusing solely on service opportunities, this program enhances residents' knowledge of SDoH, fosters the development of quality improvement initiatives, and provides opportunities to create meaningful change in the ED and the community. This program also provides residents with leadership and scholarly opportunities. We hope that this article will inspire other residencies to develop similar programs.

ACKNOWLEDGMENTS

The University of Miami-Jackson Health System Social Emergency Medicine program would not have been possible without the ingenuity, dedication, and passion of the following individuals and organizations. Thank you for everything that you have done and continue to do to create

positive change: Rachel Armstrong, MD; Tatiana Barriga, MD; Kelley Benck; Daniel Bergholtz, MD; Emily Brauer, MD; Sandra Cabrera, MD; Danielle Cohen, MD; Emily Dawra, MD; Luis De La Rosa, RN; Shaheen Emami; Joshua Goldstein, MD; Jamie Harris; Kristopher Hendershot, MD; Armen Henderson, MD, MBA; Brooke Hensley, MD; Sarah Jabre, MD; Jackson Health System Clinical Pharmacy Residency; Johnnatan Marin, MD; Julia Martinez, MD; Elizabeth May-Smith, MD; Kelly Medwid, MD; Miami Street Medicine; Victoria McKee; Samantha Mosle; Lien Morcate; Kaleb Morris; Judith Oriental-Pierre, MD; Roxcy Bolton Rape Treatment Center; Stop the Bleed; University of Miami IDEA Needle Exchange Clinic; University of Miami, Michael Wolfson Department of Community Service; and Melissa Velasquez, MD.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Reduced Time to Admit Emergency Department Patients to Inpatient Beds Using Outflow Barrier Analysis and Process Improvement

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Section Editor: Tehreem Rehman, MD, MPH
Submission history: Submitted December 12, 2023; Revision received May 22, 2024; Accepted May 24, 2024
Electronically published August 1, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18626

Objective: Because admitted emergency department (ED) patients waiting for an inpatient bed contribute to dangerous ED crowding, we conducted a patient flow investigation to discover and solve outflow delays. After solution implementation, we measured whether the time admitted ED patients waited to leave the ED was reduced.

Methods: In June 2022, a team using Lean Healthcare methodologies identified flow delays and underlying barriers in a Midwest, mid-sized hospital. We calculated barriers' magnitudes of burden by the frequency of involvement in delays. During October–December 2022, solutions targeting barriers were implemented. In October 2023, we tested whether waiting time, defined as daily median time in minutes from admission disposition to departure (ADtoD), declined by conducting independent sample, single-tailed *t*-test comparing pre- to post-intervention time periods, January 1–September 30, 2022 (273 days) to January 1–September 30, 2023 (273 days). Additionally, we regressed ADtoD onto pre-/post period while controlling for ED volume (total daily admissions and ED daily encounters) and hospital occupancy. A run chart analysis of monthly median ADtoD assessed improvement sustainability.

Results: Process mapping revealed that three departments (ED, environmental services [EVS], and transport services) co-produced the outflow of admitted ED patients wherein 18 delays were identified. The EVS-clinical care collaboration failures explained 61% (11/18) of delays. Technology contributed to 78% (14/18) of delays primarily because staff's technology did not display needed information, a condition we coined "digital blindness." Comparing pre- and post-intervention days (3,144 patients admitted pre-intervention and 3,256 patients post), the median minutes a patient waited (ADtoD) significantly decreased (96.4 to 87.1 minutes, $P = 0.04$), even while daily ED encounter volume significantly increased (110.7 to 117.3 encounters per day, $P < 0.001$). After controlling in regression for other factors associated with waiting, the intervention reduced ADtoD by 12.7 minutes per patient (standard error 5.10, $P = 0.01$; 95% confidence interval –22.7, –2.7). We estimate that the intervention translated to ED staff avoiding 689 hours of admitted patient boarding over nine months (ADtoD coefficient [–12.7 minutes] multiplied by post-intervention ED admissions [3,256] and divided by 60). Run chart analysis substantiated the intervention's sustainability over nine months.

Conclusion: After systemwide patient flow investigation, solutions resolving digital blindness and environmental services-clinical care collaboration failures significantly reduced ED admitted patient boarding. [West J Emerg Med. 2024;25(5)748–757.]

INTRODUCTION

Emergency physicians in the United States have raised the alarm about dangerous and worsening emergency department (ED) crowding.[1,2–4] Crowding is associated with patient harm,[2,5] increased staff stress,[4,6] medical errors,[7] and patient mortality.[5,8,9] Although there is not a single cause for crowding, in large part it occurs when admitted patients are boarded in the ED because access to an appropriate bed is blocked.[1,2–4,10,11] Access block stems from over-capacity units as well as a larger, long-standing issue: inefficient patient flow in US hospitals.[3,10,12–14] Inefficient patient flow not only bottlenecks patients in the ED but is also known to drive patient outcomes down and costs up,[12] two problems the US is urgently working to resolve.[15] Compared to peer high-income countries, the US ranks last in health outcomes[16] and first in costs.[17]

Considering that reducing ED boarding time is associated with reduced harm to patients and staff and reduced costs,[11] policymakers responsible for cost and outcome trends and administrators responsible for alleviating crowding are acutely interested in strategies that improve the outflow of admitted ED patients. A major obstacle to improving ED outflow is that few hospitals are adept at patient flow investigations and interventions. Hospitals tend to improve patient flow one department at a time, assuming that these within-department flow efficiencies stack up to overall gains.[13] Experts warn that this approach can backfire.[13,18] Well-intended department improvement programs can negatively impact patient flow because individuals focus on their own department's efficiency achievements and do not consider the effect of their actions on upstream or downstream departments.[18] Moreover, because hospital processes are complex and deeply interlocked,[19] it is unrealistic for staff in one department to accurately predict or observe unintended outcomes in other areas.

Administrators have tried to decrease boarding times by taking a within-ED improvement approach; however, the interventions have failed and have even worsened boarding.[2,11] For example, Kelen et al's[2] literature review found that 1) neither increasing the number of ED staff nor improving ancillary services' turnaround time had any impact on boarding, and 2) increasing the size of the ED made turnaround time worse. What has worked to improve ED outflow is directly reducing access blocks. One hospital reduced boarding by blocking their surgery department from using a certain number of beds based on a predicted number of ED admissions.[2] Another hospital took a process-improvement approach and reduced access blocks by simply discharging patients earlier in the day, incrementally improving access by improving processes.[14]

The present study is two-pronged. In Phase 1, we moved away from single-department patient flow investigations and instead conducted a multi-department, systemwide, patient flow study to identify potential process improvements to reduce access delays. In Phase 2, we evaluated the effect of our process improvements on admitted ED patient bed-wait times measured by daily median of admission disposition to departure (ADtoD) minutes comparing pre- and post-process improvement intervention. We hypothesized that a patient flow investigation would reveal delays and that the subsequent process improvement would significantly reduce the time admitted ED patients waited for a bed.

Population Health Research Capsule

What do we already know about this issue?
Boarding admitted patients in the ED threatens patient and staff health. It is at a crisis level in the US, but reducing it has proven difficult.

What was the research question?
Can a systemwide patient flow investigation lead to significant reduction in admitted patient boarding time?

What was the major finding of the study?
Admitted patient boarding was reduced by 12.7 minutes/patient ($P = 0.01$; 95% CI −22.7, −2.7). Technology was the primary issue.

How does this improve population health?
These findings will help other institutions to reduce ED boarding and preserve community access to emergent care without increasing the cost of care.

METHODS

In 2022, a mid-sized, urban-based hospital in the Midwest partnered with a university health innovation center that specializes in workflow design to help resolve admitted ED patient outflow delays, identify solutions, and measure the effectiveness of implemented solutions. The innovation team chose to use Lean Healthcare methodologies. Lean Healthcare has been applied to improve patient care processes and material flows and, to a lesser extent, patient flow.[20,21] Lean is a production improvement process developed by the Toyota Production System (Toyota Motor Corp, Toyota, Aichi, Japan), which has been used in healthcare to increase efficiency, reduce costs, and improve patient outcomes.[22] Lean provides a practical approach to understanding complex systems.[23]

The innovation center trains first- and second-year medical students in Lean Healthcare, a program designed to teach systems thinking earlier in medical education.[24] In

2022, a Lean Healthcare expert assembled a team of nine second-year medical students, trained them in Lean, and assigned the current problem to them to investigate and solve collectively. The investigation was deemed non-human subject research by the university institutional review board.

Observational Field Investigation, Process Mapping, and Delay Identification

The team's field investigation was conducted in June 2022. Hospital executives introduced the team to employees to ensure frontline worker cooperation. The team collected procedure manuals from departments and created an observation schedule to investigate segments of patient flows from ED admission through discharge. Patient delays in the ED were the longest between 3 PM–8 PM; therefore, that period was prioritized for observation.

The hospital's technology included the Epic electronic health record system (EHR) and the Epic environmental services system (Epic Systems Corp, Verona, WI) with an Ascom phone integration (Ascom Holding AG, Baar, Switzerland). Over 21 days, the team observed and mapped patient flow, observed workers, and followed patients, noting workarounds, bottlenecks, and coordination points with other departments. Team members discussed processes and patient flow with over 100 staff, including managers, ED staff, physicians, transfer coordinators, environmental services (EVS) staff, transporters, maintenance staff, and receiving floor nurses. The team identified discrepancies between protocols and actual work, gathered time-stamped data, and directly timed some process steps.

The team integrated the processes and mapped the patient journey from ED admission through discharge and the EVS processes used to turn a bed between patient occupancies. The team used "swim lanes," a technique to map processes occurring simultaneously in different departments. The team created a list of delays; delays were defined as when patient flow stalled for any reason. The swim lanes identified key staff roles across multiple departments that co-produced ED patient outflow.

Underlying Barrier Categorization and Magnitude of Burden Analysis

Post-investigation, we grouped common issues, named them, and built a conceptual framework representing system-level outflow barriers. We assessed which barriers contributed to each delay and tallied the frequency with which each barrier contributed to delays. We compared each barrier's magnitude of burden by frequency and percentage (number of delays affected by a barrier/total number of delays); more than one barrier type could be associated with each delay.

Recommended Solution Prioritization

We designed specific solutions for administrative action, organized them by barrier targeted, and sorted them into a 3×2 matrix by the degree to which the solution was deemed controllable (controllable, probably controllable, uncontrollable) and the estimated associated cost (no cost, cost). We relied on the magnitude of the burden to prioritize solutions within the high controllability and low-cost category to prioritize selected solutions. In the fourth quarter of 2022, solutions were implemented.

Intervention Effectiveness

In October 2023, we used a quasi-experimental design to evaluate whether interventions reduced the time admitted patients waited to leave the ED. Quasi-experimental designs are appropriate to assess interventions without random assignment.[25] We defined individual-level patient waiting time as the time from when a patient's disposition became "admitted" in the EHR to when that patient departed the ED, ensuring that we evaluated only admitted patients. From this data, the EHR provided a daily median time of patients' admission disposition to departure in minutes (ADtoD), and we used the daily median as a per-patient representation to detect waiting differences between two time periods. Medians were both readily available in the EHR and preferred in analysis to avoid artificially high or low daily values caused by outliers.

The two time periods we compared were pre-intervention days (January 1–September 30, 2022) and post-intervention days (January 1–September 30, 2023). We excluded the period from October–December 2022 because it was the period when solutions were being implemented. Matching months (January–September) for both time periods minimizes seasonal effects, which is a concern with ED outcome investigations because ED volumes follow seasonal trends.[26] The strength of using day-level measures across the two nine-month time periods is that they provide a good sample size (total number of days 546, 273 days in each period) for statistical comparison vs monthly level data (18 months with 9 in each period).

Days were categorized as belonging to either the pre- or post-intervention period samples. Because our hypothesis was that the ADtoD would decrease in the second period, we used a single-tailed *t*-test to compare ADtoD between periods. To describe how the time periods differed in ED volume and hospital capacity (factors that could theoretically affect ADtoD), we pulled data by day for 1) total number of occupied hospital beds, including observation beds; 2) total number of patients admitted from the ED; and 3) total number of ED encounters. In addition to descriptive analytics, we conducted independent sample two-tailed *t*-tests on these three variables to detect period differences. Finally, we used standard least squares regression to test for the effects of the intervention (pre, post) on ADtoD, while controlling for ED volume and hospital occupancy variables.

We used a run chart for a visual, temporal analytic view of improvement to evaluate whether improvement occurred after intervention and to determine whether improvements were sustainable.[27]

RESULTS

Observational Field Investigation, Process Mapping, and Barrier Identification

The total personnel cost for the investigation was $16,000. Because the hospital partnered with the university in a joint effort to train medical students in systems-based practice, the investigation came at no cost to the hospital. The university paid each of the nine medical students $12.50/hour for 0.5 full-time equivalent (FTE) for a one-month (80 hours) internship, which totaled $9,000. The Lean consultant was a full-time innovation center employee who we estimated dedicated 0.75 FTE for the month (90 hours) at a cost of $7,000, including salary and benefits.

The team identified that boarded ED patients primarily waited for two supplies from other departments: clean beds provided by EVS; and transport services. The departments' processes were interlocked; interlocking processes are defined as when one process flow is reliant on/triggered by an output of another process, such as a digital signal or an action. Mapping the supply process for each and their intersection with the ED process generated Figure 1. We called this three-department process map *global bed management*. We categorized flow through bed management into four multi-department collaborative steps: 1) processes used to provide clean, ready beds; 2) processes used to assign patients to open beds; 3) processes used to transport a patient for bed occupancy; and 4) processes used to resupply beds freed from discharge. Across these steps, we logged 18 delays. The location of the delays is depicted in Figure 1. A supplemental file provides a higher quality image; and detailed descriptions of delays are listed in Appendix Exhibit A.

Across the interlocking departments, six staff roles co-produced global bed management whom we named flow facilitators; four were patient care-based (transfer coordinator, transporters, ED nurses, and floor nurses), and two were EVS-based (supervisor and staff). The EVS and clinical care staff depended primarily on the EHR platforms to send digital signals to each other for coordination, in contrast to transport services, which were coordinated by phone. An example of clinical care sending EVS a signal was when floor nurses entered a patient's discharge into the EHR; that entry triggered the posting of that patient's bed onto the EVS cleaning queue. In total, 11 of the 18 (61%) delays were caused by EVS-clinical care collaboration failures caused by them not perceiving themselves as a collaborative team. Because they lacked a shared goal to connect patients as efficiently as possible to beds, they lacked communication processes to facilitate that process. Appendix Exhibit A details EVS and clinical care standard work processes that disregarded the effect they had on each other. The EVS staff had no visibility into clinical information due to patient data protection. There was no reason that clinical care staff's visibility into EVS systems was limited.

Barrier Types

We identified four common, system-level causes (barriers) for the 18 delays. Two stemmed from technology design (rigid system settings and "digital blindness") and two stemmed from management issues (workforce shortage and policy and procedures).

Technology-based barriers

We found rigid *system settings* embedded in technology applications prevented staff from changing inaccurate information such as when a clean bed was listed as dirty because EVS lacked access to change bed statuses not assigned to them. *Digital blindness,* a term we coined to describe the common condition when staff were unable to see pertinent information due to poor technology design, such as EVS not seeing which beds had waiting patients. In sum, users relied on inaccurate information or made decisions without complete information. Because digital blindness was widespread across clinical care and EVS, we labelled three distinct types: *true status blindness* (eg, being shown the inaccurate status of a bed), *collaboration blindness* (eg, assigning patients to beds without knowing order of readiness, causing patients to exit

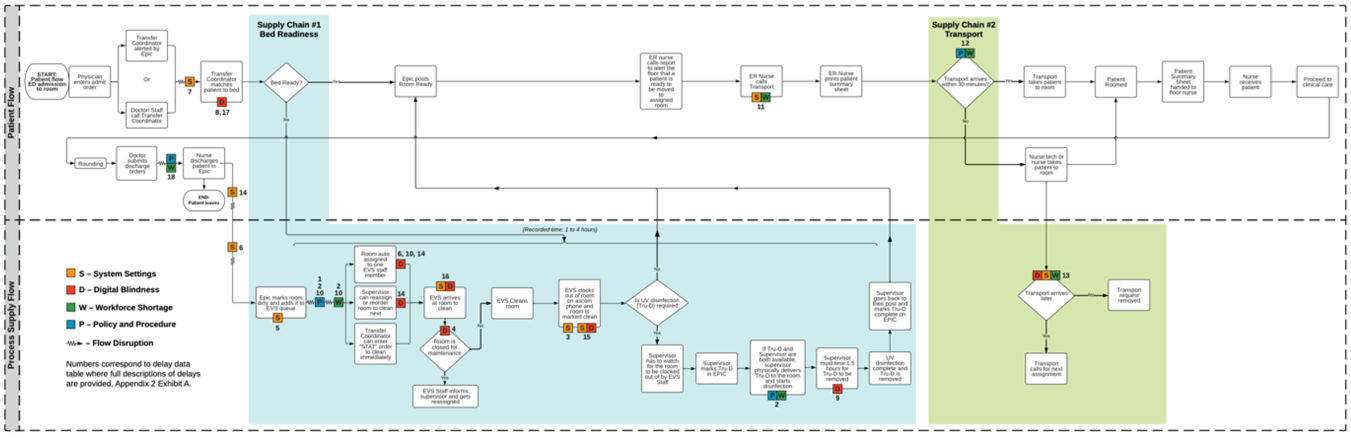


Figure 1. Three-department process map depicting patient- and supply flow.

the ED out of admission order), and *sporadic output blindness* (eg, nurse discharge data entry creating EVS dirty-bed notification in 0–20 minutes).

Delays associated with rigid system settings are designated as "S" in Figure 1 and Appendix Exhibit A. All types of digital blindness are designated as "D" in Figure 1 and Appendix Exhibit A.

Management-based barriers

Transporters, clinical care, and EVS staff suffered from understaffing due to *workforce shortages,* a management issue constrained by local resources.[28–30] *Policy and procedures* contributed to delays in two ways. First, in all cases except one the delays associated with workforce shortage were also associated with policy and procedure issues (Appendix Exhibit A). We concluded that policy and procedures can reflect an assumption of an optimal workforce supply, and adherence to them during shortages can backfire and exacerbate delays. Consider one ED policy that required ED nurses to wait 30 minutes after calling transport services before using their own techs for transport. Adherence created 30-minute delays when transporters were short-staffed and ED techs were available to transport.

Second, we discovered within-department procedures that caused delays in other areas. For example, prior to intervention, EVS procedures included all staff changing shift at the same time and conducting a brief meeting at shift change. To accommodate both shift change and the meeting, staff stopped cleaning the queued beds for one hour every day to wind down their cleaning work pre-shift change, to attend the meeting, and to ramp it up post-shift change. Compounding this problematic procedure, it occurred at 3 PM, helping to explain why ED patient waiting increased at 3 PM each day. The EVS procedures weren't the only problematic ones; others included allowing nurses to delay discharge entry, thus eliminating timely signals to EVS of dirty beds and no transporter cancellation policy causing transporters to waste time looking for already transported patients.

Delays associated with workforce shortage are designated with a "W" in Figure 1 and Appendix Exhibit A. Delays caused by policy and procedures are designated with a "P" in Figure 1 and Appendix Exhibit A.

Figure 2 summarizes the system-level barriers and underlying causes. Of these, only workforce shortage was a recognized cause for delays before our investigation.

Magnitudes of burden from barrier types

Using the delay data compiled and available in Appendix Exhibit A, we found that technology-based barriers (barriers associated with digital blindness or system settings) were twice as prevalent (14/18; 78%) compared to management-based barriers (barriers associated with workforce shortage or policy and procedures) (7/18, 39%). Digital blindness was associated with the most delays at 61% (11/18), followed by system settings 39% (7/18), policy and procedures 39% (7/18), and workforce shortage 33% (6/18) (see Figure 3).

Solution Generation and Selection

The Lean team generated and evaluated 25 solutions (Appendix Exhibit B). Over half of the identified solutions (59%; 13/22) were considered controllable and estimated to have no cost based on information technology (IT) capabilities. Solutions with costs reflected the need to hire staff, which may or may not have been viable due to local shortages.[28–30]

For solution selection, we turned to the magnitude of burden calculation pointing to digital blindness, system settings, and policy and procedure issues, each of which had a no-cost solution. The following solutions were implemented in the fourth quarter of 2022: 1) the IT department corrected the system setting that prevented EVS staff from updating dirty rooms to be cleaned by allowing EHR access to the electronic processes that assigned EVS staff to rooms—access that resolved transfer coordinator blindness to true bed status; 2) IT further decreased transfer coordinators' digital blindness by creating visibility in the EVS cleaning queue, thereby revealing the likely order of available beds; and 3) EVS management changed departmental policy and procedures by staggering EVS staff shifts, to ensure continuous progress in ready bed supply, and eliminating all-staff daily meetings. The effects of

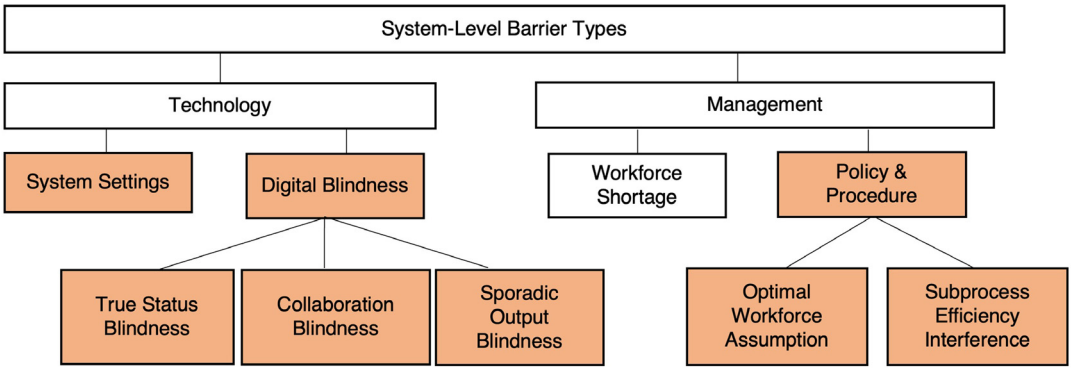


Figure 2. System-level barrier types. Barriers unknown before the investigation are shaded.

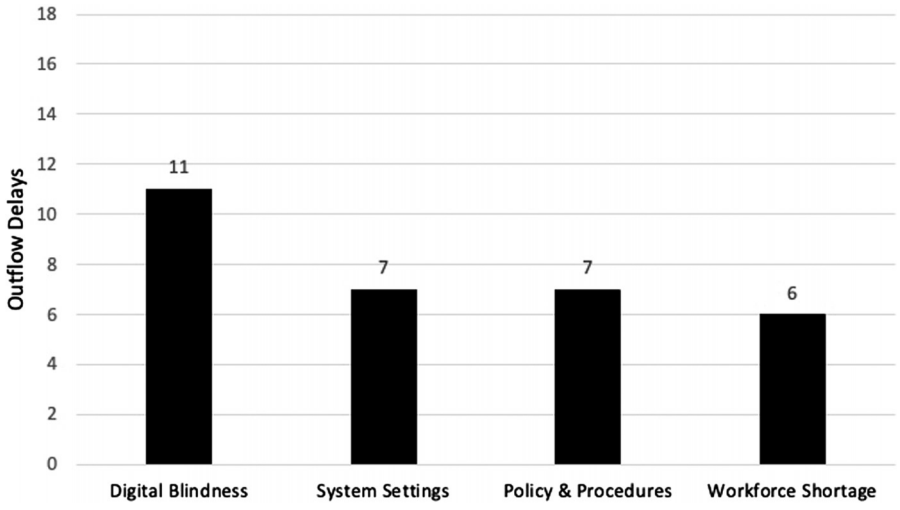


Figure 3. Comparison of barrier types' magnitude of the burden on emergency department patient outflow by frequency of barrier contribution to outflow delays.

individual solutions were not measured. Collectively, these solutions were the intervention.

Intervention Effectiveness

We completed all statistical analyses with JMP Pro 16 software (SAS Institute, Cary, NC). Sample 1 (year 2022 pre-intervention) and Sample 2 (2023 post-intervention) each had the same sample size (273). Descriptive statistics and independent sample *t*-test results are presented in Table 1.

ADtoD (the median number of minutes a patient waited each day) was significantly lower in the post-intervention period ($P = 0.04$), while the ED staff managed substantially higher average daily ED encounters ($P < 0.001$). The number of daily admits did not significantly differ ($P = 0.24$), nor did the daily census ($P = 0.51$). Notably, after the intervention, a busier ED achieved lower ADtoD times. Regression of ADtoD median time onto pre/post categorization while controlling for three other independent variables reveals that the intervention significantly reduced ADtoD times by 12.7 minutes ($P = 0.01$). Table 2 shows the intervention's effect of admission disposition to departure median times (ADtoD) while controlling for bed occupancy by day, total admitted ED patients by day, and total ED encounter by day.

To estimate the intervention's effect on ED staff's exposure to admitted patient boarding, we multiplied the ADtoD coefficient (−12.7 minutes) representing each patient's reduced waiting time by the number of post-intervention ED admissions (3,256) and divided by 60 to convert to hours, resulting in an estimation that ED staff avoided 689 hours of ED boarding over the nine-month post-intervention period.

In addition to statistical significance analyses supporting the effectiveness of the intervention, Figure 4 depicts a run chart supporting that improvement occurred after the intervention and the intervention achieved a shift, a run of at least six sub-baseline values.[27] Baseline is the

Table 1. *T*-test results of pre- and post-intervention.

	Sample 1: pre-intervention days Jan–Sep 2022 (*n* = 273)		**Sample 2: post-intervention days Jan–Sep 2023 (*n* = 273)**							
	M	SD	M	SD	Diff	df	t	SE	95% CI	Single-tailed *P*
ADtoD	96.4	55.6	87.1	63.3	−9.2	535.99	1.80	5.1	−19.3 – 0.8	0.04
										Two-tailed *P*
Daily total admitted ED patients	11.52	4.04	11.93	4.08	0.41	543.95	1.18	0.34	−0.27 – 1.93	0.24
Daily total ED encounters	110.72	18.39	117.28	14.23	6.56	511.82	4.66	1.40	3.80 – 9.33	<0.001
Bed occupancy	53.58	11.15	54.19	10.61	0.61	542.66	0.66	0.93	−1.22 – 2.44	0.51

ADtoD, admission disposition to departure; *Diff*, mean difference; *df*, degrees freedom; *SE*, standard error; *CI*, confidence interval; *ED*, emergency department.

Table 2. Standard least squares regression model results ($N = 576$).

ADtoD predictors	Estimate	SE	*P*	95% CI
Bed occupancy	−0.33	0.24	0.17	−0.81 – 0.14
Total admitted ED patients	2.38	0.69	0.001	1.02 – 3.73
Total ED encounters	0.41	0.17	0.01	0.09 – 0.74
Pre-post	−12.7	5.1	0.01	−22.7 – −2.7

ADtoD, admission disposition to departure; *SE*, standard error; *CI*, confidence interval.

pre-intervention period median ADtoD. Because run data must be interpreted in context,[27] we interpreted January ADtoD increases as reflecting peak hospital occupancy, the effect of which was reduced in January 2023 by the intervention but not eliminated. By February 2023 the median ADtoD approached baseline; afterward, improvement was sustained.

DISCUSSION

The findings from this investigation indicate that emergency physicians and their patients were enduring unnecessary outflow delays discoverable through a systemwide patient-flow investigation. Although over-capacity inpatient units tend to dominate discussions about ED boarding,[2–4,11] we discovered delays buried in technology and within-department procedures. In Phase 1, the use of Lean methodologies revealed the outflow process and its dependence on global bed management (Figure 1), flow facilitators and their reliance on technology to collaborate, and the system-level root causes driving delays (Figure 2). The investigation led to designing low-cost solutions that in Phase 2 achieved administration's goal of reducing admitted patient boarding in the ED.

The intervention consisted of three solutions geared to improve EVS-clinical care collaboration. *T*-test analysis of pre- vs post- intervention periods showed that ADtoD was significantly decreased while the ED was significantly busier (Table 1). Regression analysis controlling for effects from hospital capacity and ED volume demonstrated that the intervention decreased the median ADtoD by nearly 13 minutes (Table 2). Because we estimate that the ED staff avoided 689 hours of ED boarding in the post-period, we contend that the intervention substantially benefited staff. Finally, charting the monthly median ADtoD trend substantiated that improvement occurred after the intervention period and was sustainable (Figure 4).

Not surprisingly, given the widespread healthcare staffing shortages of 2022,[28–30] *workforce shortages* affected outflow. Patients waited for understaffed transporters to move them, understaffed nurses to complete discharges, and understaffed EVS to clean rooms. However, our analysis showed that those shortages had the lowest magnitude of burden on outflow compared to readily solvable issues: *digital blindness; system settings; and policy and procedures* (Figure 3). Before the present investigation, no one at the hospital had ever seen the inter-related, multi-department workflows necessary to move an admitted patient from the

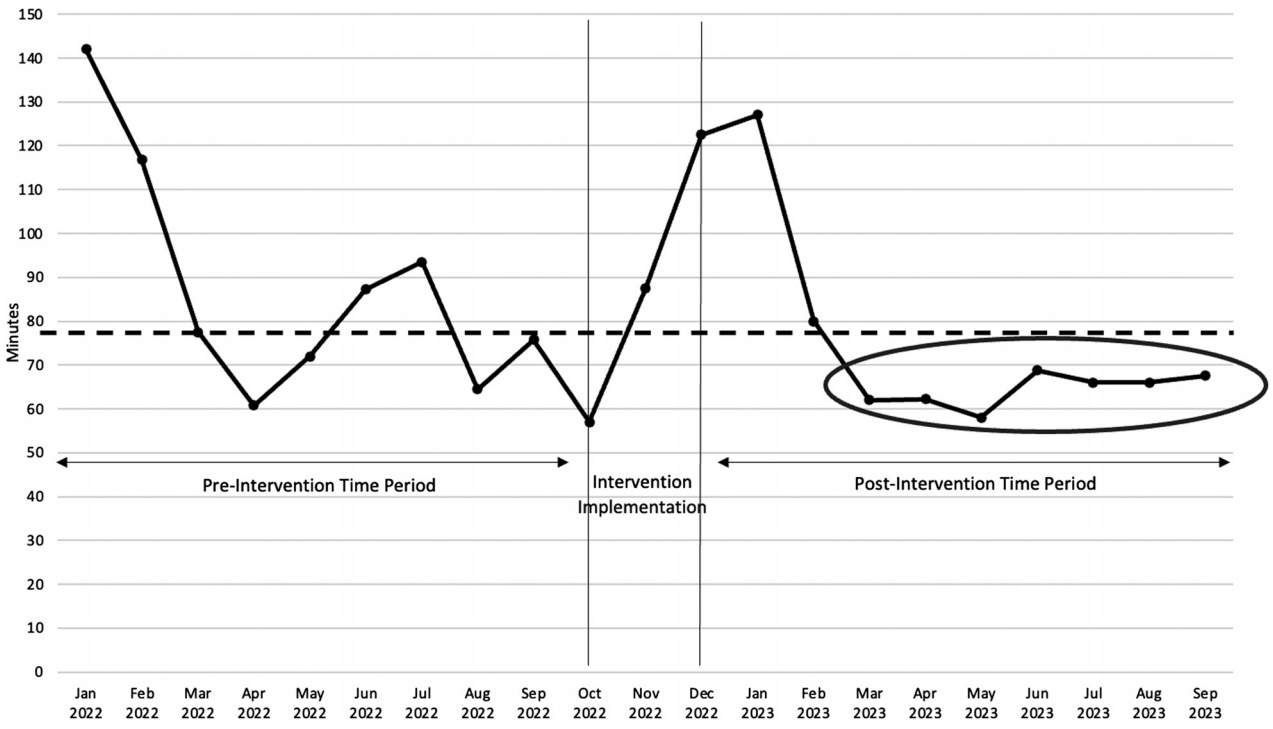


Figure 4. A run chart depicting the admitted patient ED outflow process improvement with sustained median time under pre-intervention baseline.

ED to a clean bed. The flow map and analysis shifted administration strategies for alleviating boarding from saddling frontline workers to solve to making these workflow adjustments management decisions.

The degree to which technology *hindered* patient flow was unexpected. Although research shows that nurses have called for new, effective technology tools to manage the patient flow for years[31] and some initiatives have been created,[18,32,33] our research uncovered shortcomings of existing tool design, an issue that had gone unnoticed. The upside to discovering problems with existing technology was the availability of low- and no-cost solutions.

Although EHRs are the complex backbone of hospital processes, their embedded processes were unquestioned by staff and untested for optimization by administration. Although multiple systematic reviews have reported on causes of ED crowding,[2,3,11] none suggested that the efficiency of technology processes be tested. The reality of how much staff relied on technology to collaborate with others made *digital blindness* the largest barrier. Digital blindness is an issue that has gone unnamed; thus, the magnitude of its effects on other processes, staff, and patients has gone unmeasured. Defining *digital blindness* opens the issue for practical exploration, future research, and innovation design.

The present study results also spotlight the importance of EVS, which has been overlooked in current research. Although EVS is mentioned in a few patient-flow improvement studies,[18,32] in no case was EVS-clinical care coordination central or emphasized. Policymakers should take notice of how, in this study, within-hospital integration lapses were eroding care and productivity. Although the integration of health information systems between hospitals and clinicians monopolizes initiatives across federal agencies (ie, Agency for Healthcare Research and Quality,[34] Centers for Disease Control and Prevention,[35] Centers for Medicare & Medicaid Services[36]), we call attention to how within-hospital integration issues are threatening patient outcomes and stressing staff.

Insights into ED outflow barriers are timely for practical application. There are discussions that the ED boarding time standard will be lowered from four to two hours, a 50% reduction.[2] When administrators seek strategies to meet this aggressive reduction in boarding, we recommend analyzing the bed management cycle and processes with Lean methodologies. Our process uncovered delays unnoticed by any single department, avoided individual patient variabilities that can derail flow investigations,[8] found problematic within-department efficiency solutions, and was appreciated by frontline staff. Administration reported to the innovation team that they believed the investigation improved morale and created enthusiasm for the subsequent solution implementations because the results explained confusing workplace experiences: why staff did not know what was taking so long for ED patients to flow to floor beds; why EVS staff were not cleaning a dirty room; why a clean room would go vacant; and why similar ED patients exited out of order of admission.

LIMITATIONS

The main strengths of this study are its complete review of processes and departments affecting ED patient outflow and the durability of the intervention's gains. However, the generalizability of our findings is limited because it is a single-site study of a mid-sized hospital operating one EHR system during a one-month timeframe. Data was not tested with time series modeling, which could provide additional temporal insights not provided by pre/post design. A limitation to replicability is a hospital's access to Lean Healthcare training, which could drive up the price of the intervention but may be justified given how quickly the team could practically apply new Lean skills. Moreover, the solutions identified do not address other issues driving crowding, such as high community demand for ED services.

CONCLUSION

A systemwide patient-flow investigation at a single hospital used Lean methods, which proved effective in identifying the barriers that increased the time admitted ED patients waited for access to beds. The barriers were system-level issues (technology, workforce shortage, and policy and procedures); the greatest was technology. Given healthcare systems' dependence on technology and the crisis level of ED boarding, this study calls for multicenter regional and national research to understand to what extent within-hospital technology integration lapses are blinding staff and eroding care. Meanwhile, administrators should test how their technology supports (or hinders) environmental services-clinical care coordination and be wary of the effect of *within-department* efficiency gains on patient flow. Because the cost of the investigation was low and we were able to generate solutions for flow barriers with little to no associated costs, we conclude that these types of investigations can reduce ED crowding by moving admitted patients out of the ED more quickly without escalating the cost of care.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Interfacility Patient Transfers During COVID-19 Pandemic: Mixed-Methods Study

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Section Editor: Shira Schlesinger, MD, MPH
Submission history: Submitted April 24, 2024; Revision received August 21, 2024; Accepted August 23, 2024
Electronically published September 10, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.20929

Introduction: The United States lacks a national interfacility patient transfer coordination system. During the coronavirus 2019 (COVID-19) pandemic, many hospitals were overwhelmed and faced difficulties transferring sick patients, leading some states and cities to form transfer centers intended to assist sending facilities. In this study we aimed to explore clinician experiences with newly implemented transfer coordination centers.

Methods: This mixed-methods study used a brief national survey along with in-depth interviews. The American College of Emergency Physicians Emergency Medicine Practice Research Network (EMPRN) administered the national survey in March 2021. From September–December 2021, semi-structured qualitative interviews were conducted with administrators and rural emergency clinicians in Arizona and New Mexico, two states that started transfer centers during COVID-19.

Results: Among 141 respondents (of 765, 18.4% response rate) to the national EMPRN survey, only 30% reported implementation or expansion of a transfer coordination center during COVID-19. Those with new transfer centers reported no change in difficulty of patient transfers during COVID-19 while those without had increased difficulty. The 17 qualitative interviews expanded upon this, revealing four major themes: 1) limited resources for facilitating transfers even before COVID-19; 2) increased number of and distance to transfer partners during the COVID-19 pandemic; 3) generally positive impacts of transfer centers on workflow, and 4) the potential for continued use of centers to facilitate transfers.

Conclusion: Transfer centers may have offset pandemic-related transfer challenges brought on by the COVID-19 pandemic. Clinicians who frequently need to transfer patients may particularly benefit from ongoing access to such transfer coordination services. [West J Emerg Med. 2024;25(5)758–766.]

INTRODUCTION

In early 2020, critically ill patients with coronavirus disease 2019 (COVID-19) overwhelmed many hospitals and emergency departments (ED) across the United States. Surges were unpredictable. Patients overran some hospitals, while other facilities made significant preparations for COVID-19 patients who never arrived.[1] Smaller hospitals needed to transfer patients to facilities with more beds, staffing, and specialist services. The unpredictable distribution of patients and bed availability placed strain on

some larger regional receiving hospitals, leading some states and health systems to identify mechanisms to "load-level" patient transfers among receiving facilities.[2]

Historically, interfacility patient transfers between small or rural hospitals and larger regional hospitals has offered access to care that may not otherwise have been available. Hospitals in the US transfer over one million patients for admission annually,[3] and nearly every US hospital participates in the transfer process either as a receiver, a sender, or both.[4] These transfers, driven by limited bed capacity, the need for specialty services, or a lack of certain diagnostic modalities, are challenging for referring hospital clinicians.[5]

National efforts to track available hospital capacity and coordinate transfers during the early COVID-19 pandemic were seen as largely disorganized and unreliable, leading many states, cities, and hospitals to develop their own systems.[6] The Arizona Department of Health Services created the Arizona Surge Line, a centralized system staffed by transfer coordinators with access to updated bed and ventilator capacity data around the state.[2] New Mexico created a Central Command Center to coordinate placement of critical care patients through a "hub-and-spoke" model.[7] Hospitals in Boston, New York City, Chicago, Washington, and Minnesota made similar efforts.[1,8–12]

While viewpoints and lay press articles have explored transfer center efficacy, research describing the reach of transfer centers and their impact, as perceived by clinicians, policymakers, and hospital leadership are lacking. We used a mixed-methods approach, including a national survey to describe access to transfer centers before and during COVID-19, and semi-structured interviews with stakeholders in two states to generate an in-depth picture of the function and the impact of transfer centers. We hypothesized that implementation of a new transfer center would lead to easier transfer processes.

Population Health Research Capsule

What do we already know about this issue?
Interfacility patient transfers are challenging for clinicians to arrange in rural and limited resource settings. This was exacerbated by the COVID-19 pandemic.

What was the research question?
Did transfer coordination centers improve the clinician experience of arranging patient transfers during the pandemic?

What was the major finding of the study?
Survey results and interviews suggest transfer centers may have offset pandemic transfer challenges.

How does this improve population health?
Clinicians who frequently transfer patients may benefit from ongoing access to transfer coordination services.

METHODS

We conducted an explanatory, mixed-methods study with a national, web-based survey to capture the transfer-center experiences in a variety of emergency care practice settings followed by semi-structured qualitative interviews with sending facility clinicians and administrators in two states (Arizona and New Mexico) to provide deeper insight into the experiences of sending facilities. Both states established new interfacility transfer coordination systems during peak COVID-19. The first author's institutional review board approved the study design.

Web-based National Survey

A multidisciplinary team of Arizona- and New Mexico-based researchers from a mix of urban and rural hospitals developed and revised the survey. Attending physicians with clinical, administrative, and research experience who practice in referring and receiving hospital settings pilot-tested the survey to ensure question-and-response relevance and clarity. Published guidelines informed survey development.[13,14]

We administered our survey using the American College of Emergency Physicians Emergency Medicine Practice Research Network (EMPRN), a nationwide cohort of 765 emergency physicians who have volunteered to answer short research surveys several times a year. The survey included questions on practice setting, transfer center presence during COVID-19, and transferred patients' characteristics (Appendix A). No incentives were offered for participation. The EMPRN sent survey invitations on March 3, 2021, with three additional reminder emails over a six-week window.

Variables and data analysis

We calculated survey response rate based on the number of EMPRN participants who were emailed the survey (765) and the number of submitted survey responses. No surveys were excluded due to item nonresponse, since all but one of the questions were required for survey submission. We collected ordinal responses for yearly ED volume, inpatient bed capacity, and views on the future utility of transfer coordination systems and Likert-scaled responses for perception of COVID-19 impact and transfer metrics. We defined *sending* facilities as those that *always* or *mostly* tended to transfer patients out compared to receiving patients. We defined *receiving* facilities as those that *always*

or *mostly* tended to receive transfers. We defined a transfer center as a "new/expanded centralized entity (such as a call center) created to coordinate interfacility transfers." In addition to descriptive characteristics, our primary outcome measure of interest was the transfer center effect on patient transfers during COVID-19. We compared sending and receiving respondents, facility characteristics, effects of the COVID-19 pandemic, and perceptions of transfer centers using chi-square, Student *t*-test, Spearman's rho, Wilcoxon signed-rank tests, and Mann-Whitney tests, as appropriate. We used a two-tailed type I error rate of 5% to determine statistical significance. We used JASP 0.14.1.0 (University of Amsterdam, Netherlands) for statistical analyses.

Qualitative Interviews

We conducted semi-structured interviews to further explore clinician and policymaker perceptions of interfacility transfers before and during the pandemic, along with the benefits and challenges of the new transfer systems. Researchers iteratively developed the interview guides with input from physicians frequently involved in the transfer process. Clinicians who gave input on the development of the interview tool were not included among the final interviews. The interview questions focused on the organization of and overall challenges associated with interfacility transfers and on the perceived impacts of transfer centers on the transfer processes (Appendix B).

Three authors conducted the interviews between September–December 2021. Clinicians who gave input on the survey tool helped identify the first interviewees. We then used snowball sampling to recruit clinicians from rural (sending) hospitals that frequently needed to transfer patients to other facilities and administrators tasked with implementing and running the transfer centers during COVID-19. We interviewed five clinicians and three administrators from New Mexico and six clinicians and three administrators from Arizona before thematic saturation was reached and no further participants were recruited. Interviews generally ranged from 30–60 minutes in length. With permission, we recorded the interviews, saved them securely, and transcribed them using Rev transcription services (Rev.Com Inc, San Francisco, CA). We assigned alphanumeric identifiers to transcripts for confidentiality. Each of the three interview-team members independently coded the same administrator and clinician interview to ensure concordance and to develop a coding structure before inductively coding and analyzing themes on the remaining interviews. We used an iterative process throughout the analysis to ensure reliability in thematic category development.

RESULTS

Survey

A total of 141 physicians (of 765 who were sent the survey, 18.4% response rate) from 39 states responded to the EMPRN survey. Respondent average age was 53, and most were White and male. Facilities that primarily transferred patients to larger centers (ie, sending facilities) tended to have lower yearly ED volumes ($P < 0.001$) and less inpatient bed capacity ($P < 0.001$) compared to facilities that primarily received patients in transfer (ie, receiving facilities) (Table 1). Lack of specialty services was the most common reason for transfer reported among both senders and receivers; other reasons included inadequate local inpatient- and intensive care unit (ICU) capacity (Figure 1).

Most respondents reported moderate-to-high perceived severity of COVID-19 impact in their areas (mean 3.9 with 1 being the lowest severity and 5 the highest severity). Physicians at receiving facilities perceived the severity of the COVID-19 pandemic to be greater than sending physicians ($P = 0.05$), see Table 1. Most respondents also reported transfers over greater distances (mean 3.58) and increased number of transfer partners (mean 3.54) required to accomplish patient transfers during the COVID-19 pandemic compared to prior (mean 3.00, indicating no change). Reported COVID-19 intensity appeared to be correlated to distance of transfers (Spearman's rho 0.141, $P = 0.10$) and number of transfer partners (Spearman's rho 0.140, $P = 0.10$) although not statistically significant.

Most respondents reported no access to a transfer center prior to the COVID-19 pandemic, or implementation of a new or expanded transfer center in response to COVID-19 (Table 1). A total of 37 respondents (30%) reported implementation or expansion of a transfer coordination center in response to the COVID-19 pandemic. Those who had a new or expanded center reported similar amounts of overall effort (mean 2.91, where a mean = 3 indicates no change, Wilcoxon rank-sum test, $P = 0.55$) and time to achieve transfers (mean 3.17, Wilcoxon $P = 0.32$). In comparison, those who did not have a new or expanded center generally reported a higher difficulty (mean 3.89, Wilcoxon rank-sum test $P < 0.001$) of transferring patients because of the COVID-19 pandemic.

Of those with access to new or expanded transfer centers during COVID-19, most saw utility in having these transfer services available in the future. Among 36 respondents with new or expanded transfer centers, 15 (42%) thought they would be useful in the future but only in emergency circumstances and 16 (44%) thought they would be useful in all situations. In comparison, of 83 respondents without transfer centers, only 17 (20%) thought transfer centers could help in future emergencies, 35 (42%) thought they would be useful in all situations, and 31 (37%) thought these would not be helpful in the future.

Interviews

Interviews with administrators and sending facility clinicians provided additional insight on the utility of transfer centers. The 17 interviewees included five clinicians and three

Table 1. Demographics and general characteristics of respondents and respondent facilities from national EMPRN* survey.

		Overall	Receivers	Senders	*P*-value
Total		141	79	62	
Unique states		39	35	25	
Mean age (years)		53.4	52.1	55.0	0.11
Ethnicity (%white)		82.5	79.2	86.7	0.26
Gender (%male)		80.9	79.7	82.3	0.71
Yearly volume (%)	<10k patients	5	0	11.3	<0.001
	10–30k	20	11.5	30.6	
	30–60k	35.7	34.6	37.1	
	>60k	39.3	53.8	21	
Inpatient beds (%)	None (freestanding)	3.5	1.3	6.5	<0.001
	<25 beds	7.8	0	17.7	
	25–99	9.9	2.5	19.4	
	100–299	34.8	26.6	45.2	
	300–500	22.7	32.9	9.7	
	>500	21.3	36.7	1.6	
COVID-19 impact, Likert 1–5 (SDEV)		3.90 (0.905)	4.04 (0.884)	3.73 (0.908)	0.05
Pre-COVID-19 transfer	City/county/region	10.1	11.7	8.1	0.22
center (%)	State	4.3	3.9	4.8	
	Hospital-based	15.8	18.2	12.9	
	No	65.5	59.7	72.6	
	Don't know	4.3	6.5	1.6	
New or expanded	City/county/region	5.7	6.3	4.8	0.21
transfer center (%)	State	9.2	13.9	3.2	
	Hospital-based	11.3	8.9	14.5	
	No/unchanged	59.6	51.9	69.4	
	Don't know	11.3	15.2	6.5	

*EMPRN, Emergency Medicine Practice Research Network.

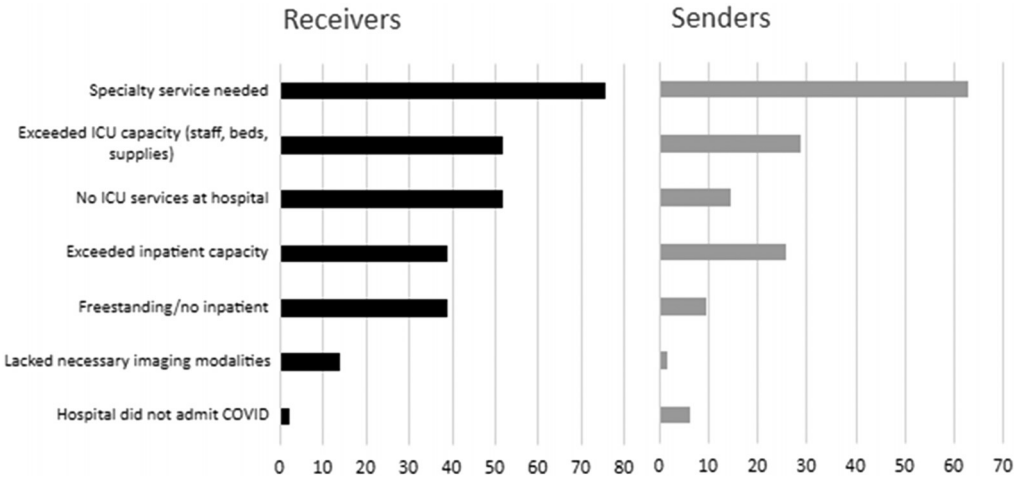


Figure 1. Perceived reasons necessitating patient transfers during the COVID-19 pandemic, receiving vs sending facilities (% of respondents).
COVID, coronavirus 2019; *ICU*, intensive care unit.

administrators from New Mexico and six clinicians and three administrators from Arizona. The interviewees were mixed in gender and age. The 11 clinicians included six working on tribal health sites of varying sizes (a large number of rural facilities in the region serve Native American tribes), one at a non-tribal nonprofit critical access hospital, two at mid-sized community nonprofit hospitals, one at several freestanding EDs, and one at a rural community teaching hospital.

We identified four primary themes related to the functioning and utility of transfer centers, including the following: 1) limited resources for facilitating transfers even before COVID-19; 2) increased number of and distance to transfer partners during the COVID-19 pandemic; 3) generally positive impacts of transfer centers on workflow; and 4) the potential for continued use of centers to facilitate transfers.

Theme 1: Limited resources to coordinate transfers

Interviewees reported that, prior to and during the COVID-19 pandemic, transfer coordination placed a large burden on clinicians and staff at sending facilities. One respondent noted that they spent *"half my shift on the phone,"* and another called *"as many as 10 to 12 facilities"* before completing a transfer. Without centralized access to learn about which receiving facilities had needed beds and specialty services, *"you had no way of knowing that until you actually talk to somebody."*

Respondents at sending facilities reported a variety of reasons for patient transfer. A respondent summarized the relationship between resources and decisions to transfer:

> There are three [reasons], one is lack of capacity . . . The other reason is called 'service is not available' . . . And the third reason is higher level of care . . . that the patient is too sick for us and our system.

Before transfer center implementation, decisions were often based on sending clinicians' personal relationships and knowledge of receiving facilities, to the extent that one interviewee noted their *"first-name relationships"* with those at receiving facilities.

Theme 2: Increased transfer complexity during COVID-19

Survey respondents reported increased numbers of transfer partners and increased distances of transfers, suggesting increasing complexity of patient transfer as an early result of the pandemic. Interview respondents elaborated on the complexities of this expanded transfer area, with one noting that *"transferring patients much farther distances"* places strain on *"the patient and onto the family and their support network."* Another interviewee had a similar number of transfers as pre-pandemic but *"the complexity increased, the number of phone calls increased."* Many needed to identify new receiving facilities beyond their normal transfer partners to access the needed level of care, specifically ICU beds. A respondent reported,

> Before this [COVID-19 pandemic], I've never had to transfer for bed availability, but we did start having to do that for ICU beds. [For these reasons] "length of stay in the emergency department has gone up dramatically.

Theme 3: The positive impact of transfer centers

Almost all respondents noted that the transfer centers decreased the burden of patient transfer, providing an important resource in maintaining workflow. A primary impact was reduction in time spent on the phone, with one respondent liking that they *"only had to dial one number, give some basic info . . . you only had to have one conversation with one doctor . . . it dramatically decreased administrative work."* Another interviewee noted, *"better flow throughout our emergency department so that other patients could be seen and cared for as well."* Even those who did not see a big impact on their transfer process acknowledged the possibility that the centers helped subtly:

> As the transferring physician, I did not see much change . . . Now, what I can't tell you is what it would be like, given the ongoing surges, if there had been an absence of that call center, things could have been much worse . . . Maybe no change was a good thing, because the alternative was that things would've declined in a very bad way.

Theme 4: Transfer centers as a potential policy solution

The transfer center experience led interviewees to consider how this arrangement may contribute to improved care delivery beyond the pandemic. Despite lower numbers of COVID-19 patients at the time of interview, one clinician noted transfers still *"taking quite a bit of time . . . transfer center assistance could still be very helpful . . . even though technically the COVID crisis has subsided."*

One respondent suggested a standing statewide transfer center could assist sending facilities and increase patient agency: *"One phone number that you call for any transfers within your state . . . you can put that patients' preference is transferred to X hospital or to stay near home."* Others stated they would like to *"expand this out to other disease states other than just COVID."* Another wanted to see *"a [phone] line at a minimum that dealt with all ICU beds within a region . . . able to know what hospitals had what services and put you in touch with them rather than . . . [taking] away from patient care."*

Meeting the needs of both facilities and communities requires significant planning and coordination. One respondent noted,

Table 2. Additional qualitative findings and extended-length quotes.

Theme	Quote
Limited resources to coordinate transfers	You make all your own phone calls. So I've spent up to half my shift on the phone, randomly dialing phone numbers for non-COVID patients before.
	There are times when they call as many as 10 to 12 facilities before you can find an acceptable bed . . . so the more time spent trying to find an appropriate facility for patient, the fewer other patients that that provider can see.
	I've spent more time on the phone . . . trying to get people transferred due to COVID than I ever thought was possible.
	Even if a place said that they have specialty services covering specialty X, they may not have it that day or that week and you had no way of knowing that until you actually talk to somebody. You wouldn't know who had the type of bed available that you were looking for. So you'd [make] multiple phone calls say requesting an ICU bed until you found somebody who had an open ICU bed. And so just a lot of redundancy of work that took away from patient care time.
	There are three [reasons], one is lack of capacity, because we can't admit that many patients because we don't have enough nurses. The other reason is called "service is not available", which means we just don't have the service, we don't have the specialist, we don't have the MRI, we don't have the CT, our CTs went down. There's a lot of things we don't have. We don't have platelets, we don't have dialysis, don't have anyone to do a cardiac check. Either we don't have the specialist, we don't have the equipment, but we don't have the service that service is not available. And the third reason is higher level of care. And that's that the patient is too sick for us and our system, which is different than service is not available. Service is not available would be if we had a neurologist and MRI, we could probably keep the patient. So those are only three reasons we send people out.
	We have first name relationships with some of the attending physicians, and they're more familiar with our setting and our limitations
Increased transfer complexity during COVID	We are now transferring patients much farther distances, which is very significant onto the patient and onto the family and their support network. Many patients are being transferred now to locations where they don't have a ride home
	I think the proportion of transfers was probably similar. But, the complexity increased, the number of phone calls increased
	We don't have a lot of specialists and so it is not infrequent that we have to transfer for certain specialists but before this [COVID pandemic], I've never had to transfer for bed availability, but we did start having to do that for ICU beds
	Our length of stay in the emergency department has gone up dramatically, compared from even in the last month, we were up 109 minutes on average for patients that were being admitted
The positive impact of transfer centers	I think where it was most notable was just the fact that you or a secretary only had to dial one number, give some basic info. And then once there was an accepting hospital, then as a physician, you only had to have one conversation with one doctor. Sometimes not even that. And so from sort of that end of the administrative work, it dramatically decreased administrative work.
	So patients having to wait less time to get to an appropriate inpatient facility would be beneficial and then would also allow us to have better flow throughout our emergency department so that other patients could be seen and cared for as well
	From my end, as the transferring physician, I did not see much change . . . Now, what I can't tell you is what it would be like, given the ongoing surges, if there had been an absence of that call center, things could have been much worse. So in the back of my mind, I think about that. Maybe no change was a good thing, because the alternative was that things would've declined in a very bad way
Transfer centers as a potential policy solution	We're still finding that the process to find an appropriate facility is taking quite a bit of time. And so that transfer center assistance could still be very helpful even now because of the fact that the state is just seeing limited bed availability, even though technically the COVID crisis has subsided.
	One phone number that you call for any transfers within your state. And that you can put that patients' preference is transferred to X hospital or to stay near home or whatever [their preference] is.

(*Continued on next page*)

Table 2. Continued.

Theme	Quote
Transfer centers as a potential policy solution	I think that I would love to expand this out to other disease states other than just COVID. I think having that centralized communication system seemed to be a very effective manner.
	Having a line at a minimum that dealt with say all ICU beds within a region. But ideally one line that was able to know what hospitals had what services and put you in touch with them rather than having hospital staff spending most of their time dialing numbers and away from patient care
	I would be fully in favor of a robust, well-supported transfer mechanism. My impression is that outside of pandemic times there is not a well-coordinated transfer architecture for getting patients from deeply rural to urban centers and tertiary care centers . . . very hopeful that we can pull together a well-coordinated transfer framework, which revolves around transfer centers
	Even if they cannot cover every single transfer, especially, when we're seeing higher volumes and pressed for time and resources in the ER, anything that could be done to facilitate patients ultimately getting the care they need is a huge benefit. I think there's also sort of a sense that if we can optimize the resources within the state to allow for coordination across the hospital systems, just here for these patients, that would be ideal as well
	I don't feel like I need it during non-crisis times, personally. I usually have been able to transfer patients pretty quick
	We're so rural. There's nowhere . . . When it takes us so long to get a bed, we also still have to arrange for flight and for the actual transportation. So, if it takes 22 hours to get a bed, and then I don't have a flight team available for six hours, that's 28 hours before the patient leaves my emergency department, you know?

CT, computed tomography; *COVID*, coronavirus 2019; *ICU*, intensive care unit; *MRI*, magnetic resonance imaging.

> Outside of pandemic times there is not a well-coordinated transfer architecture for getting patients from deeply rural to urban centers and tertiary care centers . . . [I am] hopeful that we can pull together a well-coordinated transfer framework.

Another commented,

> When we're seeing higher volumes and pressed for time and resources in the ER, anything that could be done to facilitate patients ultimately getting the care they need is a huge benefit . . . if we can optimize the resources within the state to allow for coordination across the hospital systems . . . that would be ideal.

A subset of respondents was less enthusiastic about transfer centers outside the pandemic context. One stated, *"I don't feel like I need it during non-crisis times, personally. I usually have been able to transfer patients pretty quick."* Others noted interrelated challenges that would need to be overcome before fully realizing the benefits of a transfer center: *"We're so rural . . . we also still have to arrange for flight and for the actual transportation."* Additional and expanded respondent quotes are provided in Table 2.

DISCUSSION

In this mixed-methods study, we hypothesized that physicians participating in patient transfers during COVID-19 would find utility in having access to transfer coordination centers. In our national survey, those without access to transfer centers reported a significant increase in the difficulty of executing transfers during COVID-19 surges, contrasting to respondents with access to new transfer coordination services reporting no significant change in effort or time to organize a patient transfer. This suggests that transfer center implementation may have offset pandemic-related transfer challenges. Respondents who had experience with transfer centers also were more supportive of their ongoing use, particularly in future health crises.

Our qualitative interviews in Arizona and New Mexico, two states where transfer centers were implemented, shed additional light on their benefits while identifying areas for future improvement. With few exceptions, these clinicians found the transfer center services to be helpful, specifically in reducing transfer workflow complexity. Since the completion of this study, feedback in Arizona was so positive that the state evolved its temporary transfer center into the federal grant-funded "AZ REACH" system, administered by the Arizona Poison and Drug Information System.[15]

Most US healthcare practitioners do not work in areas served by transfer coordination centers, consistent with our survey results.[1,2,6–12] In the wake of the September 11, 2001, terrorist attacks, attempts were made to create a national centralized system but were never widely implemented.[6] While some regions have transfer patterns for specific conditions such as trauma and acute myocardial infarction,[16,17] transfers generally occur through informal, loosely coordinated regional networks that suffer from fragmentation and poor

communication.[4,5] Our study concurs with prior research finding that the laborious transfer process requires the sending clinician to identify an accepting facility using their knowledge of historical transfer patterns and informal relationships, and the complex coordination and multiple phone calls can distract from patient care.[5] It is possible that existing transfer services were available to some of our respondents prior to COVID-19 but clinicians only became aware of them due to the strains of the pandemic.

Our survey found receiving centers reported a greater perceived impact of COVID-19. Receiving hospitals are generally located in urban areas, which experienced the first waves of COVID-19 during a time of intense uncertainty and fear. This, along with subsequent surges of rural transfers to urban facilities, may have influenced the perspectives of receiving hospital respondents.[18] It is also possible that sending facilities and rural respondents from the survey may have lived in regions less impacted by COVID-19, or that closer relationships between rural facilities and their local communities may yield increased resilience in responding to crises.[19] However, the qualitative interviews revealed that significant stresses from COVID-19, including with transfers, also affect clinicians at smaller facilities. This is likely exacerbated by the struggles of rural facilities to hire physicians who often choose to work in urban centers,[2] while inability to retain staff and rising rural hospital closures[21] place an increased burden among those who remain. Lack of specialist services and inpatient/ICU capacity were the top reasons prompting transfers per sending and receiving physicians, similar to what was reported in prior studies.[5]

Small and rural hospitals have had longstanding challenges transferring patients with time-sensitive conditions, which were amplified during COVID-19. Transfer centers seem to hold great promise in making patient transfer less onerous. As the US healthcare system continues to struggle with worsening staffing issues and patient crowding, transfer centers may be one part of the larger solution to get patients needed care.

LIMITATIONS

The low response rate in the national survey potentially limits interpretation and introduces bias. The strict requirement to complete nearly all questions on the survey may also have led to unit non-response among some physicians. While we tried to improve response rates with multiple email reminders and a shorter survey, other proven strategies could have been considered, such as reaching out via postal mail or including incentives.[22,23] It does appear that survey response rates may be decreasing over time and may also vary by medical specialty, with some having low response rates below 30%.[24,25]

Since EMPRN requests surveys be as short and simple as possible to encourage participation, we further explored clinicians' experiences via key informant interviews. The small pool of interview respondents limited our qualitative data, while the use of snowball sampling from two neighboring, largely rural states (and many tribal sites) may have limited the diversity of viewpoints and external generalizability. Future studies could incorporate expanded interviews to gather perspectives from clinicians in different states and practice settings.

CONCLUSION

The widespread strain on the US healthcare system during the COVID-19 pandemic manifested significant challenges in interfacility patient transfers. Clinicians at small, rural facilities in Arizona and New Mexico found centralized transfer coordination centers to be helpful. In the future, other states could consider trialing implementation of similar services, both in crisis and non-crisis times.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This work was supported by a Research Seed Grant from the Arizona College of Emergency Physicians (awarded on January 15, 2021). There are no other conflicts of interest or sources of funding to declare.

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Impact of Medical Trainees on Efficiency and Productivity in the Emergency Department: Systematic Review and Narrative Synthesis

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Section Editor: Casey M. Clements, MD, PhD
Submission history: Submitted November 13, 2023; Revision received March 8, 2024; Accepted March 22, 2024
Electronically published July 18, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18574

Introduction: Effective medical education must balance clinical service demands for institutions and learning needs of trainees. The question of whether these are competing demands or can serve complementary roles has profound impacts on graduate medical education, ranging from funding decisions to the willingness of community-based hospitals and physicians to include learners at their clinical sites. Our objective in this article was to systematically review the evidence on the impact of medical trainees on productivity and efficiency in the emergency department (ED).

Methods: We queried PubMed, Embase, Scopus, and Web of Science from earliest available dates to March 2023. We identified all studies evaluating the impact of medical students and/or residents in the ED on commonly used productivity and efficiency metrics. Only studies in EDs in the United States were included. No additional filters were used. We assessed the risk of bias of included studies using the Risk of Bias in Non-randomized Studies – of Interventions (ROBINS-I) tool. Certainty of evidence was rated using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach. Study findings were combined in a narrative synthesis and reported according to PRISMA guidelines.

Results: The literature search yielded 3,390 unique articles for abstract screening. Eighty-one abstracts were identified as relevant to our PICO question (population, intervention, control, and outcomes), 76 of which had retrievable full-text articles and the themes of which were discussed in a narrative synthesis. We selected 13 of the full-text articles for final inclusion in a systematic review. Studies were roughly split between observational (6) and quasi-experimental (7) designs. The majority of studies (11) were single-site studies. Only two studies could be graded as low risk of bias per the ROBINS-I tool.

Conclusion: Low-GRADE evidence suggests that students and residents decrease ED efficiency by a statistically small effect size of debatable clinical importance. Residents provide a moderate boost to ED productivity. Students do not produce a statistically or clinically significant impact on ED productivity. Residents increase emergency department relative value units revenue by $26.30 an hour, while students have no impact. Both types of learners decrease efficiency. [West J Emerg Med. 2024;25(5)767–776.]

INTRODUCTION

There are conflicting opinions on the perceived value of medical trainees, stemming from their dual roles of learning and service. Trainees define value as maximizing learning opportunities and interactions with faculty. Attending physicians identify value as trainees completing clerical

tasks and freeing up time for patient care. Administrators see value through the lens of addressing economic challenges of the hospital, with trainees providing potential value via documentation and improvement of organization-wide metrics—both of which are seen as low-value activities by trainees.[1] It is not possible to sidestep the conflict between these roles, as time spent on teaching activities during an EM shift is independently associated with resident perceptions on the education value of the shift.[2]

There are several additional stakeholder considerations pertinent to our research question. Community preceptors are increasingly seeking compensation for teaching time.[3] Current practices regarding compensation for teaching time of community preceptors are inconsistent.[3] A logic model might posit that trainees decrease compensation to the supervising physician by decreasing relative value units (RVU) or increasing the amount of time spent post-shift via teaching, feedback, or deferring on-shift activities for these purposes. If this is the case, then this would strengthen arguments for compensating physicians for accommodating learners on shift. Of course, trainees also provide services that might be valued by attendings physicians, such as decreasing their documentation burden, arranging consults, and gathering patient histories.

Stakeholders in the administrator and hospital leadership category might be more or less inclined to enter an affiliation agreement with a medical school or graduate medical education (GME) program depending on the projected impact on important efficiency metrics. Lastly, and perhaps most controversially, there are high-stakes decisions regarding the continuation of indirect graduate medical education (IME) funding, which rely on the implicit assumptions that trainees increase the cost of care at least partly due to impacts on attending physician productivity and efficiency. This is based on data from training sites that historically have represented large, urban, university-affiliated hospitals, with limited generalizability to the majority of EDs across the country. Medicare has reimbursed hospitals for IME costs since 1983 based on the ratio of residents per hospital bed and the premise that the higher costs of patient care at teaching hospitals is due to the presence of trainees.[4] In 2019, over $10 billion in IME payments were distributed to teaching hospitals, supporting roughly 90,000 residents at a cost of $110,000 per resident.[5]

Despite this clearly demonstrated need for data on the impact of trainees on efficiency and productivity in the ED, there are no randomized controlled trials, systematic reviews, or meta-analyses on the subject. In this article we aimed to fill that void by examining existing evidence on the topic, clarifying current gaps in the literature, and making suggestions for future research.

Population Health Research Capsule

What do we already know about this issue?
Learners can be both an asset and a liability in terms of emergency department operations.

What was the research question?
What is the net impact of learners on efficiency and productivity in the emergency department.

What was the major finding of the study?
Residents increase emergency department relative value units revenue by $26.30 an hour, while students have no impact. Both types of learners decrease efficiency.

How does this improve population health?
This finding may guide stakeholders regarding decisions about reimbursement for education services or having learners in their department.

METHODS

We queried PubMed, Embase, Scopus, and Web of Science from earliest available date to March 9, 2023. Search terms and search strategy were developed collaboratively by two content experts in medical education, one content expert in healthcare administration and public policy, and two research librarians. Our PICO question (population, intervention, control, and outcomes) was "What is the impact of learners in the (ED) on efficiency and productivity metrics?" The population for our question was learners. We included broader terms such as "trainee" and "learner" in our search strategy in case there was literature on non-traditional rotators such as students in undergraduate, scribe, or advanced practice practitioner programs. We also included synonyms used to describe medical students and resident such as "clerk" and "intern" (Appendix A).

The intervention of interest was presence of a learner, compared to absence of a learner. The learner had to be present in the ED and under the direct supervision of an emergency medicine attending. Our outcome was efficiency and productivity. Efficiency described how quickly patients moved through the department and included synonyms such as "throughput." Productivity referred to how much work an attending physician was able to complete, most commonly measured by patients seen or RVUs generated per unit of time (Appendix A). These PICO characteristics were captured by the search terms outlined in Appendix B.

The first author reviewed the initial 6,175 results to ensure that the automatically detected duplicates were appropriate and manually excluded undetected duplicates. The remaining 3,390 abstracts were screened by two reviewers to judge whether the article would satisfy our PICO question, with differences adjudicated by a third reviewer. Reviewers worked independently and were blinded to the result of the first vote for cases in which they served as second reviewer. Adjudication also occurred blindly, without access to the individual reviewer's votes. Of these 81 abstracts, 76 were available for full-text review. Full-text reviews were performed by the first author with notations describing justification for proposed inclusion or exclusion. Annotated full texts were then put to a consensus vote among the four reviewers. We applied an additional inclusion criterion of studies conducted in the United States during this step, owing to differences in training and supervision requirements for medical trainees in other countries. Records were compiled using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

The references sections of included studies were hand-checked for additional candidates for inclusion, but this search did not reveal any new studies to add to the final inclusion list. Data was extracted by the first author and organized by population and outcome. The impact of residents and students on the outcome categories were displayed separately when possible. We constructed tables and figures according to the *Cochrane Handbook for Systematic Reviews of Interventions*.[6] A standardized effect size (Cohen *d*) with 95% confidence intervals was calculated for studies that provided the necessary data. We rated certainty of evidence using the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) approach, adapted for reviews not including a single estimate of effect.[7]

We assessed risk of bias was assessed using the Risk of Bias in Non-randomized Studies – of Interventions (ROBINS-I) tool,[8] with notations made through Covidence and consensus assessment voted upon by the four reviewers. Effect measures were presented as reported by each included article. We presented results of the systematic review and narrative synthesis according to PRISMA guidelines.[9]

RESULTS

A search of PubMed, Embase, Scopus, and Web of Science identified 6,175 articles with 2,785 duplicates, leaving 3,390 article abstracts to be screened. We excluded 3,309 abstracts that did not address our PICO questions, yielding 81 full-text articles sought for retrieval, five of which were unavailable as they were abstract-only publications. Themes from these 76 articles are discussed in the narrative synthesis, with a final 13 selected for inclusion for the systematic review (Figure 1). Characteristics of included studies are summarized in Appendix C.

Themes of Excluded Studies

Common reasons for exclusion after full-text review were wrong setting or wrong outcome. Some studies evaluated fellows[10] or moonlighting residents[11,12] who were practicing independently and not being directly supervised by an EM attending. An Emory-based study showed EM-trained critical care fellows caring for boarding intensive care unit patients generated an additional 3.07 RVUs/hour for the department.[10] Northwestern University evaluated the economics of paying residents to serve as triage physicians in a moonlighting role in their ED and found that the return on investment from "left without being seen" charge capture was +54%.[11] Svirsky et al (2013) showed a similar moonlighting program reduced length of stay (LOS) by 25 minutes. These studies were not included in our review as the residents and fellows were neither acting in a learner role nor being supervised by the on-shift EM attending physician.

Several excluded studies involved learners in the ED on non-EM services who were not supervised by the on-shift EM attending. Replacing a surgical resident with an MLP (midlevel practitioner) during protected education time added 67 minutes to ED LOS.[13] Resident presence on a trauma rotation decreased ED LOS for admitted trauma patients.[14] Residents on a trauma consult service did not take any longer than attending surgeons to complete consultations.[15] Presence of an in-house cardiology fellow decreased door-to-balloon times for ST-segment elevation myocardial infarction (STEMI).[16]

Some studies evaluated the impact of learners on efficiency or throughput measures but compared them to MLPs or simultaneously adjusted attending physician staffing.[16–18] McGarry et al (2010) used a pre-post design evaluating LOS after a new EM residency program was created at their hospital. They redistributed 33% of the attending physician coverage toward the low-acuity "urgent-care" area of their department. There was a slight increase in LOS post-implementation of the residency program, but greater differences may have been masked by the fact that the low-acuity area—the area most likely to be bottlenecked by clinician efficiency—had more coverage. French et al (2002) found that patients waited an additional 20 minutes for disposition decisions when residents were absent on conference days. However, conclusions regarding learner presence would be difficult to make, as they replaced the roughly 60 hours of resident coverage with 40 hours of MLP and faculty coverage. Clearly, residents were viewed as assets requiring increased staffing to offset their absence, but these studies compare trainee performance to MLP or attending physician performance rather than strictly presence vs absence of learners and were thus omitted from our review.

Other studies took place in a pediatric-only ED. These studies generally demonstrated an increase in LOS with resident and/or medical student teams, likely mediated

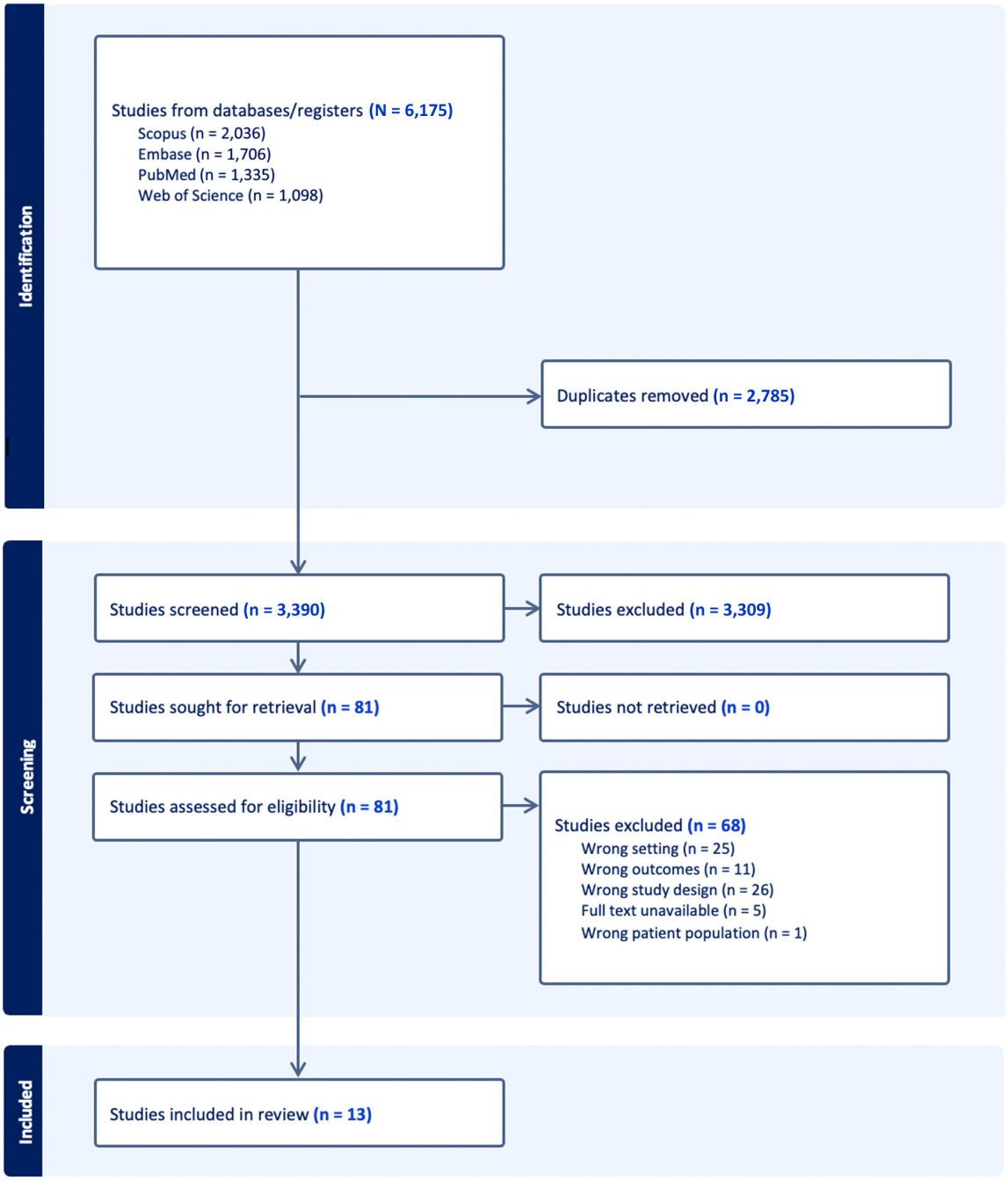


Figure 1. PRISMA* flow diagram.
PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses.

through increased laboratory and imaging utilization.[19,20,21] Jadhav et al (2019) showed a clear association between resident involvement in a case, the number of studies ordered, and the LOS increase for those cases. Corey et al (2022) redemonstrated these findings and also showed that resident involvement was linked with an increase in RVUs/patient, again likely mediated by increased test utilization. While this result is potentially positive from a hospital administration perspective in that it increases revenue, it also likely represents low-value care that inflates the patient's bill and the cost of healthcare as a whole. We did not include studies from pediatric EDs as they have very different operational characteristics than adult or combined EDs.

There were multiple studies in other countries using a natural experimental condition offered by junior physicians going on strike, but the applicability of these junior doctors to resident physicians in the US is limited due to differences in training and supervision requirements.[22,23,24,25] Studies from

Korea,[22] New Zealand,[23] Spain,[24] and Australia[25] all provide interesting case studies, but the "junior doctor" terminology is variably defined, sometimes referring to independently practicing physicians and at other times referring to physicians in training.

Studies excluded on the basis of wrong outcome tended to measure patient satisfaction or quality of care metrics. Perhaps most interestingly, Michael et al (2022) showed that EM residents improved time-limited quality metrics for stroke, sepsis, and STEMI, while off-service residents in the ED had a negative impact.[26]

Narrative Synthesis of Included Studies

The 13 included studies addressed our PICO question by isolating presence vs absence of learner as the intervention and comparison groups, restricting the population to learners in the ED under the supervision of the on-shift emergency medicine attending physician, and included a measure of efficiency or productivity.

Efficiency metrics were as defined by the Emergency Department Benchmarking Alliance Consensus Summit (Figure 2).[27] Non-standardized definitions are explained in relation to the figure. Other abbreviations encountered included dLOS, which stands for length of stay for discharged patients, and TT, which is the interval from treatment space time "to when [the patient] is either discharged or admitted to the hospital."[28] It was unclear whether the endpoint of this interval was disposition or departure time, and the authors did not respond to email inquiries requesting clarification.

Seven studies assessed the impact of residents on efficiency in the ED (Table 1). Most (6/7) of the studies showed a small decrease in efficiency. The measured impacts on efficiency were all statistically small (Cohen *d* ranged from −0.15 to 0.15), but the clinical significance of the impact is more difficult to determine. The net difference in efficiency ranged from (−58) to 73 more minutes spent in the ED, with studies clustering reasonably well around the median value of 26 minutes. At academic departments with very long average LOS, 26 minutes may not be a meaningful increase. These seven studies, with the exception of the Pitts et al study (2014), were conducted at a single academic site.[32] Each study, with the exception of Lammers et al (2003),[31] included an average time metric above three hours, helping to explain the small statistical effect size. We identified three issues with interpretation of clinical meaningfulness of the impact of resident presence on ED efficiency.

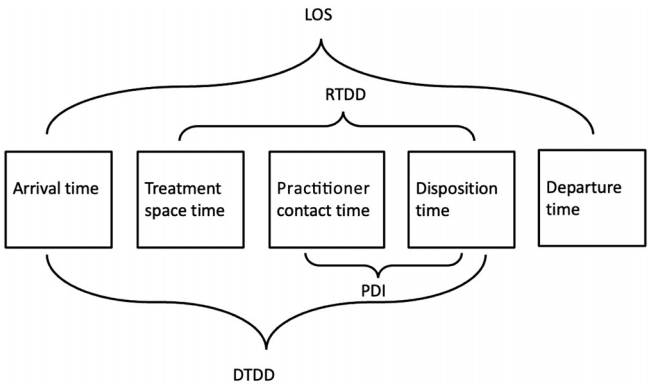


Figure 2. Emergency Department Benchmarking Alliance time stamps and intervals.
LOS, length of stay; *DTDD*, door to disposition decision; *RTDD*, room to disposition decision; *PDI*, practitioner disposition interval.

Firstly, the varying measures of efficiency make synthesis of effect size problematic. Metrics that include the interval between disposition and departure time are influenced by boarding, which is a throughput bottleneck that is largely unaffected by resident presence in the ED and serves to attenuate any differences in efficiency between groups.[28,29,32] The efficiency of the emergency team caring for a patient who spends several hours awaiting an inpatient bed is poorly reflected in these metrics.

Secondly, some of the studies excluded "fast-track" patients.[28,33] Emergency departments have several names for these split-flow models, which all emphasize identifying patients with lower departmental resource needs with the aim of expediting their workup and disposition. These are the patient encounters in which efficiency is potentially most subject to the presence of a trainee, as there may be no competing throughput bottlenecks like imaging or laboratory turnaround time. Exclusion of fast-track patients attenuates measured efficiency differences.

Thirdly, selection and group allocation biases were present in varying degrees of the included studies. When the unit of analysis is the individual patient encounter,[30,32] there is a high risk of selection bias as the residents may be preferentially opting for complex cases, which are more likely to meaningfully augment their learning. The presence of a resident is thus best viewed as a confounder, tightly associated with case complexity, which is a known driver of LOS.[41] This limitation is perhaps most strongly present in the Pitts et al (2014) study.[32] This nationally representative sample assessed LOS for patient encounters that included a resident compared to encounters with only an attending physician. While the authors attempted to limit confounding by adjusting for patient factors such as age and triage acuity, the nuances of patient complexity are likely to escape the simplification of a control variable. The authors' suggestion that "residents see virtually all patients in major teaching EDs" appears empirically untrue given the multiple studies in our review that note the absence of learner involvement for lower acuity patients in split-flow ED models.

Group allocation bias arises when the propensity for attending physicians to work with residents is linked to differences in efficiency metrics. For example, physicians in education leadership (core faculty, assistant program

Table 1. Study characteristics grouped by participant and outcome categories.

Study (measure)	Intervention N	Control N	Net difference (I–C)	Effect size (*d*)	95% CI [Lower, Upper]	Test	*P*-value
Efficiency – Residents							
Anderson et al, 2013[28] (TT)	246 visits	7,689 visits	–58 minutes[t]	–0.15	[–0.27, –0.02]	K–S	0.02
DeLaney et al, 2013[29] (LOS)	153,703 visits	40,331 visits	26 minutes*	N/A	N/A	K–W	<0.001
DeLaney et al, 2013[29] (DTDD)	153,703 visits	40,331 visits	30 minutes*	N/A	N/A	K–W	<0.001
Kraut et al, 2020[30] (RTDD)	4,537 visits	3,421 visits	10 minutes	0.10	[0.06, 0.15]	N/A	0.01
Lammers et al, 2003[31] (DTDD)	N/A	N/A	40 minutes	N/A	N/A	*t*	<0.001
Pitts et al, 2014[32] (LOS)	3,374 visits	25,808 visits	73 minutes*	N/A	N/A	N/A	<0.05
Robinson et al, 2020[33] (PDI)	103,871 visits	7,283 visits	18 minutes	0.15	[0.13, 0.17]	*t*	<0.001
Efficiency – Students							
Chan and Kass, 1999[34] (dLOS)	1,336 visits	639 visits	–5.4 minutes	–0.06	[–0.15, 0.04]	*t*	0.40
DeLaney et al, 2013[29] (LOS)	13,949 visits	40,331 visits	24 minutes*	N/A	N/A	K–W	<0.001
DeLaney et al, 2013[29] (DTDD)	13,949 visits	40,331 visits	15 minutes*	N/A	N/A	K–W	<0.001
Ioannides et al, 2015[35] (LOS)	1,029,165 visits	343,696 visits	5.9 minutes	0.02	[0.02, 0.03]	*t*	<0.001
Smalley et al, 2014[36] (dLOS)	6,880 visits	2,188 visits	14 minutes*	N/A	N/A	W	N/A
Efficiency – Mixed Trainees							
Dehon et al, 2015[37] (LOS)	377 days	18 days	2.4 minutes	0.07	[–0.41, 0.54]	*t*	0.28
Productivity – Residents							
Bhat et al, 2014[38] (PPH)	1,935 shifts	2,199 shifts	0.12 PPH	0.34	[0.28, 0.41]	*t*	<0.005
Clinkscales et al, 2016[39] (RVUs/patient)	12,494 visits	11,560 visits	0.2 RVUs/patient	0.53	[0.50, 0.55]	*t*	<0.001
Robinson et al, 2020[33] (PPH)	103,871 visits	7,283 visits	0.4 PPH	0.21	[0.19, 0.24]	*t*	<0.001
Productivity – Students							
Bhat et al, 2014[38] (PPH)	514 shifts	2,199 shifts	0.0 PPH	0.00	[-0.10, 0.10]	*t*	0.99
Hiller et al, 2014[40] (RVUs/shift)	101 shifts	101 shifts	0.13 RVUs/shift	0.01	[–0.27, 0.28]	*t*	0.95

[t]Denotes differences of medians. Mean values not explicit but were displayed graphically and acceptably close to stated median values.
*Denotes differences of medians.
TT, treatment time; *LOS*, length of stay; *DTDD*, door to disposition time; *RTDD*, room to disposition time; *dLOS*, discharge length of stay; *PDI*, practitioner disposition interval; *PPH*, patients per hour; *RVU*, relative value unit;
t, two-tailed Student *t*-test; *K–S*, Kolmogorov–Smirnov test; *K–W*, Kruskal-Wallis test; *W*, Wilcoxon rank-sum test.

directors, and program directors) would likely be pulled to attend conference. These physicians as a group may exhibit different practice patterns and efficiency trends than their colleagues.[42] The direction and magnitude of this bias is difficult to guess owing to the paucity of literature on the topic. Robinson et al (2020) did a commendable job at controlling this bias by only including data from attendings with "balanced schedules"—meaning those who routinely work shifts both with and without residents.[33] The rest of the studies that used shifts as the unit of analysis do not mention or control for this possible interaction between learner and attending schedules.[28,29,31]

Four studies assessed the impact of medical students on efficiency metrics in the ED. Most (4/5) showed that student

Table 2. Certainty of evidence of included studies.

Outcome	Effect	Number of studies	Certainty of the evidence (GRADE)
Resident impact on efficiency	Most (6/7) studies showed a small to moderate decrease in efficiency.	7	LOW 00 (due to serious risk of bias and indirectness)
Student impact on efficiency	Most (4/5) studies showed a small decrease in efficiency.	5	LOW 00 (due to serious risk of bias and indirectness)
Resident impact on productivity	All 3 studies showed an increase in productivity, centering around a medium effect size.	3	LOW 00 (due to serious risk of bias and moderate indirectness)
Student impact on productivity	Both studies showed no association with productivity.	2	LOW 00 (due to moderate risk of bias and severe indirectness)

GRADE, Grading of Recommendations Assessment, Development and Evaluation.

presence had a statistically small decrease on ED efficiency, with impacts ranging from (−5) to 24 minutes and a median effect of 14 minutes. Similar difficulties as mentioned above precluded conclusions on the clinical significance of this impact. The efficiency measures generally included boarding time,[29,34–36] although exclusion of fast-track patients was less of a threat for this group, as Chan and Kass (1999) and Smalley et al (2014) focused only on discharged patients.[34,36] Selection bias was likely present in the Smalley study, since the medical students were part of a specially designated teaching service that only saw patients in particular treatment rooms, presumably in the higher-acuity areas of the ED.[36]

Group allocation bias was relatively well-protected against in the Ioannides et al (2015) study by using a natural experimental block design with students being pulled from the department to attend anesthesia training for the last week of each month-long rotation.[35] Smalley et al used a similar condition of student absence during the last Friday of each rotation, during which students took their end-of-rotation exam.[36] There would be a less obvious connection between attending characteristics (ie, involvement in education leadership) and learner presence under these conditions than with one based on resident conference time as commonly seen in the studies on resident impact of ED efficiency.

All three studies that measured resident impact on productivity showed a moderate to large statistical increase, with Cohen *d* ranging from 0.21–0.53.[33,38,39] The clinical significance can perhaps be best illustrated in the following example, which assumes the average of level 4 charting, reimbursed at the 2022 rate of 2.74 RVUs per level 4 patient. The PPH difference (0.26) and RVUs/patient difference (0.2) add 0.76 RVUs/hour to an attending physician's productivity.[43] The Centers for Medicare and Medicaid Services reimbursed $34.61/RVU in 2022.[43] Thus, a resident would bring an additional $26.30/hour of revenue from work RVUs to the ED. The two studies on medical student impact on productivity showed no statistically significant difference.[38,40]

Lastly, Dehon et al (2015) offered a unique analysis incorporating the total number of learners in the ED, inclusive of both students and residents.[37] The correlation approach to total number of learners and efficiency and productivity metrics is interesting but potentially flawed in that there is reason to think resident and student presence has an interactive rather than cumulative effect. The suspicion that residents may mitigate student impacts on efficiency and productivity is reflected in Hiller et al's (2014) observation that "residents performed the bulk of teaching and clinical supervision" of medical students.[40]

A summary of the certainty of evidence of included studies is provided in Table 2.

DISCUSSION

Our systematic review evaluated 13 studies examining the effect of learner presence on efficiency and productivity in EDs. The majority of these studies (10 out of 13) showed moderate to severe risk of bias, leading to low-GRADE (Grading of Recommendations Assessment, Development and Evaluation) evidence for the four investigated outcomes. This bias was primarily due to potential confounders and indirectness of outcome measures, factors which led us to downgrade the review's evidence level.

The low-GRADE evidence suggests that students and residents cause statistically small-to-moderate decreases in ED efficiency, with debatable clinical meaningfulness. Residents increase ED productivity by a statistically

and clinically moderate effect size. Students do not produce a statistically or clinically significant impact on ED productivity.

We can review the implications of this review on the multiple parties involved in the decision to host medical students and residents at an emergency department.

Hospital and departmental administrators may continue to have concerns about learner impact on ED efficiency. This appears to be at most a modest effect and can be reframed as a necessary cost for ensuring a viable physician pipeline.

From a public policy standpoint, the role of trainees in the inefficiencies of teaching hospitals and increased cost of care should continue to be investigated. In EM, there is 24/7 bedside supervision, and most resource utilization and all disposition decisions are run by an attending physician. This may explain the non-intuitive suggestion that EM postgraduate year- (PGY) 3 residents slow down a department as much as interns do,[31] possibly due to greater deference to the PGY-3 resident on medical decision-making, which increases laboratory and imaging utilization.[19–21] Important differences likely exist between service lines in the relative contribution of trainees to inefficiency and decreased productivity. While cost-of-care differences were not directly addressed by this review, it would not appear that trainees in the ED are a large source of variance for efficiency or productivity. For attending physicians, this review should provide reassurance that having learners on shift will not negatively impact their RVU-based compensation.

Medical schools without salaried clinical faculty that have built-in teaching expectations will need to continue recruiting community preceptors. The decision to compensate these preceptors remains complicated.[3] The review suggests that attending physicians balance teaching obligations without sacrificing productivity. However, this balance may be achieved by deferring less urgent clinical obligations, such as charting, until after shift end. This could create a significant, unmeasured time cost. Future studies might investigate the time spent after shifts when accommodating trainees, using time stamps pulled from electronic health records.

LIMITATIONS

This review is subject to certain limitations. Inconsistencies in outcome reporting precluded meta-analysis. As an example, the relative contribution of a study with 1,935 shifts vs one with 103,871 patient encounters is difficult to reconcile, even if standardized effect sizes are available. Also, it would be challenging to combine an indirect efficiency measure like LOS with a more direct measure like door-to-disposition decision. The learner populations' varying service lines and training levels added another layer of nuance precluding direct comparison between studies.

We identified four repeated themes leading to an increased risk of bias. First, the methods of group allocation were often unclear in the studies. A physician's tendency to work shifts without trainees could relate to their efficiency or productivity. Only two studies controlled for this influence.[33,41] Given the ethical issues that would arise from a randomized experimental design, having a natural experimental setting is likely the best evidence-generating opportunity that will be offered on the topic of trainees' impact on ED efficiency and productivity. Future research should explicitly address or control this potential bias from group allocation.

Second, cross-sectional designs should continue to be used. Data from the Emergency Department Benchmarking Alliance have shown a consistent, gradual increase in ED LOS from 2010–2022,[44] indicating a risk of maturation bias in pre-/post-residency designs.[31,39] Third, LOS is not a reliable marker of ED efficiency as it is greatly influenced by external factors such as boarding times, which are beyond the ED's control. Future studies should focus on metrics primarily influenced by ED operations.

Fourth, the unit of analysis should be shifts, not individual patient encounters. This approach can reduce the risk of reverse causation, where residents are preferentially assigned to more complex patients. The presence of this bias was highlighted in several studies.[29,30,32] This would also control for varying practices among attending physicians in which some may independently see low-complexity cases that are felt to be unlikely to meaningfully contribute to learning.

The finding that residents may decrease ED efficiency and only modestly increase productivity may contrast with the experience of physicians at "resident-run" or "county" programs. Anecdotally, these are under-resourced departments that rely on residents to perform necessary services that would be offloaded to non-physician staff at other departments. These non-RVU-generating activities such as gathering equipment for procedures, starting intravenous lines, and transporting patients would not be captured in our study's productivity metrics but are certainly necessary and value-added activities.

The legal mandate of EHR implementation as part of the 2009 American Recovery and Reinvestment Act may challenge applicability of earlier studies since part of resident and student efficiency benefits likely include offloading the documentation burden from the attending physician. However, the time increase spent charting and documenting post-EHR implementation seems to be small, not warranting the exclusion of pre-EHR studies.[45]

Historically, the vast majority of medical trainees have been located at university-associated hospitals that represent large, urban, tertiary-care, trauma centers. Thus, we expect any systematic review to be skewed toward these characteristics. Our review included 11 studies from academic sites and only one from a community site,

which limits generalizability to EDs not matching those characteristics.

We recommend future research on this topic to focus on community training sites, given their increasing role in GME training.[46,47] Applying findings from academic EDs to community EDs can be misleading due to differences in operational characteristics.[48] The impact of trainees on efficiency and productivity could be more pronounced in smaller community EDs that serve a lower percentage of complex patients and do not employ the split-flow models commonly used in the studies included in our review.

CONCLUSION

Our systematic review provides low-GRADE evidence that the presence of learners in the ED may modestly decrease efficiency. However, this effect may be offset by a similarly modest increase in attending physician productivity when supervising residents. Medical students do not impact attending physician productivity. The discussion highlights how these effects impact the multiple stakeholders in medical education and offers several considerations for future research on this topic.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This research was supported (in whole or in part) by HCA Healthcare and/or an HCA Healthcare-affiliated entity. The views expressed in this publication represent those of the author(s) and do not necessarily represent the official views of HCA Healthcare or any of its affiliated entities. There are no other conflicts of interest or sources of funding to declare.

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Telemedical Direction to Optimize Resource Utilization in a Rural Emergency Medical Services System

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Section Editor: Scott Goldstein, DO
Submission history: Submitted August 11, 2023; Revision received April 23, 2024; Accepted June 17, 2024
Electronically published August 27, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18427

Background: Telemedicine remains an underused tool in rural emergency medical servces (EMS) systems. Rural emergency medical technicians (EMT) and paramedics cite concerns that telemedicine could increase Advanced Life Support (ALS) transports, extend on-scene times, and face challenges related to connectivity as barriers to implementation. Our aim in this project was to implement a telemedicine system in a rural EMS setting and assess the impact of telemedicine on EMS management of patients with chest pain while evaluating some of the perceived barriers.

Methods: This study was a mixed-methods, retrospective review of quality assurance data collected prior to and after implementation of a telemedicine program targeting patients with chest pain. We compared quantitative data from the 12-month pre-implementation phase to data from 15 months post-implementation. Patients were included if they had a chief complaint of chest pain or a 12-lead electrocardiogram had been obtained. The primary outcome was the rate of ALS transport before and after program implementation. Secondary outcomes included EMS call response times and EMS agency performance on quality improvement benchmarks. Qualitative data were also collected after each telemedicine encounter to evaluate paramedic/EMT and EMS physician perception of call quality.

Results: The telemedicine pilot project was implemented in September 2020. Overall, there were 58 successful encounters. For this analysis, we included 38 patients in both the pre-implementation period (September 9, 2019–September 10, 2020) and the post-implementation period (September 11, 2020–December 5, 2021). Among this population, the ALS transport rate was 42% before and 45% after implementation (odds ratio 1.11; 95% confidence interval 0.45–2.76). The EMS median out-of-service times were 47 minutes before, and 33 minutes after ($P = 0.07$). Overall, 64% of paramedics/EMTs and 89% of EMS physicians rated the telemedicine call quality as "good."

Conclusion: In this rural EMS system, a telehealth platform was successfully used to connect paramedics/EMTs to board-certified EMS physicians over a 15-month period. Telemedicine use did not alter rates of ALS transports and did not increase on-scene time. The majority of paramedics/EMTs and EMS physicians rated the quality of the telemedicine connection as "good." [West J Emerg Med. 2024;25(5)777–783.]

INTRODUCTION

Telemedicine has improved healthcare delivery and outcomes for rural populations.[1–5] As rural communities across the United States (US) struggle to recruit, train, and retain paramedics and emergency medical technicians (EMT), these commuities are left with a shortage of qualified individuals to provide healthcare and an increased cost to deliver that care.[6–9] Telemedicine for emergency medical services (EMS) may be particularly useful in rural communities that face paramedic shortages.[2–4]

With paramedic shortages, many rural EMS agencies often depend on a lone paramedic to serve their community. In this setting, when two 911 calls overlap, the rural community is left without Advanced Life Support (ALS) coverage. This gap in ALS service is particularly important in the care of patients with chest pain. For example, assume an ALS transport is needed in a rural community and the sole paramedic is taken out of the service area for hours. Then assume that during that same period, a second 911 call for chest pain occurs. For that second call, the community is left with only a Basic Life Support (BLS) responder who cannot interpret electrocardiograms (ECG). In this scenario either a helicopter is called, increasing cost of service delivery, or the patient is transported emergently by BLS responders, increasing risk to both the EMTs and the patient. Clearly, in this scenario there is the potential for a telemedicine physician to reduce some of the burden placed on resource-limited communities.

However, we found that some EMS systems are reluctant to implement these programs for a variety of reasons. Paramedics shared concerns that a physician's policy of mandating ALS transport for all patients might lower the physician's liability at the expense of increasing the number of ALS-required transports. Others were concerned that performing a telemedicine visit would take a significant amount of time, thus further reducing availability of ALS resources. Finally, there were also some concerns about the lack of access to cellular data and whether the telemedical solution would be available when needed.

These potential barriers are important to evaluate prior to widespread implementation of EMS telemedicine solutions. To evaluate the benefits and potential risks, a rural EMS telemedicine pilot project was implemented targeting patients with chest pain. Throughout that pilot project, program partners collected quality improvement (QI) data to ensure that the telemedicine program was functioning as designed and did not adversely affect system performance. Our aim in this analysis was to evaluate quality data points and assess the impact of telemedicine on EMS management of patients with chest pain; we also evaluated perceived barriers by EMS staff.

Population Health Research Capsule

What do we already know about this issue?
Telemedicine remains underused in rural EMS systems, with concerns about increasing ALS transports, extending on-scene times, and connectivity issues.

What was the research question?
How does implementing telemedicine in rural EMS affect patient management and system performance for chest pain cases?

What was the major finding of the study?
Telemedicine did not change ALS transport rates (42 vs. 45%, OR 1.11, 95% CI 0.45–2.76) or increase on-scene times (47 vs. 33 minutes, p = 0.07), and 64% of EMS staff rated call quality good.

How does this improve population health?
Telemedicine allows rural EMS to maintain ALS availability, reducing strain on limited resources and potentially improving outcomes for chest pain patients.

METHODS

Study Design

This study was a retrospective review of data collected by a single EMS agency throughout the project. We collected data for the primary purpose of QI and evaluation of the telemedicine platform. STROBE methodology was used.[10] We used two datasets for this retrospective review. Firstly, we looked at quantitative data from a prehospital QI dataset in which a 12-lead ECG was performed. Secondly, we analyzed the primary chief complaint of chest pain. Cases from that QI dataset were included in this analysis if they occurred during the 12-month pre-implementation study period or the 15-month post-implementation period. We also evaluated qualitative data from a second QI dataset that was completed by paramedics/EMTs and EMS physicians after each telemedicine platform use. That dataset contained the paramedic/EMT and EMS physicians' subjective evaluation of the telemedicine call quality.

Study Setting

The AzQuality project served as a pilot initiative designed to establish a telemedicine service, enabling rural paramedics and EMTs to access urban medical resources during emergency care for patients experiencing chest pain who dialed 911. The EMS telemedicine pilot was implemented at a single, rural EMS agency. At the time of introduction and during new employee orientation, both EMTs and paramedics were taught how to use the telemedicine system via a brief lecture and a hands-on practice session. After

implementation, EMTs and paramedics were instructed to use the Telemedicine tool to contact board-certified EMS physicians for patients experiencing chest pain 24 hours a day, 7 days a week. They could also use the tool for other encounters as needed. Telemedicine services were provided by board-certified EMS physicians from a single, large EMS physician group.

The telemedicine pilot program was implemented by the Sonoita-Elgin Fire District, a rural EMS agency and sole 911 responding agency for a large, geographically diverse area in Southeastern Arizona. The GD "e-Bridge" communication platform (General Devices LLC, Ridgefield, NJ) was selected by the program leadership group as the telemedicine platform for this pilot program. This software allowed paramedics/EMTs to conduct the telemedicine visit as well as transmit photos of ECGs or other clinical data to the EMS physicians. The e-Bridge system was operated on commercially available smartphones.

Prior to and during the pilot project, when available, paramedics responded to all 911 calls. When unavailable, BLS crews would respond alone. Both paramedics and EMTs were asked to use the telemedicine system any time they encountered a patient with chest pain. After EMT or paramedic patient assessment, the EMS physician was contacted via e-Bridge and given a brief patient presentation. The EMS physician had access to the patient's vital signs and 12-lead ECG through the e-Bridge software. After a brief interaction with the patient, the physician risk-stratified patients as low, moderate, or high risk for adverse events during transport to definitive care. The paramedics/EMTs were then given online medical direction for ground transport by BLS for low-risk patients, ALS ground transport for moderate-risk patients and helicopter EMS transport (HEMS) of patients who were felt to be at high risk for adverse events during transport.

Outcome Measures

The primary outcome of this retrospective review was the rate of BLS, ALS, and HEMS transport. Secondary outcomes (Table 1) included EMS system service delivery times and subjective evaluation of how well the interaction went (good, fair, poor). The EMS service delivery times were collected from EMS agency computer-aided dispatch systems. Subjective data on the overall system performance and telemedicine platform call quality were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at the University of Arizona. REDCap is a secure, web-based software platform.[11,12] A survey was also launched immediately after each telemedicine encounter. Basic call data (data and time) was then used to link the subjective telemedicine platform evaluation to EMS call data.

Data Analysis, Regulatory Approval and Role of Funding

The EMS agency and its medical director provided deidentified QI data for the purpose of review for this analysis. Simple descriptive statistics summarized the results. The University of Arizona Institutional Review Board approved the review of this project's QI data analysis and publication. The Rural Health EMS Flex Supplement grant from the federal Health Resources and Services Administration (HRSA-19-095) funded this project. Funding was used for project training, implementation and QI, but not for reporting on the project. The funding agency was not involved in 1) designing or conducting the study; 2) collecting, managing, analyzing, or interpretating the data; 3) preparing, reviewing, or approving the manuscript; or 4) deciding to submit the manuscript for publication.

RESULTS

Program Information and Demographics

The telemedicine pilot program was initiated on September 10, 2020. There were 58 cases for which the telemedicine platform was used. Quality improvement data for patients with chest pain or for whom a 12-lead ECG had been obtained were analyzed 12 months prior to telemedicine implementation (September 9, 2019–September 10, 2020), and 15 months after implementation (September 11, 2020–December 5, 2021). During the pre-implementation period, the EMS agency had a total of 326 medical calls. During the post-implementation period, there were 411 calls. There were

Table 1. Secondary outcomes in study of telemedicine use by first responders in rural Arizona.

Secondary outcome	Definition
Total unit out-of-service time	Time from dispatch to when the transporting unit becomes available.
Response time	The interval from dispatch to arrival on scene.
On-scene time	Duration from arrival on scene to either the initiation of transport or the point at which the patient refuses transport or the unit becomes available without transport.
Transport time	Time from the initiation of transport to when the unit is again available.
Responder/clinician experience	Subjective experience of paramedics/EMTs and EMS physicians using the telemedicine system rates as poor, fair, or good.

EMT, emergency medical technician; *EMS*, emergency medical services.

Table 2. Demographics and chest pain call quality improvement benchmark performance.

	Pre-implementation	Post-implementation	*P*-value (p) or odds ratio (OR) with 95% confidence interval (95% CI)
Number of 911 calls	38	38	
Mean age	72	75	$P = 0.34$
Gender, female	39% (n = 15)	53% (n = 20)	1.70 (0.69–4.24)
Ethnicity			
% White	82% (n = 31)	74% (n = 28)	0.63 (0.21–1.89)
% Non-White	11% (n = 4)	24% (n = 9)	4.02 (1.09–14.84)
% Unknown	8% (n = 3)	3% (n = 1)	0.31 (0.03–3.09)
Benchmark performance			
3-lead acquired	100% (n = 38)	97% (n = 37)	0.33 (0.01–8.23)
12-lead acquired	97% (n = 37)	97% (n = 37)	1.00 (0.06–16.59)
Aspirin administered	45% (n = 17)	42% (n = 16)	1.11 (0.45–2.76)
Nitroglycerin administered	21% (n = 11)	18% (n = 7)	1.80 (0.61–5.30)
O_2 administered	37% (n = 14)	37% (n = 14)	1.00 (0.40–2.48)
Primary impression			
Chest pain	76% (n = 29)	79% (n = 30)	0.91 (0.29–2.82)
Palpitations	11% (n= 4)	13% (n = 5)	1.29 (0.32–5.22)
Difficulty breathing	5% (n = 2)	3% (n = 1)	2.06 (0.18–23.68)
Hypertension	5% (n = 2)	3% (n = 1)	2.06 (0.18–23.68)
Abdominal pain	3% (n = 1)	3% (n = 1)	1.00 (0.06–16.59)

O_2, oxygen.

38 chest pain cases in the pre-implementation QI dataset and 38 cases during the post-implementation period.

After implementation of the telemedicine program, 24 (63%) patients eligible for telemedicine consultation received telemedicine services in real time, compared to two (5%) patients in the pre-implementation period. Pre-implementation patients received real-time online medical direction by either phone or radio. During the entire 15-month project, paramedics/EMTs used the telemedicine system 58 times. Outside the primary use for patients with chest pain, other uses included various complicated medical and medicolegal situations in which the paramedic/EMT would have normally called by phone or radio for online medical direction.

The demographic and quality benchmark data collected as part of the pilot program is illustrated in Table 2. The pre-implementation chest pain patient mean age was slightly lower at 72 years old (interquartile range [IQR] 55–80) than the post-implementation patients mean of 75 (IQR 55–80). The percent of non-White ethnicity (identified by paramedic) increased from 11% in the pre-implementaion cohort to 24% in the post-implementation cohort. The EMS agency medication administration rates and ECG acquisition rates were essentially the same.

Primary Outcome

Overall, there was a slight reduction in BLS transports and slight increase in ALS transports, although these did not achieve statistical significance (see Table 3). There was also a non-significant increase in HEMS transport rates in the implementation group. Lastly, there was a non-significant reduction in patient refusal.

Table 3. Disposition of patients included in the chest pain quality improvement dataset.

Mode of transport	Pre-implementation percent (n)	Post-implementation percent (n)	Odds ratio	95%CI	*P*-value
BLS transports	8% (3)	5% (2)	0.65	0.10–4.12	0.65
ALS transports	42% (16)	45% (17)	1.11	0.45–2.76	0.82
HEMS transport	16% (6)	29% (11)	2.17	0.71–6.65	0.17
Refusal	24% (13)	21% (8)	0.51	0.18–1.43	0.20

BLS, Basic Life Support; *ALS*, Advanced Life Support; *HEMS*, helicopter emergency medical service; *CI*, confidence interval.

Secondary Outcome – EMS System Performance

The EMS agency response and transport times did not change significantly following implementation (see Table 4). Median out-of-service time was 127 minutes (IQR 49–172) before and 95 minutes (IQR 52–159) after implementation. This total out-of-service interval included a median response time of 11 minutes (IRQ 1–19) in the pre-implementation cohort and 13 minutes (IQR 7–16) post-implementation. Median on-scene time was 27 minutes (IQR 21–61) in the pre-implementation group and 28 minutes (IQR 20–29) post-implementation. Among those patients who were transported, median transport time was 124 minutes (IQR 49–172) before and 90 minutes (IQR 14–141) after implementation.

Secondary Outcome – Performance of Telemedicine Platform

Following implementation, QI data were collected from the caller/call recipients for 35 of 58 (60%) calls. In post-call surveys completed by paramedics/EMTs, the call quality was noted to be "good" or "fair" in 86% of the calls. The EMS physicians judged 98% of the calls to be "good" or "fair." Connectivity issues were identified as concerns more often by paramedics/EMTs than by EMS physicians (see Table 5).

DISCUSSION

While larger EMS agencies have adopted telemedicine services to improve the breadth of services provided to their communities (eg, MDAlly, ETHAN project),[13–15] rural EMS agencies have been slower to adopt these services due to limited access to high-quality telecommunication systems and low utilization rates.[16,17] Increasingly, platforms such as AT&T's "FirstNet" and Verizon's "Frontline" have become more accessible to rural EMS systems.[18,19] These systems provide high-speed data services and prioritize first-responder communications in times of high system usage.[17,20,21] With these tools now available to rural EMS agencies, it is important to evaluate the impact that telemedicine programs have on these systems.

In this retrospective review, a rural EMS telemedicine system was used 58 times during the 15-month pilot project for patients with a variety of out-of-hospital medical emergencies. Overall, the telemedicine system functioned well with 89% of EMS physicians and 65% of paramedics/EMTs rating the technical quality of the telemedicine encounter as "good." Of note, the use of any form of online medical direction increased dramatically to 63% in the post-implementation phase in comparison to 5% in the pre-implementation phase.

Our primary goal in this study was to evaluate the impact of telemedicine service on the care of patients with chest pain and determine whether telemedicine might change mode of transport (BLS vs ALS vs HEMS) to the closest hospital with percutaneous intervention capabilities. The ultimate goal was to allow ALS responders to stay in the community and increase the amount of time ALS service was available. In this retrospective analysis, we found no statistically significant difference demonstrated in the BLS/ALS transport rates after the telemedicine program was implemented despite a goal of increasing BLS transports. There are several possible reasons that no change in transport rates was observed. Primarily, the small patient-sample size

Table 4. Emergency medical services system utilization times.

	Pre-implementation	Post-implementation	*P*-value
Response time (minutes)			
Mean	11	11	0.96
90th percentile	24	20	
On-scene time (minutes)			
Mean	47	33	0.07
90th percentile	101	61	
Transport time (minutes)			
Mean	114	98	0.54
90th percentile	156	178	
Total EMS call time (minutes)			
Mean	113	105	0.61
90th percentile	194	196	

EMS, emergency medical services.

Table 5. Emergency medical services responder and physician subjective evaluation of telemedicine call quality.

	Paramedics/EMTs, percent (number)	EMS physicians, percent (number)
Completed surveys	62% (36)	60% (35)
Call quality		
Good	64% (23)	89% (31)
Fair	22% (8)	9% (3)
Poor	14% (5)	3% (1)
Connectivity issue		
Any issue	64% (23)	14% (5)
Poor cell signal	6% (2)	3% (1)
Lagging video	6% (2)	6% (2)
Poor sound	3% (1)	0% (0)
Missed call	6% (2)	6% (2)
Other	19% (7)	0% (0)

EMS, emergency medical service; *EMT*, emergency medical technician.

both before and after the intervention limits the ability to detect a change. Moreover, the period following the intervention coincided with the onset of the COVID-19 pandemic, an event that likely increased patient acuity levels as well as the utilization of HEMS transport, given the heightened concern over virus transmission. In this context, ground ambulance transport for long distances may have been considered less safe compared to HEMS, due to the perceived increased risk of COVID-19 exposure, as ground transport times are much longer than HEMS transport times.

During implementation, paramedics/EMTs voiced several concerns about using telemedicine in the rural EMS setting. These included the concern that contacting a physician via the telemedicine platform would increase their on-scene time and overall out-of-service times. In this small cohort, the EMS system on-scene times and out-of-service times were not increased but rather trended toward being shorter. Two factors likely contributed to this finding. First, with multiple responders on scene for most 911 responses, one team member was able to discuss the case with a physician while the rest of the team continued to provide patient care. Second, although not measured as part of this project, telemedicine call duration seemed to be very brief (1–2 minutes) and likely this short encounter did not significantly change a relatively longer EMS on-scene time.

The quality of telemedicine communication was a concern for rural paramedics/EMTs. In this retrospective review we found that self-reported telemedicine system performance was mostly reported as good. Paramedics/EMTs were more likely to have concerns about the telemedicine system than were the EMS physicians. System performance could have been worse in the rural setting due to limited data transfer; in other words, cellular service was more likely to be poor in the rural than urban setting. However, if that had been the case, one would expect both parties to have the same issue. It is also possible that with a large EMS user group and a small EMS physician user group, the EMS physicians were simply more comfortable using the platform and experienced fewer technical issues.

The majority of telemedicine concerns expressed by paramedics/EMTs, and EMS physicians were lagging video and poor cell signal. There were seven instances in which paramedics/EMTs listed "other" issues with the platform, but further information was not available. It would be expected that there would be more telemedicine technical issues on the paramedic/EMT side in rural areas than on the EMS physician side where physician took calls in an urban, academic center.

LIMITATIONS

Limitations included the data collection and implementation of the telemedicine pilot project at a single EMS agency. Additionally, this analysis relied on retrospective review of data collected for the purpose of QI. These two factors introduce both the strong possibility of observer bias and reporting bias. Also, the small number of encounters limit statistical analysis and significance. It is possible that not all chest pain patients were included in the QI dataset and missing or included patients created an inclusion bias.

The post-intervention study period coincided with the COVID-19 pandemic. The massive psycho-social changes that occurred during this period almost certainly impacted the community in which this pilot program was conducted. Unfortunately, the impact of the pandemic on this dataset is unknown; however, the unfortunate timing likely introduced a confounder into our results. Finally, the EMS agency participating in this project was highly engaged and motivated, as demonstrated by high performance on EMS benchmarks. It is possible that it was difficult to detect a change in system performance due to both the low call volume and the high-quality patient care already provided by the EMS agency.

CONCLUSION

In this rural EMS system, a telehealth platform was successfully used to connect paramedics/EMTs to board-certified EMS physicians over a 15-month period for 58 patients. Among those patients with chest pain, the use of telemedicine did not result in any change in the rate of ALS transports or increase on-scene times. Overall, paramedics/EMTs and EMS physicians rated the quality of the telemedicine connection as good. Future studies could expand upon this work by exploring larger patient populations and diverse clinical conditions to further establish the efficacy of telemedicine in rural EMS settings. Additionally, examining long-term patient outcomes and cost effectiveness could provide more insight into the sustained impact of telehealth interventions on rural emergency care.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Portions of this work were supported by the Health Resources and Service Administration (HRSA) Medicare Rural Hospital Flexibility Program – Emergency Medical Services Supplement; Arizona Rural EMS Advanced Telemedicine Demonstration Initiative (AzREADI); HRSA-19-095. There are no other conflicts of interest or sources of funding to declare.

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Impact of Prehospital Ultrasound Training on Simulated Paramedic Clinical Decision-Making

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Section Editor: Scott Goldstein, DO
Submission history: Submitted August 21, 2023; Revision received March 8, 2024; Accepted March 22, 2024
Electronically published June 28, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18439

Introduction: When used appropriately, focused limited-scope ultrasound exams could potentially provide paramedics with accurate and actionable diagnostic information to guide prehospital decision-making. In this study we aimed to investigate the impact of a 13-hour prehospital ultrasound training course on the simulated clinical decision-making of paramedics as well as their ultrasound skills, knowledge, and self-confidence.

Methods: We evaluated the ultrasound competence of 31 participants using post-course written and practical assessments. Written clinical decision scenarios were administered pre- and post-training. Post-training scenarios included an uninterpreted ultrasound clip to aid decision-making. Scenarios included extended focused assessment with sonography in trauma, pulmonary exam, and focused echocardiography combined with carotid pulse check exams. Correct answers to scenarios were defined as those selected by a veteran emergency physician. Participants also indicated their confidence in each of their decisions using a Likert scale.

Results: Training yielded a statistically significant increase in both mean scenario score (35.5% absolute increase) and mean participant self-confidence (15.8% relative increase), across all exam/decision types assessed ($P \leq 0.001$). The focused pulmonary exam yielded the largest increase in both mean score improvement (59.7% absolute increase) and paramedic confidence in their decisions (28.6% increase).

Conclusion: Trained paramedics can perform focused ultrasound exams and accurately interpret and apply actionable exam findings in the context of written scenarios. Analysis through our model characterized the theoretical clinical yield of each prehospital ultrasound exam and demonstrated how each exam may provide improved decision accuracy in several specific simulated clinical contexts. These results provide support for growing evidence that focused limited-scope ultrasound may be an effective prehospital diagnostic tool in the hands of trained paramedics. [West J Emerg Med. 2024;25(5)784–792.]

INTRODUCTION

Paramedics make critical prehospital treatment and transport decisions that often greatly impact patient outcomes. Appropriate prehospital treatment and receiving facility choices, as well as effective pre-arrival alerts, improve patient outcomes, decrease treatment cost, and reduce

emergency department (ED) crowding.[1–3] The prehospital environment is inherently complex and dynamic and can be resource limited, creating significant barriers to obtaining accurate diagnostic information needed to make appropriate decisions.[4–6] While studies indicate that prehospital lung auscultation is 54% accurate[7] and palpated carotid artery pulse check is 55% accurate,[8] prehospital predictions of hospital care and clinical course are generally inaccurate.[9,10] Diagnostic limitations render decision-making in the field difficult and can negatively impact patient outcomes. (For example, 22% of patients treated with prehospital needle decompression for tension pneumothorax were found to not have a pneumothorax after assessment in the ED.[11])

Integration of advanced diagnostic tools in the prehospital setting has historically been successful in reducing decision barriers and improving outcomes. Use of electrocardiograms improved prehospital diagnostic positive predictive value for acute myocardial infarction from 33% to 93%.[12] Point-of-care ultrasound (POCUS) is an advanced diagnostic tool that has immense potential to improve the accuracy of prehospital decision-making. Limited-scope POCUS is being implemented in emergency medical services (EMS) agencies across the United States and internationally. In 2014, 4.1% of responding EMS medical directors reported use of POCUS by their agencies, and 21.7% were considering future implementation.[13] Common prehospital ultrasound (PHUS) exams include the extended focused assessment with sonography in trauma (eFAST), pulmonary exam, and focused echocardiography during cardiac arrest. When used appropriately, these exams can provide paramedics with accurate and actionable diagnostic information to guide prehospital decisions.[14]

For limited-scope PHUS to be safely implemented, we need a comprehensive understanding of three critical elements: paramedic performance; paramedic interpretation of POCUS exams; and the appropriate application of those exam findings to support prehospital decisions. Previous studies have demonstrated successful exam acquisition and interpretation by paramedics, such as eFAST, with 100% interpretation accuracy in a mean 2.6-minute exam time,[15] lung ultrasound with a sensitivity of 80% and specificity of 72% for detecting pulmonary edema,[16] and 88% accurate image interpretation of echocardiography during cardiac arrest.[17] To our knowledge, no study has examined how POCUS training and education impact a paramedic's ability to appropriately integrate PHUS exam findings into prehospital care in a simulated environment. Training paramedics to appropriately apply findings is essential to safe implementation of these skills in the field.[14] A thorough understanding of how PHUS findings impact decisions about prehospital treatment, receiving facility choice, and pre-arrival alert is needed prior to safe and effective implementation of POCUS in the prehospital setting.

Population Health Research Capsule

What do we already know about this issue?
Appropriate prehospital treatment improves patient outcomes and reduces ED crowding.

What was the research question?
How does focused prehospital ultrasound training and knowledge affect paramedic clinical decisions in a simulated environment?

What was the major finding of the study?
There was a significant increase ($p \leq 0.001$) in both mean scenario score (absolute 35.5%, from 55.1% to 90.6% correct) and mean self-confidence (6.0% absolute from 38 to 44%, 15.8% relative) across all exam/decision typesassessed.

How does this improve population health?
Focused, limited-scope ultrasound exams could provide paramedics with accurate and actionable diagnostic information to guide prehospital decision-making.

We examined how a hands-on PHUS training program impacted accuracy of simulated paramedic decision-making regarding prehospital treatment, receiving facility choice, and pre-arrival alerts using written, clinical decision scenarios administered pre- and post-training. The scenarios included eFAST, pulmonary exam, and focused echocardiography combined with carotid pulse check exams. In this study we also examined the impact of PHUS training and imaging on paramedic self-confidence in their simulated clinical decisions. To add context regarding the effectiveness of the education provided by the PHUS training administered, we also report the performance of the participants on course assessments including a written knowledge exam and scenario-based practical exams.

METHODS

Study Design and Equipment

This was a prospective observational cohort study designed to evaluate the effectiveness of a small-scale, mixed-modality (containing asynchronous digital independent prework, hands-on scanning practice, and clinical application scenarios) training program. The 13-hour course covered limited-scope POCUS exams that were focused specifically on aspects and applications of the exams with relevance to prehospital care. Exams included were the eFAST, focused pulmonary exam, and focused

echocardiography combined with focused vascular exam for Doppler and visual carotid artery pulsatility in cardiac arrest. This study was approved and given an exempt determination by the Institutional Review Board Committee for the Protection of Human Subjects at Dartmouth College (#00032581). Ultrasound machines used in the course sessions included Clarius HD portable ultrasound units (Clarius Mobile Health Corp, Vancouver, BC, Canada), and Butterfly iQ+ (Butterfly Network Inc, Burlington, MA).

Setting and Participants

New Hampshire has a population of 1.39 million with >1,100 licensed paramedics working in the state.[18,19] New Hampshire poses a unique challenge to EMS systems, given its rural geography with often extended travel times to tertiary care centers. Participants in this study were primarily full-time paramedics licensed in New Hampshire. Participants were recruited for two in-person PHUS courses delivered on two different days through advertisement via the New Hampshite Division of Fire Standards and Training and Emergency Medical Services mailing list and website. Participants were given an overview of the study, provided an option to opt-out, and signed written consent forms. Thirty-one participants were enrolled. We collected participant experience-level, demographic, and employment data in a post-training survey.

Course Procedure

The New Hampshire Fire Academy & EMS hosted the course at their training facility in. The was not involved in planning or conducting this study and did not financially support any members of the study team to conduct this research project. The course and its materials (Appendix 2) were assembled, created, overseen, and delivered by a board-certified emergency physician and ultrasound expert who also serves as an EMS medical director in conjunction with paramedics. This physician also selected and trained a small team of instructors with expertise in ultrasound imaging, paramedicine, and ultrasound education to assist him in delivering the course. Course objectives included learning appropriate indications for PHUS, ultrasound transducer manipulation, comfort with the user interface, ability to interpret results from selected POCUS exams, and ability to apply findings to clinical decision scenarios relevant to prehospital care. Specific details regarding course structure, content, and student/instructor ratios can be viewed in Appendix 2.

Prior to the in-person component, participants were provided with three hours of asynchronous education consisting of an introduction to relevant physics, use of ultrasound units, integration of ultrasound into workflow, selected POCUS exams, and cases. The in-person component of the course consisted of short didactic lectures, ample time for hands-on practice using live models, group discussion of cases, and standardized scenarios. Lectures reviewed selected POCUS exams and examples of pathology relevant to prehospital care. An instructor provided guidance and real-time feedback to participants in small groups. Content was reinforced and discussed in a large-group setting using integration questions and polling software.

Measurements

Course Assessments

Participants ended the in-person course by taking a written knowledge test and completing six scenario-based exams covering cardiac arrest, respiratory distress, and trauma in EMS cases as part of a practical exam (Appendix 2). For the practical, participants performed selected POCUS exams on live models in small groups and received predetermined results via uninterpreted ultrasound video clips after successfully completing the exam. Scenario stations were operated by course instructors, and participants received "pass" or "fail" grades based on pre-established criteria for performance, image interpretation, and treatment/transport decisions. Case-based scenarios were completed as a team to simulate the prehospital environment, although each participant had to individually acquire a cardiac, lung, and eFAST exam on a model with normal findings and subsequently interpret a unique ultrasound image with pathology displayed on a computer screen and then apply findings to their treatment and transport plan without input from other team members. The post-course written exam consisted of 24 multiple-choice questions mapped to course objectives (topics covered in written exam questions can be viewed in Appendix 2). A score of ≥80% was set as the passing threshold for the written portion of the post-course exam.

Clinical Decision Scenarios

Prior to receiving educational content, participants were given written clinical decision scenarios (Table 1 and Appendix 1). This instrument was designed to measure the impact of PHUS training and availability of uninterrupted ultrasound images on paramedic clinical decisions. The instrument consisted of 10 vignettes that were intentionally ambiguous, reflecting the reality of prehospital emergency care. Scenarios provided an extensive description of the scene, patient assessment and history of present illness/injury, and were edited by multiple investigators.

Editing investigators included an emergency physician and ultrasound expert who also serves as an EMS medical director; a paramedic with over 20 years of experience in prehospital EMS education; and several paramedics, advanced emergency medical technicians (EMT), and EMT-Bs with field experience. Each scenario included one or more questions about prehospital treatment, receiving facility choice and transport modality, and/or pre-arrival alert. Scenario-based decisions were designed to specifically

Table 1. Clinical decision topics and the type of prehospital ultrasound exam included within each written, clinical decision scenario listed by scenario number. Each scenario number correlates with the number listed in Appendix 1, which shows the complete text of each scenario.

Scenario number	PHUS exam assessed	Scenario type	Clinical decision questions
Prehospital treatment scenarios			
2	eFAST	Trauma	Needle decompression vs no needle decompression in possible pneumothorax
4	eFAST	Trauma	TXA infusion vs no TXA with an unclear bleeding source
3	Focused pulmonary	Respiratory	Treatment of CHF vs COPD
5	Focused pulmonary	Respiratory	Treatment of CHF vs COPD
7	Echo + carotid pulse	Cardiac arrest	Continuation vs termination of resuscitation
8	Echo + carotid pulse	Cardiac arrest	Continuation vs termination of resuscitation
Transport and pre-arrival alert scenarios			
1	eFAST	Trauma	Trauma center vs closest ED, ground vs air transport, pre-arrival trauma alert vs no alert
6	eFAST	Trauma	Trauma center vs closest ED, ground vs air transport, pre-arrival trauma alert vs no alert
9	eFAST	Trauma	Trauma center vs closest ED, ground vs air transport, pre-arrival trauma alert vs no alert
10	eFAST	Trauma	Trauma center vs closest ED, ground vs air transport, pre-arrival trauma alert vs no alert

PHUS, prehospital ultrasound; *eFAST*, extended focused assessment with sonography in trauma; *TXA*, tranexamic acid; *CND*, chest needle decompression; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *ED*, emergency department; *POCUS*, point of care ultrasound.

map to an associated element of the New Hampshire EMS protocols.

Participants also indicated their confidence in their decisions using a 1–5 Likert scale. Post-training, participants were given the same instrument, with the addition of an uninterpreted ultrasound clip that could be feasibly acquired in the field as a decision aid in each scenario. Correct answers were defined as those selected by a veteran emergency physician with expertise in both POCUS and EMS, who reviewed each clinical decision scenario with and without the associated ultrasound clip to establish the correct decisions for each scenario regardless of availability of ultrasound images. For scenarios where transport to a trauma center was indicated as correct, ground and air ambulance transport to a trauma center were both considered as correct answers to reduce scenario-based error around air ambulance availability, weather conditions, and specific location, etc. (Appendix 1).

Data Analysis

We calculated descriptive statistics for categorical variables as frequencies with their respective percentages. Pre- vs post-score improvement was expressed in percentages; however, all assessments for association performed on the pre vs post were performed using paired *t*-tests on the actual scores. We evaluated normality assumptions in a preliminary evaluation of the distribution of the score and confidence variables using graphical methods (boxplots and histograms); no major concerns with meeting the normality assumptions were observed. We used non-parametric Wilcoxon rank-sum tests for pre vs post confidence-assessments scores. This was to accommodate for Likert scales used. Confidence assessments are expressed as sums and are displayed with their respective interquartile ranges. Associations to previous experiences with ultrasound were assessed through linear models where previous experience was coded as a categorical variable. Preliminary power analysis was not performed because participants were recruited via convenience sampling. We performed all analyses using SAS/STAT v.9.4 (SAS Institute Inc, Cary, NC). Significant differences were declared at $P \leq 0.05$, although exact *P*-values are presented.

RESULTS

Participant Demographics

Of the 31 participants in this study, 30 completed the demographics survey (Table 2). A majority of the participants came from fire departments or private EMS agencies serving rural areas or small towns. A majority of paramedics were highly experienced with >63% having more than 16 years in EMS. Nine of the 30 paramedics reported having prior ultrasound experience in some capacity, three of whom described their training as specific to PHUS. Prior ultrasound experience consisted of vascular access training

Table 2. Participant demographics and employment context survey. Participant-reported data regarding their prior experience working in emergency medical services and with ultrasound imaging.

Category	Frequency (%) N = 30*
EMS agency type	
Fire department	17 (56.7)
Private organization	4 (13.3)
Hospital	8 (26.7)
Air medical	1 (3.3)
Primary service provided	
911 with or w/o transport capability	21 (70.0)
Interfacility transport	1 (3.3)
Equal mix of 911 and interfacility transport	6 (20.0)
Clinical services	1 (3.3)
Mobile integrated healthcare and community paramedicine	1 (3.3)
Years of EMS experience	
>21 years	16 (53.3)
16–20 years	3 (10.0)
11–15 years	5 (16.7)
8–10 years	3 (10.0)
5–7 years	3 (10.0)
Size of community served	
Rural (<2,500)	5 (16.7)
Small town (2,500–24,999)	19 (63.3)
Medium-size town (25,000–74,999)	6 (20.0)
Prior ultrasound experience	
Received prior training–any capacity	6 (20.0)
Received prior training-specifically for EMS use	3 (10.0)
No prior training	21 (70.0)
Prior ultrasound use on the job	
Prior use–any capacity	4 (13.3)
Prior use–specifically in EMS job	2 (6.7)
No prior use	24 (80.0)

*30 of the 31 study participants are represented, (One participant did not complete the employment context survey.)
EMS, emergency medical services.

for all but two participants who reported more in-depth prior training. During analysis no significant associations were found between participants' prior ultrasound or EMS experience and performance on course assessment or written clinical decision scenarios.

Course Assessments

Of the 31 (87.1%) participants, 27 obtained a passing grade on the written post-course exam. The cohort average score was 92.2%, with a range of 62.5–100%. The scenario-based practical exam had a 100% pass rate.

Clinical Decision Scenarios

Data depicting the comparison of the pre- and post-course written, clinical decision scenarios are shown in the Figure. The addition of PHUS imaging yielded a statistically significant increase in both mean score and mean participant self-confidence across all PHUS exam types and decision types assessed by this instrument ($P \leq 0.001$). The pulmonary exam yielded the largest increase in both mean score improvement (59.7%) and paramedic confidence in their decisions (28.6%). The smallest increases in improvement were observed in the echo/carotid pulse exam categories at 29% and 12.5%, respectively. When comparing changes in prehospital treatment, transport, and receiving facility decisions, the largest increase in mean score and confidence was seen in prehospital treatment choices.
Of the 14 scenario questions answered by all 31 participants (434 unique answers), 168 answers (38.7%) were changed from incorrect to correct with the aid of ultrasound images.

Previous Participant Ultrasound Experience

Participant previous experiences with ultrasound are presented in Table 2. Only 9 of 30 participants reported having any type of previous experience using or being trained with ultrasound imaging and only two individuals reported having used ultrasound on the job before participation in this study. We used linear models to look for associations between any type of prior experience with ultrasound that a participant had, and their performance on study assessments; however, no associations were detected for any of the previous ultrasound experience-types reported.

DISCUSSION

Course Assessments

The post-course written test evaluated participant mastery of the course objectives; 87.1% of participants passed the test with an average score of 92.2%, demonstrating that the course educated paramedics in basic theory, knowledge, and interpretation of the three, goal-directed, limited window PHUS exams. This result supports a growing body of evidence that 1–2 days of instruction across a variety of instructional modalities and exam types is largely adequate for paramedics to achieve competency with limited scope PHUS exams.[17,20–23]

The practical test evaluated participant psychomotor skills, as well as the ability to integrate PHUS into EMS workflow, accurately interpret exams, and appropriately apply findings in real time. One hundred percent of participants passed the practical, demonstrating that the course successfully trained paramedics to acquire, interpret, and integrate PHUS into practical EMS scenarios. This

A. Scenario Category	Mean Pre-course Score	Mean Post-course Score	Mean Score Improvement	Pre vs Post *P*-value	Pre-course Confidence Sum (IQR)	Post-course Confidence Sum (IQR)	Mean Confidence Improvement	Pre vs Post *P*-value
All Scenarios	55.07%	90.55%	35.48%	2.94E-11	38 (31-40)	44 (42-47)	15.79%	7.42E-05
By Exam Type								
eFAST	57.43%	89.68%	32.26%	1.43E-09	22 (20-24)	26 (24-28)	18.18%	0.00042
Lung	29.03%	88.71%	59.68%	8.27E-08	7 (6-8)	9 (8-10)	28.57%	0.00003
Echo/Carotid Pulse	69.36%	98.39%	29.03%	2.97E-06	8 (6-9)	9 (8-10)	12.50%	0.00089
By Decision Type								
Treatment	46.23%	89.78%	43.55%	4.46E-11	23 (19-24)	27 (24-29)	17.39%	0.00025
Receiving Facility Choice	59.67%	94.35%	34.68%	2.81E-07	15 (12-16)	17 (16-19)	13.33%	0.00034
Receiving Facility Alert	63.71%	88.71%	25.00%	5.02E-05	15 (12-16)	17 (16-19)	13.33%	0.00034

B. Clinical decision scenarios-decision change Pre vs Post-course for all scenarios	Frequency (%)
Incorrect → Correct	168 (38.71)
Correct → Correct	226 (52.07)
Correct → Incorrect	14 (3.23)
Incorrect → Incorrect	26 (5.99)

Figure. Changes in paramedics' simulated clinical decision-making and self-confidence following training.
Panel A depicts the mean improvement in both mean score and participant self-confidence associated with each written clinical decision scenario (Table 1 and Appendix 1). Scores are sorted by specific prehospital ultrasound (PHUS) exam type and clinical decision type. Panel B reports how aggregate participant responses to all 10 scenarios changed with regard to correctness when they had access to uninterpreted PHUS images as a decision aid. All changes are highly significant at $P \leq 0.001$.
IQR, interquartile range; *eFast*, extended focused assessment with sonography in trauma.

supports previous evidence that paramedics can acquire and interpret PHUS images in the field.[15–17,24]

Clinical Decision Scenarios

The written clinical decision scenarios used in this study present a novel way to evaluate the impact of PHUS on paramedic decision-making in a risk-free manner. The pre-course scenarios did not include ultrasound images and required the paramedic to make difficult and potentially ambiguous decisions based on history, physical exam, and conventional diagnostics alone, accurately mimicking the difficulty of real decisions made on shift. Many studies have shown the inaccuracy of conventional prehospital diagnostics and highlight the difficulty in predicting patient condition and disposition based on prehospital history and physical exam alone.[1,5–10] Access to uninterpreted, raw ultrasound clips that the participants were trained to acquire and could feasibly obtain in the field yielded a statistically significant increase in correct decision making in every category evaluated, including treatment, transport, and pre-arrival alert. Mean scores also increased significantly in all types of PHUS exams evaluated (Figure). Despite potential sources of error described above, these results provide a compelling theoretical framework to analyze how PHUS may impact paramedic decisions.

Focused Pulmonary Exam

Access to focused pulmonary ultrasound across respiratory distress scenarios (3 and 5) improved decision accuracy in prehospital treatment by 59.7% and confidence by 28.6% (Figure). Scenarios 3 and 5 required participants to determine whether to follow the congestive heart failure (CHF) or chronic obstructive pulmonary disease (COPD) treatment protocols in a patient in respiratory distress of unclear etiology suspected to have CHF vs COPD. Access to uninterpreted PHUS significantly improved these decisions. This result supports existing data that paramedics can accurately interpret lung ultrasound in the setting of pulmonary edema.[16] It also indicates that in the unclear circumstance of a respiratory distress patient where CHF vs COPD is suspected, focused pulmonary ultrasound may provide improved accuracy of paramedic working diagnosis, increased confidence, and accuracy of prehospital treatment in this specific clinical setting. The ability of paramedics to appropriately apply findings to support simulated decisions indicates that the improved diagnostic accuracy of pulmonary ultrasound in undifferentiated dyspnea demonstrated outside the US may also be applicable in the prehospital context within the US.[25]

Extended Focused Assessment with Sonography in Trauma

Access to eFAST images in trauma (scenarios 1, 2, 4, 6, 9, 10) improved overall decision accuracy by 32.3% and confidence by 18.2% (Figure). This result theoretically supports previous studies that paramedics can accurately interpret an eFAST exam.[15,24] It also indicates that eFAST may improve paramedic accuracy in determining the appropriate transport method and receiving facility type in complex trauma patients. Similarly, eFAST may improve the accuracy of needle decompression in this specific clinical setting, which may help to reduce the demonstrated incidence of unnecessary prehospital needle decompression, as well as

improve the appropriate use of tranexamic acid infusion in unclear circumstances such as when an intra-abdominal bleeding source is not obvious on physical exam.[11]

Focused Echocardiography and Point-of-care Ultrasound (Carotid) Pulse Check

Access to focused echocardiography and POCUS (carotid) pulse check (scenarios 7 and 8) significantly improved mean decision accuracy by 29%, and confidence by 12.5%. Scenarios represented a pulseless electrical activity (PEA) or asystole cardiac arrest case where termination parameters were met by a small margin. Pseudo-PEA was a feasible possibility in scenario 7. Access to PHUS improved the accuracy of appropriate termination of resuscitation in the asystole scenario (8) as well as appropriate continuation of resuscitation in the PEA scenario, which was actually pseudo-PEA as identified by ultrasound exam.

This result demonstrates that paramedics can accurately interpret these exams in the setting of simulated cardiac arrest, supporting existing data on prehospital echocardiography interpretation.[17,24] Additionally, focused echocardiography and carotid pulse check in cardiac arrest may improve paramedic accuracy in determining whether and when termination of resuscitation is appropriate. These results also provide a novel theoretical representation that PHUS may be effective in identifying and acting on prehospital pseudo-PEA cardiac arrest. Lastly, the result demonstrates that access to PHUS in cardiac arrest may improve paramedic confidence in resuscitation decisions, which can often be difficult and stressful.[17]

Although significant, these changes in mean score and confidence are the smallest in magnitude that we observed. This may have been due to increased complexity and difficulty in image acquisition and interpretation of cardiac images as compared to other PHUS exams. Although results demonstrate that paramedics can perform and then interpret and apply simulated findings from a focused vascular exam for presence or absence of carotid pulse as an adjunct to cardiac arrest echocardiography, this is in the context of a purely simulated theoretical environment and does not provide any insight into the clinical validity, utility, or ideal method of carotid pulse check, which remains an area of active study.[26,27]

Integration of Prehospital Ultrasound

As PHUS is implemented, its safety and efficacy will depend on a thorough understanding of how paramedics apply exam findings to prehospital treatment decisions. The current body of evidence has not yet established the clinical yield, benefits, and risks regarding each PHUS exam type. Understanding which exams result in significantly improved accuracy of decisions that lead to an actionable change in prehospital management is a crucial next step. Judicious and precise integration of exams that are proven to have good prehospital yield may have the potential to improve patient care through improved diagnostic accuracy. Conversely, inaccurate application of PHUS test characteristics, incongruence with the overall clinical picture, or imaging resulting in unactionable information may result in poorly applied exam findings with risks such as overtriage, extended assessment time, or deviation from existing standards of care. Analysis of PHUS, like the theoretical model in this study, may help to inform paramedic education and protocols needed to ensure that PHUS findings are applied in a manner that improves decisions and minimizes these potential harms.

LIMITATIONS AND FUTURE DIRECTIONS

This study used a relatively small sample size of 31 participants. It examined participant data across two repeated PHUS courses with identical curricula, the same course director, and similar instructors. There is potential variability between the two course sessions due to uncontrollable factors such as course dynamics or participant interaction or varying prior experience with ultrasound imaging and EMS. The three hours of course assigned prework were completed on the honor system, and the study team could not verify completion of that prework. This course was publicly advertised to paramedics; thus, self-selection bias could have influenced those who participated by attracting paramedics with more experience and advanced training. The clinical decision scenarios were a theoretical framework to simulate real-world prehospital care. As with any such instrument, there are potential sources of error such as variable simulation fidelity and potential misinterpretation of depicted scenes.

The repeated use of the same written clinical decision scenarios before and after intervention without a control group may have introduced potential confounding. Because the post-training scenarios contained additional information in the form of ultrasound imaging, it is difficult to determine whether changes in paramedic accuracy were influenced by repeated assessment, the additional imaging, the training itself, or a combination of these factors. Additionally, some of the clinical decision scenarios are written in a manner that may have flagged the uninterpreted ultrasound image as abnormal. However, the participants were still required to identify the type of positive findings in the image attached to each scenario, and correctly apply that information within the clinical context of each vignette.

Lastly, none of the models possessed pathology; therefore, study participants were not able to scan pathology themselves during the course. Rather, relevant pathological images were covered thoroughly during the didactic sessions of the course. In terms of previous ultrasound experience affecting participant scores, the cohort was limited in its capacity to detect such associations. This could be because of low power due to a small portion of the participant having

previous experience with ultrasound in general or because those effects are small in the large context of this prehospital application.

Further study in the field is necessary to expose paramedics to the typical distractions and suboptimal imaging conditions they will experience in the field to validate these theoretical, scenario-based findings, and to continue classifying the clinical yield and decision support of PHUS, to guide the development of PHUS protocols and best practices. Further study is also needed to characterize PHUS knowledge and skill retention over time.

CONCLUSION

This study showed that with a 13-hour mixed modality training program, paramedics can competently perform focused eFAST, pulmonary, and cardiac arrest ultrasound exams during course assessments. They can also accurately interpret exam findings and apply these actionable findings within a scenario context resulting in a theoretical significant increase in decision accuracy and potential improvement in prehospital care. Decision analysis through our clinical decision scenarios model characterized the theoretical clinical yield of each focused PHUS exam and demonstrated how each exam may provide improved decision accuracy in several specific clinical contexts. These results provide support for growing evidence that focused eFAST, pulmonary, and cardiac arrest ultrasound may be safe and effective prehospital diagnostic tools in the hands of trained paramedics.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. The authors received financial support from the Carmen Pettapiece Student Research Fellowship and the University of New England College of Osteopathic Medicine. There are no other conflicts of interest or sources of funding to declare.

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Use of Long Spinal Board Post-Application of Protocol for Spinal Motion Restriction for Spinal Cord Injury

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Section Editor: Scott Goldstein, DO
Submission history: Submitted June 2, 2023; Revision received April 9, 2024; Accepted May 16, 2024
Electronically published August 27, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18342

Introduction: Historically, prehospital care of trauma patients has included nearly universal use of a cervical collar (C-collar) and long spine board (LSB). Due to recent evidence demonstrating harm in using LSBs, implementation of new spinal motion restriction (SMR) protocols in the prehospital setting should reduce LSB use, even among patients with spinal cord injury. Our goal in this study was to evaluate the rates of and reasons for LSB use in high-risk patients—those with hospital-diagnosed spinal cord injury (SCI)—after statewide implementation of SMR protocols.

Methods: Applying data from a state emergency medical services (EMS) registry to a state hospital discharge database, we identified cases in which a participating EMS agency provided care for a patient later diagnosed in the hospital with a SCI. Cases were then retrospectively reviewed to determine the prevalence of both LSB and C-collar use before and after agency adoption of a SMR protocol. We reviewed cases with LSB use after SMR protocol implementation to determine the motivations driving continued LSB use. We used simple descriptive statistics, odds ratios (OR) with 95% confidence intervals (CI) to describe the results.

Results: We identified 52 EMS agencies in the state of Arizona with 417,979 encounters. There were 225 patients with SCI, of whom 74 were excluded. The LSBs were used in 52 pre-SMR (81%) and 49 post-SMR (56%) cases. The odds of LSB use after SMR protocol implementation was 70% lower than it had been before implementation (OR 0.297, 95% CI 0.139–0.643; $P = 0.002$). Use of a C-collar after SMR implementation was not significantly changed (OR 0.51, 95% CI 0.23–1.143; $P = 0.10$). In the 49 cases of LSB use after agency SMR implementation, the most common reasons for LSB placement were ease of lifting (63%), placement by non-transporting agency (18%), and extrication (16.3%). High suspicion of SCI was determined as the primary or secondary reason for not removing LSB after assessment in 63% of those with LSB placement, followed by multiple transfers required (20%), and critical illness (10%).

Conclusion: Implementation of selective spinal motion restriction protocols was associated with a statistically significant decrease in the utilization of long spine boards among prehospital patients with acute traumatic spinal cord injury. [West J Emerg Med. 2024;25(5)793–799.]

INTRODUCTION

Prehospital care of trauma patients in the United States has historically included the near universal use of spinal immobilization (SI) by prehospital professionals.[1] Traditional SI includes cervical collar (C-collar) application, a long rigid spine board (LSB), securing straps, and head blocks or other rotational support.[1] The historical rationale to maintain this practice assumes safety and efficacy of traditional SI and aims to minimize medicolegal concerns, high morbidity, and cost associated with spinal cord injuries (SCI).[2] Assumptions have been made throughout the years that SI performed in this manner is protective by reducing movement of potential spinal fractures and that the risk of secondary SCI and associated morbidity is mitigated with use of LSB.[2]

Prehospital evidence to support these assumptions is sparse, leaving open to question the supposed benefits.[3–6] Hauswald et al performed a large, retrospective review comparing immobilized and non-immobilized trauma patients and demonstrated lower rates of neurologic injury in patients who were not immobilized on LSBs.[7] Further complicating the use of LSBs is the difficulty in quantifying the actual risks and benefits of SI due to the complex nature of SCI.[8–10] Numerous studies describe the real and potential harms of using rigid LSBs and other traditional practices of SI equipment during the care of acutely injured patients. While LSB use may facilitate extrications in the trauma setting, their use increases morbidity by causing pain and injury, including pressure necrosis, especially in patients requiring long transport times.[11] Furthermore, LSB use has been correlated with an increased number of radiology studies ordered and subsequent radiation exposure to patients, increased hospital cost, inhibition of respiratory function, and increased intracranial pressure.[11–18]

In 2018, a position statement on spinal motion restriction (SMR) was published by the American College of Emergency Physicians, the National Association of EMS Physicians, and the American College of Surgeons Committee on Trauma. This position statement highlighted the need for SMR as the preferred method of reducing spinal motion after an injury and that complete SI is not possible. This position statement helped provide a standard of care for prehospital patients with possible SCI, including language stating that LSBs "should not be used as a therapeutic intervention or precautionary measure."[19] To address this recommendation, the state of Arizona implemented a statewide SMR protocol with the goal of decreasing LSB use in high-risk trauma patients. This protocol (IMAGE) de-emphasized LSBs by recommending that patient time on LSBs be minimized.

In this study we aimed to evaluate rates of LSB use after statewide implementation of this SMR protocol in high-risk trauma patients, whom we defined as having a discharge diagnosis of SCI. This study will inform future research on the effectiveness of SMR protocol implementation and hopefully result in the reduction of secondary injury in patients with SCI. Additionally, we aimed to clarify clinical reasoning used by clinicians in their decision to apply and not later remove a LSB, in contrast to SMR protocol guidance.

Population Health Research Capsule

What do we already know about this issue?
Long spine boards (LSB) have been shown to cause harm. Spinal motion restriction (SMR) protocols aim to reduce LSB use in patients with suspected spinal injury to minimize negative effects.

What was the research question?
We sought to evaluate the rates of and reasons for LSB use in high-risk patients after statewide implementation of a SMR protocol.

What was the major finding of the study?
Statewide SMR protocol implementation was associated with a 70% lower rate in LSB use (OR 0.297, 95% CI 0.139–0.643; P = 0.002).

How does this improve population health?
Implementation of SMR protocols decreases LSB use and, thus, the potential harms resulting using them.

METHODS

Data Sources and Study Population

This was a retrospective, observational, multiagency, prehospital study including cases from January 1, 2013–December 31, 2015 in the Arizona Prehospital Information and Emergency Medical Services Registry System (AZ-PIERS) and the Hospital Discharge Database (HDD). Both data sources are maintained by the Arizona Department of Health Services. The AZ-PIERS dataset, which is managed by the department's Bureau of Emergency Medical Services and Trauma System, is a voluntary patient registry that allows EMS agencies to collect and transmit electronic patient care data to the State. The database includes both required and optional reporting elements in National EMS Information System format. The AZ-PIERS captures agency information, patient demographics, response times, incident location, and treatment. The HDD collects inpatient and emergency department visits from all Arizona licensed hospitals except federal healthcare facilities

such as the Veteran's Administration, Department of Defense, or tribal hospitals.

The EMS transports in AZ-PIERS were linked to the state discharge database using a stepwise deterministic linkage algorithm with direct identifiers (first name, last name, date of birth, Social Security number, gender, date of incident/hospital admission, hospital name). Pre- and post-SMR protocol implementation cohorts were identified based on agency protocol implementation date, excluding a three-month run-in period. For agencies that implemented an SMR protocol during the study period, we reviewed the protocol to verify that critical components of SMR were present. These components included the following: protocol application to patients with traumatic injury; identification of a subgroup of patients very unlikely to have a spinal injury who were subsequently excluded; and restriction of spinal motion without requiring LSB use, meaning that a C-collar, scoop stretcher, vacuum splint, or ambulance stretcher was used. Of note, SMR protocols did require the use of a C-collar and most allowed for the patient to be positioned with the head of the gurney elevated to 30° if the patient did not have pain with elevation for the head of the bed.

Of the cases with matched EMS and hospital data, this study included only patients with a hospital-diagnosed SCI. These patients were included because of the higher risk nature of injury and risk for subsequent secondary SCI. These patients were identified as those with a principal diagnosis of traumatic injury (International Classification of Diseases, 9th and 10th Revisions, Clinical Modification [ICD-9] code 800–959 or [ICD-10] code S00–T34 or T79) mapping into the US Centers for Disease Control and Prevention's ICD-9-CM (Barell matrix) and the proposed framework for ICD-10-CM diagnosis codes for a diagnosis of SCI.[20] For those cases identified, prehospital documentation was reviewed to determine C-collar and LSB use. Cases were excluded if agency SMR implementation date was unknown; encounters were noted to be in duplicate; patients had no trauma in the prior 24 hours; reviewers deemed insufficient documentation to determine method of immobilization; or management involved interfacility transport. The prevalence of both LSB and C-collar use was determined among patients with SCI and compared between the pre- and post-SMR cohorts using simple descriptive statistics including odds ratios (OR) with 95% confidence intervals (CI).

The cases of SCI post-SMR implementation that had LSB placed by prehospital crew were secondarily reviewed by two independent physician reviewers using a qualitative methodology to determine the likely reasons for LSB use. They categorized cases based on what they determined to be the most likely reason for applying a LSB and for not removing it prior to transport. We used simple descriptive statistics to analyze this qualitative analysis, with calculation of kappa statistic to evaluate the reliability of the two raters' determination.

The following possible reasons for initial and continued LSB use were defined a priori:

- To improve the ease of lifting due to the location of the injured patient relative to the ambulance gurney or size of the patient.
- LSB was placed by a non-transporting agency on scene.
- LSB was required for extrication of the patient from a difficult-to-access location.
- Cases in which the reviewers were unable to determine the reason for placing the patient on a LSB.

The following possible reasons for not removing the LSB once in the transport vehicle were defined a priori:

- Documented neurologic symptoms or other documented finding making the patient high probability of having SCI.
- Patient required LSB for multiple transfers from one agency to another for transport purposes.
- Documented medically complicated patient with critical illness, who had altered level of consciousness or was intubated.
- Cases in which the reviewers were unable to determine a clear reason for maintaining LSB immobilization throughout transport.

Human Subjects Committee Review

This study was reviewed by the Arizona Department of Health Services Human Subjects Review Board and approved for publication on March 17, 2016.

RESULTS

There were 1,123,178 EMS transports entered into the AZ-PIERS dataset during the study period, and a total of 1,005,978 (89.6%) were successfully linked to HDD cases. We included 63 EMS agencies with a known SMR implementation status in the analysis. Of these, 52 transitioned to an SMR protocol, resulting in identification of 417,979 EMS encounters in the full study population. From those, we identified a cohort of patients with any diagnosis of spinal trauma, totaling 5,178 encounters. Within this population, 225 unique SCI cases were identified. Narrative reports of those records were examined by two independent reviewers to determine the method of immobilization. Seventy-four cases were excluded from the analysis for being SCI of nontraumatic cause (21), interfacility transfers (11), and those that did not contain enough information to determine the method of immobilization (42). The study group included 151 cases, which were divided into pre- (64 cases) and post-implementation (87 cases) cohorts. (Figure 1)

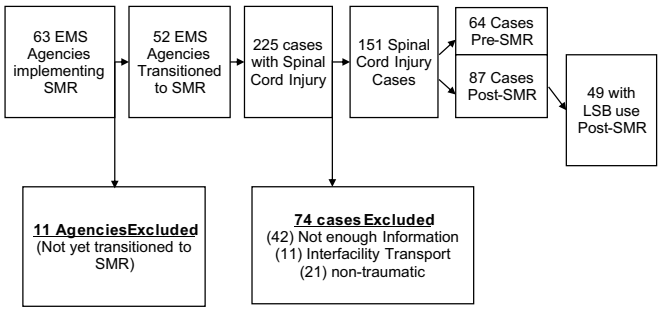


Figure 1. Flowchart of spinal cord injury cases and long spinal board use before and after implemention of a spinal motion restriction protocol.
EMS, emergency medical services; *SMR*, spinal motion restriction.

The distribution of demographic, mechanism/intent of injury, and outcome information were similar between the pre- and post-SMR cohorts as illustrated in Table 1. The results of the primary analysis can be seen in Table 2. Of the 151 SCI cases included, LSBs were used in 52 pre-SMR (81%) and 49 post-SMR (56%) cases. The odds of LSB use after SMR implementation were 70% lower than it was before implementation (OR 0.297, 95% CI 0.139–0.643; $P = 0.002$). C-collar use after SMR implementation was not significantly changed (OR = 0.51, 95% CI: 0.23–1.143; $P = 0.10$).

The secondary analysis identifying reasons for LSB use after SMR protocol implementation are illustrated in Table 3. Of the 49 cases, the most common reasons for LSB placement were as follows: ease of lifting (63%); placement by non-transporting agency (18%); and extrication (16.3%). High suspicion of SCI was thought to be the primary or secondary reason for not removing LSB after assessment in the majority (53%) of cases, followed by multiple transfers required (10%), and critical illness (10%). In 26% of cases, there was not a clear reason for maintaining full

Table 1. Demographics.

	Pre-SMR (N = 1,932)	Post-SMR (N = 3,246)	*P*-value
Median age (Q1, Q3)	70 (48, 83)	70 (50, 84)	0.09
ISS, n (%)			
<15	1,631 (84.4%)	2,715 (83.6%)	0.46
> = 15	301 (15.6%)	531 (16.4%)	
Missing	0 (0.0%)	0 (0.0%)	
Gender, n (%)			
Female	1,072 (55.5%)	1,811 (55.8%)	0.83
Male	860 (44.5%)	1,435 (44.2%)	
Missing	0 (0.0%)	0 (0.0%)	
Race/ethnicity, n (%)			
White	1,557 (80.6%)	2,680 (82.6%)	<0.001
Black	28 (1.4%)	72 (2.2%)	
Hispanic/Latino	232 (12.0%)	373 (11.5%)	
Asian or Pacific Islander	22 (1.1%)	46 (1.4%)	
Native American or Alaskan Native	57 (3.0%)	44 (1.4%)	
Refused/unknown	36 (1.9%)	31 (1.0%)	
Mechanism of injury, n (%)			
Fall	1,015 (52.5%)	1,715 (52.8%)	0.25
Motor vehicle traffic	523 (27.1%)	874 (26.9%)	
Struck by/against	42 (2.2%)	67 (2.1%)	
Cut/pierce	1 (0.1%)	2 (0.1%)	
Overexertion	48 (2.5%)	49 (1.5%)	
Other	224 (11.6%)	351 (10.8%)	
Missing	79 (4.1%)	188 (5.8%)	
Intent of injury, n (%)			

(*Continued on next page*)

Table 1. Continued.

	Pre-SMR (N = 1,932)	Post-SMR (N = 3,246)	*P*-value
Unintentional	1,855 (96.0%)	3,076 (94.8%)	0.91
Suicide	6 (0.3%)	10 (0.3%)	
Homicide	31 (1.6%)	49 (1.5%)	
Other	4 (0.2%)	4 (0.1%)	
Undetermined	36 (1.9%)	107 (3.3%)	
Hospital discharge status, n (%)			
Home	1,028 (53.2%)	1,609 (49.6%)	<0.001
SNF/ALF/rehab/long term	673 (34.8%)	1,312 (40.4%)	
Expired/hospice	68 (3.5%)	142 (4.4%)	
Other	163 (8.4%)	183 (5.6%)	

ISS, Injury Severity Score; *SNF*, skilled nursing facility; *ALF*, assisted living facility; *rehab*, rehabilitation facility.

Table 2. Rates of long spinal board and cervical-collar use pre- and post-implementation of a spinal motion restriction protocol.

	Pre-SMR implementation (n = 64)	Post-SMR implementation (n = 87)	Odds ratio (95% CI)
Patients with LSB placed for transport (%)	52 (81.25)	49 (56.32)	0.297 (0.139–0.643) $P = 0.002$
Patients with C-collar placed for transport (%)	53 (82.81)	62 (71.26)	0.51 (0.23–1.143) $P = 0.10$

LSB, long spinal board; *SMR*, spinal motion restriction; *CI*, confidence interval; *C-collar*, cervical collar.

Table 3. Reasons for long spinal board use in patients with diagnosed spinal cord injury.

Reason for LSB initial placement (n = 49)		Primary reason LSB was not removed prior to transport (n = 49)	
Extrication (%)	8 (16.33)	High suspicion of spinal cord injury (%)	26 (53.06)
Ease of lifting non-ambulatory patient from the ground (%)	31 (63.27)	Required transfer between agencies (%)	5 (10.20)
Placed by non-transporting agency (%)	9 (18.37)	Critical illness (ie, unconscious, intubated) (%)	5 (10.20)
Other (%)	1 (2.04)	Other or unclear reasoning (%)	13 (26.53)

LSB, long spinal board.

spinal precautions throughout transport. There was a strong level of agreement between the raters' determinations of the reasons for LSB placement and reasons for no discontinuation (kappa, 0.8209 and 0.8108, respectively).

DISCUSSION

Results of this study suggest that implementation of a selective SMR protocol, which focused on reducing LSB use, was associated with a statistically significant decrease in but not elimination of LSB use among prehospital patients with acute traumatic SCI. It is notable that there was such a significant decrease in LSB use even in the very highest risk cohort of trauma patients studied here—those with hospital-diagnosed SCI. As expected, the rate of C-collar use was not affected by these protocol changes as the protocol implemented did not make them optional. This data supports that the adoption of SMR protocols by prehospital agencies does lead to decreased rates of LSB use, even in patients with high-risk injuries, and may subsequently reduce the secondary comorbidity associated with these devices.

The use of C-collars did not decline significantly as a result of the protocol changes, as EMS professionals were required to use the device for patients meeting high-risk criteria. This finding was expected given that the SMR protocol requires continued use of these tools to limit spinal motion. The observation that rates of C-collar use did not decrease lends additional support to the conclusion that the SMR protocol resulted in a decrease in LSB use rather than other system-related changes or confounders resulting in this change.

The most practical and least controversial use of LSB in trauma care is for extrication. It does seem that this was a factor in a small number of cases. Similarly, the most common reason for LSB use after SMR protocol implementation (63% of cases where LSBs were used) was that EMS professionals appeared to use the LSB to lift a non-ambulatory patient from the ground to the gurney. Perhaps more controversial is limiting the use of LSB for patients with exam findings suggestive of SCI. In this study, in more than half of cases with LSB placement, clinicians documented a concerning or abnormal neurological exam finding and documented that a LSB had been used due to a possible SCI. In these cases, perhaps improved educational outreach would limit LSB use to the practical need to lift a patient and encourage LSB removal prior to transportation.

In patients who had a LSB placed for their movement to a gurney, frequently no reason was cited as to why the patient was not rolled off the spine board prior to transportation. In some cases, the patient's care required multiple transfers between agencies, or the patient was intubated or had other signs of critical illness or airway compromise, which may have made removing the spine board challenging or simply was not a priority in treatment at the time.

LIMITATIONS

Limitations of this study include the retrospective collection of the data from prehospital EMS documentation. Additionally, the AZ-PIERS database lacks data fields that would have provided specific reasons EMS used a LSB, and limited information was available from the narratives to qualitatively assess why they chose to use a LSB. As mentioned above, the reasons for LSB use were not clear in some of the narratives, and while providing insight into the thought process of the EMS professionals, the narratives may not represent the actual primary motivation for placing and not removing patients from LSBs. Neither were we able to guarantee that each EMS agency implemented their SMR protocol in the same manner. While many of the EMS agencies' selective SMR protocols were reviewed for the presence of certain critical elements, they were not identical; and although standardized educational material was available, the uniformity of the education given to the the EMS professionals could not be evaluated.

CONCLUSION

Prehospital use of a long spinal board in high-risk patients and those with a hospital-diagnosed spinal cord injury, significantly decreased after implementation of spinal motion restriction protocols. Continued use of the long spinal board after SMR protocol implementation appeared to be most common when EMS professionals perceived a practical difficulty or unease with being able to lift, move, and carry injured patients without the use of a LSB. As with all paradigms shifts in policy, it does take time for complete adherence to new practices and procedures. This is where visual feedback and quality improvement programs play a large role, highlighting the need to provide guidance regarding when a LSB should be used and the optimal timing of removing patients from a LSB to minimize complications.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Association of Gender and Personal Choices with Salaries of New Emergency Medicine Graduates

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Section Editor: Mark I. Langdorf, MD, MHPE
Submission history: Submitted August 13, 2024; Revision received August 22, 2024; Accepted August 23, 2024
Electronically published September 9, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.33606

Objective: The medical literature has demonstrated disparities and variability in physician salaries and, specifically, emergency physician (EP) salaries. We sought to investigate individual physician characteristics, including sex and educational background, together with individual preferences of graduating EPs, and their association with the salary of their first job.

Methods: The American College of Emergency Physicians and the George Washington University Mullan Institute surveyed 2019 graduating EPs. The survey included respondents' demographic and educational background, post-training job characteristics and location, hospital characteristics, importance of different personal priorities, and starting salaries. We performed a multivariable regression analysis to determine how salaries were associated with job types and individuals' characteristics.

Results: We sent surveys to 2,192 graduating residents in 2019. Of these, 487 (22.2%) responded, and 270 (55.4%) accepted first-time clinical jobs and included salary data (12.3% of all surveys sent). Male sex, osteopathic training, and full-time work were significantly associated with higher salary. Men and women prioritized different factors in their job search. Women were more likely to consider such factors as parental leave policy, proximity to family, desired practice setting, type of hospital, and desired location as important. Salary/compensation was considered very important by 51.8% of men and 29.6% of women. Men's median salary was $30,000 more than women's ($p = 0.01$, 95% CI +$6,929 – +$53,071), a significant pay differential.

Conclusion: Salaries of graduating emergency medicine residents are associated with the resident's sex and degree type: doctor of osteopathic medicine or doctor of allopathic medicine. Multiple factors may contribute to men having higher salaries than women, and some of this difference reflects different priorities in their job search. Women were more likely to consider job conditions and setting to be more important, while men considered salary and compensation more important. [West J Emerg Med. 2024;25(5)800–808.]

INTRODUCTION

Background

Previous reports have demonstrated disparities and variability in physician salaries and, specifically, emergency physician (EP) salaries by a variety of factors.[1–7] Disparities by sex with men earning more than women is well documented,[3,5–7] but the possible causes of this disparity along with the association of other factors with salary differences is not as well described. We review possible associations with this variability in starting salaries of new EP residency graduates in 2019.

Importance

Graduating emergency medicine resident physicians have personal characteristics that may influence the selection of their very first job. These include personal preferences that influence their job-selection decisions and may impact the final salary of the job they ultimately select. Individuals may have preferences in selecting their job. The choices made by women and men may be different. Unfortunately, very little is known about these factors to guide young EPs as they go through the process of job selection.

Population Health Research Capsule

What do we already know about this issue?
Physician salaries have demonstrated disparities and variability. Multiple factors may be associated with salary differences.

What was the research question?
What factors impact salaries of emergency medicine graduates?

What was the major finding of the study?
Men's median salary was $30,000 more than women's ($p = 0.01$, 95% CI +$6,929 – +$53,071).

How does this improve population health?
This study suggests that the salaries of new EM graduates are impacted by multiple factors including gender.

Goals of This Investigation

We present the results of an analysis of a survey of EPs completing their residency training that included a wide range of questions about the type of jobs they considered, their personal and professional demographics, factors that impacted their job selection decision and, finally, the job that was chosen and resulting salary. Our goal was to describe the association of personal traits and job characteristics with the salary of the first job, including the impact of the graduate's sex. We compared and contrasted the priorities of women and men in their job hunt. We performed a secondary regression analysis to investigate the impact of sex alone on salary, independent of these preferences. By focusing on individuals obtaining their very first job post training, we eliminated the impact of mid-career job changes or job changes for career advancement in assessing the impact of such factors as the EP's sex.

METHODS

Survey Instrument

As part of a larger initiative to study the workforce needs for EPs in the near future, the American College of Emergency Physicians (ACEP) and the George Washington University Mullan Institute fielded a survey to all 2019 graduating EM residents, approximately 4–8 weeks prior to graduation.[8] This study reviewed a subset of graduating EM residents' personal characteristics, educational background, and characteristics of their job choices. We used a multivariable quantile regression analysis to estimate the possible impact of some of these factors on the salaries of their first post-residency clinical job.

The research design and survey were approved by the George Washington University Institutional Review Board. We adapted the survey tool from similar surveys used by the Mullan Institute for studies of other physician specialty graduates and further adjusted it based on feedback from subject experts and pilot-testing among EPs. The survey questions offered a four-point Likert scale (very important, important, of little importance, not important at all), with a not-applicable option, for priority factors in a job. (See Supplementary Material.)

Survey Dissemination

The survey was distributed via email in May and June 2019, approximately 4–8 weeks prior to their graduation, to 2,192 residents within the ACEP database who reported they would complete their training program in 2019. The 2,192 residents represented approximately 97.3% of the 2,253 residents in their final year of training on December 31, 2018, as reported by the American Board of Emergency Medicine.[9] An original email was followed by up to three reminders for non-respondents. As an incentive, 10 gift cards with a value of $150 were distributed randomly to respondents. The online survey used REDCap (Research Electronic Data Capture) software, hosted at George Washington University Mullan Institute.[10]

Outcome and Measures

We collected data including respondents' demographic and educational background, educational debt, post-training jobs, job market experiences, and factors influencing post-

training job plans. We looked at these factors and their association with the salaries of the first job selected by the 270 graduates of EM residencies who had accepted a clinical position post-residency and supplied their base salary.

Statistical Analysis

Physician income is associated with factors such as specialty, sex, race, ethnicity, academic practice, board-certification status, and work intensity.[2–6] The primary statistical analysis involved an overview of these factors.[11] In a secondary analysis we used quantile regression in a multivariable analysis estimating the remaining salary differences by sex when multiple factors were controlled for. Selection of variables for the model was guided by a similar regression analysis in a survey of all US-based ACEP members in which the variables used were chosen to represent income-associated factors including specialty, sex, race, ethnicity, academic practice, board-certification status, and work intensity.[1–7] The variables included in the model were as follows: age; working full vs part time; racial minority status (Black, American Indian or Alaskan Native vs White or Asian); ethnicity (Hispanic vs non-Hispanic); urban vs rural or semi-rural practice (where "urban" means being located in a city of 50,000 or more residents, "semi-rural" refers to "urban clusters" of 2,500 to 49,999 residents as defined for the 2010 census, and "rural" refers to areas with fewer than 2,500 residents); employment in an academic medical center; country of medical school (international medical graduate vs graduate of US and Canadian medical school); medical degree type (doctor of allopathic medicine vs doctor of osteopathic medicine [MD vs DO]); whether working a secondary job; and working for a for-profit vs a non-profit organization.

All respondents were asked to self-define their situation according to the stated criteria. For the regression model we treated the categorical income variable as a point variable by defining annual income as the mid-point of the $10,000 ranges used in the survey questionaire, while age was treated as a continuous (whole number of years) variable. All other variables were dichotomous with values derived from yes/no survey responses, with the exception of whether working for for-profit or non-profit organizations where the response options were yes/no/don't know. To avert the loss of 51 respondents who stated that they did not know the for-profit or non-profit status of their employing organization, the value of this variable for "don't know" respondents was imputed as the mean of the yes/no response value across respondents who did respond yes or no; it was assumed that not knowing for-profit or non-profit organizational status was randomly distributed across both sexes.

Quantile regression is typically used when the assumptions of normal distribution do not hold, as is often the case in salary distributions.[12] This method enabled us to generate results at the lower (25%) and higher (75%) income quartiles of the income distribution as well as at the distribution's center (median). The results of the lower and higher quantile regression analysis are not separately reported as they closely resembled the result at the median. They are available from the authors.

Owing to missing data among the 270 respondents, the final regression analysis included 258 observations. The 13 independent variables used in the model and 258 observations allowed the regression model to adhere to the general overfitting guideline of approximately 20 observations per outcome variable.[11] We carried out a test for overfitting out using the Stata "overfit" command, which reports both in-sample and out-of-sample shrinkage statistics, for each regression result.[13] Data were analyzed using Stata 16[14] (StataCorp, LLC, College Station, TX).

RESULTS

A total of 487 graduating residents returned the survey. Of these, the 270 respondents who accepted first-time clinical jobs and included salary data comprised the group that was analyzed. Three of the 270 respondents who did not identify a binary gender were excluded from the sex-specific analysis. Of the 270 respondents, 258 had complete data that could be analyzed for the regression. Of the 270, 169 (62.6%) self-identified as men, 98 (36.3%) as women, and three (1.1%) preferred to self-describe or not answer. Of 262 who gave their age, 234 (89.3%) were under 36 years old. Of 268 respondents, 211 (78.7%) were White, 35 (13.1%) were Asian, five (1.9%) were Black, and 17 (6.4%) were "other" or more than one race. Of the 270 graduates, 171 (63.3%) had three years of training, 94 (34.8%) had four years and five (1.9%) had ≥5 years.

Compared to ABEM data, the proportion of respondents who reported completing three-year programs was less than the percentage of those completing three-year programs nationally at the end of calendar year 2018 (63.6% vs 70.2%) and skewed more White than EM residents nationally (78.7% vs 63%), and less Black (1.9% vs 4%) than residents in training during 2018–2019.[9] Of 264 respondents with data, 93 (35.2%) had educational debt exceeding $300,000, while the median educational debt was $237,500. Almost three quarters (72.4%) reported "quite a bit" or "a great deal" of salary variability in their job search (Table 1).

Table 1. Perceived variability of physicians' salaries.*

How much salary variability (in terms of total annual income) was there?	Number	Percent
Quite a bit	138	51.5%
A great deal	56	20.9%
Very little or none	51	19.0%
Only got one offer so can't say	23	8.6%
Total	268	100

*268 of the 270 responded to this question.

Multivariable Analysis of Salary Differences

To assess the multiple factors that appeared linked to the salaries earned by newly graduating residents we used a quantile regression analysis to control for many of these factors together at different quantiles of the income distribution. The assessment accounted for both part-time and full-time work. The most statistically significant factor was gender gap, with men making a median $30,000 more than women ($244,200 vs $214,200), followed by DO graduates who made a median $30,000 more than their MD counterparts (median $274,200 for men vs $244,200 for women who are DO graduates), and full-time workers making a median of $43,000 more than those working part-time ($287,349 for men vs $257,349 for women who are full-time workers) (Table 3).

Other factors that were not significant but trended toward a positive impact on salary were non-academic center employment compared to academic and semi-rural/rural compared to urban jobs. Two thirds of graduates accepted jobs at sites in cities despite lower salaries. Men were more likely to accept jobs associated with higher pay in smaller communities, non-academic settings, and smaller hospitals.

Sensitivity analysis included running the model with and without the for-profit variable. With and without imputation of the values of the for-profit variable did not significantly alter the results, which appeared to be robust to minor variations in the model. Similarly, the results did not change substantially between linear regression and quantile regression, likely because the income distribution in this sample appeared to closely follow a normal distribution based on Shapiro-Wilk and Shapiro-Francia tests of normality and Stata's "sktest" for skewness and kurtosis.

Factors Considered by Women and Men in Their Job Search

Respondents rated factors they considered in selecting a job with response options ranging from "very important" to "not important at all." We focused on factors rated as "very important" compared to other responses (excluding "not applicable"), reported in Table 2A, and "very important" and "important" together compared to of "little importance" and "not important," reported in Table 2B. The rationale behind this is that "very important" factors could be considered critical in the job selection decision and their absence could eliminate a possible job, while "important" factors could be considered nice to have and, therefore, only a swing factor in job selection if the "very important" criteria were met. The factors are listed in order of the percent difference of preferences of women over men. Factors at the top of Tables 2A and 2B have the greatest difference in what women considered important compared to men; factors at the bottom are those that men considered more important than women.

Generally, women considered lifestyle and work-life balance factors in their job-seeking choices more than men. Parental leave policy, proximity to family, the practice setting, the type of hospital, and location of the hospital were statistically more often cited by women as "very important" factors, while salary/compensation was statistically more frequently noted for men. When adding "nice to have" "important" factors to the "very important" factors, a different list of priorities was statistically different for women and men. For women, the parental leave policy, meeting visa requirements, the patient population, employment options for the spouse, staying in the same region as the training program, availability of mentors, supportive academic environment, and urban vs rural setting could be considered "nice to have". Salary/compensation was the only factor statistically more important for men than for women.

DISCUSSION

There are many factors associated with the salaries that graduates receive.[1–6] Three factors are statistically significant. The most significant factor resulting in greater pay is the gender gap, followed by a DO degree and, not surprising, that full-time employment pays more than part-time employment.[15] In comparison, a similar recent survey of all ACEP members found sex was significantly associated with base salary but type of degree was not.[1] New osteopathic graduates are reported in other studies to be more inclined to choose positions in non-academic settings in smaller communities, both of which appear associated with higher salaries.[16,17] A predominance of all graduates accepted jobs at sites in cities despite the lower salaries. This is not surprising when considering the "very important" preferences that are summarized in Table 2A.

There are annual surveys of employers that collect data on average salary and compensation by specialty such as the Modern Healthcare Physician Compensation Database and the Medical Group Management Association.[18,19] Most surveys include all jobs for new and experienced physcians in different phases of their careers and usually do not differentiate between type of hospital, hospital site, and other factors that are inherent to their local community. The jobs may have different proportions of clinical and administrative or leadership responsibilities, which may make it difficut to compare between jobs. This ACEP-Mullen Institute survey is unique in that it focused specifically on starting salaries of graduates taking their very first entry-level job. Even for this well-defined type of position, there was "quite a bit" or "a great deal" of variance in the jobs they were offered, (Table 1) as noted by graduates.

A persistent gender gap has been identified in numerous studies, despite many years of attention in many professions, many other specialties; EM appears to be no different.[5,6,7,15,20,21,22] We found a gap attributable to sex

Table 2A. "Very important" factors influencing job selection for men and women* sorted by difference in percent.*

	"Very important" for women			"Very important" for men					
Factor is "very important"	**Freq. women**	**N****	**Percent women**	**Freq. men**	**N****	**Percent men**	**Diff in percent**	**Pearson chi sq**	***P*-value**
Parental leave policy	20	79	25.3	6	142	4.2	21.1	21.7520	<0.001*
Proximity to family	41	93	44.1	42	164	25.6	18.5	9.2653	0.002*
Jobs/practice in desired practice setting	52	98	53.1	68	168	40.5	12.6	3.9591	0.05*
Type of hospital	22	98	22.4	16	164	9.8	12.6	7.9700	0.01*
Jobs/practice in desired location	76	98	77.6	110	167	65.9	11.7	4.03	0.05*
Employment for spouse/partner	26	75	34.7	33	142	23.2	11.5	3.2373	0.07
Patient population to be served	24	97	24.7	22	162	13.6	11.1	5.1753	0.02*
Weather	25	96	26.0	31	166	18.7	7.3	1.9643	0.16
Availability of mentors	16	93	17.2	17	163	10.4	6.8	2.4204	0.12
Supportive academic environment	13	92	14.1	12	160	7.5	6.6	2.8736	0.09
Availability of part-time position	10	76	13.2	11	137	8	5.2	1.4468	0.23
Type of community (eg, rural/urban)	21	97	21.6	27	165	16.4	5.2	1.1406	0.29
Job/practice meets visa requirements	4	26	15.4	6	54	11.	4.4	0.2930	0.59
Frequency of weekend duties	23	98	23.5	32	167	19.2	4.3	0.6968	0.40
Frequency of overnight shifts	27	98	27.6	39	165	23.6	4.0	0.5012	0.48
Opportunities for teaching	11	94	11.7	15	162	9.3	2.4	0.3890	0.53
Staying in the same city/region as EM training	8	89	9.0	11	154	7.1	2.1	0.2666	0.61
Use of NP, PA, and other clinical staff	3	93	3.2	4	161	2.5	0.7	0.1209	0.73
Length of work day	43	98	43.9	73	168	43.5	0.4	0.0045	0.95
Cost of living	14	97	14.4	24	164	14.6	−0.2	0.0020	0.96
Opportunities for research	0	90	0	2	160	1.2	−1.2	1.1341	0.29
Predictable work day start and end times	33	97	34	67	167	40.1	−6.1	0.9700	0.33
Organizational structure of practice	14	97	14.4	37	164	22.6	−7.6	2.5611	0.11
Partnership opportunity	6	82	7.3	23	149	15.4	−8.1	3.1760	0.08
Other factors	2	27	7.4	7	47	14.9	−14.5	0.8996	0.34
Salary/compensation	29	98	29.6	87	168	51.8	−22.2	12.3975	<0.001*

Sorted in order of the difference in percentage of women responding as "very important" compared to men (column 7).
*$P < .05$ significance.
**Since not every respondent answered every question, N is the total number of women and men responding to the question.
EM, emergency medicine; *NP*, nurse practitioner; *PA*, physician assistant.

alone of $30,000 at the median, which was consistent across the income distribution. Reisdorff et al found a significant gender gap of $43,565 for a sample of all ACEP members, and Madsen et al found a smaller but still significant difference of $19,418 for academic EM faculty.[1,22] The impact of sex in physician pay seems persistent throughout a career and could translate to an over $2 million net income difference over a 40-year career.[23] Our results on difference in job preferences by sex suggest that the reasons for the gap may not be entirely systemic but may be at least partly associated with the different locations and type of jobs that men and women select.

Graduating residents have many factors to consider and each individual will have different personal priorities as well

Table 2B. "Very important" and "important" vs of "little importance" and "not important at all": factors influencing job selection for men and women sorted by difference in percent.*

	"Important" for women			"Important" for men					
Factor is "very important"	Frequency women	N**	Percent women	Frequency men	N**	Percent men	Difference in percent	Pearson chi square	*P*-value
Parental leave policy	51	79	64.6%	31	142	21.8	42.8%	39.7066	<0.001*
Job/practice meets visa requirements	9	26	34.6%	7	54	13%	21.6%	5.1425	0.02*
Patient population to be served	72	97	74.2%	91	162	56.2%	18.0%	8.4776	0.004*
Employment for spouse/partner	53	75	70.7%	75	142	52.8	17.9%	6.4636	0.01*
Availability of part-time position	32	76	42.1%	34	137	24.8%	17.3%	6.8317	0.01*
Staying in same city/region as EM training	30	89	33.7%	26	154	16.9%	16.8%	9.0029	0.003*
Availability of mentors	61	93	65.6%	82	163	50.3%	15.3%	5.6106	0.02*
Supportive academic environment	41	92	44.6%	50	160	31.2%	13.4%	4.4889	0.03*
Rural vs urban	71	97	73.2%	100	165	60.6%	12.6%	4.2713	0.04*
Frequency of weekend duties	69	98	70.4%	98	167	58.7%	11.7%	3.6434	0.06
Type of hospital	70	98	71.4%	98	164	59.8%	11.6%	3.6330	0.06
Proximity to family	68	93	73.1%	102	164	62.2%	10.9%	3.1622	0.08
Opportunities for teaching	38	94	40.4%	53	162	32.7%	7.7%	1.5431	0.21
Frequency of overnight shifts	73	98	74.5%	117	165	70.5%	4.5%	0.3931	0.53
Opportunities for research	7	90	7.8%	6	160	3.75%	4.05%	1.8956	0.17
Organizational structure of practice	59	97	60.8%	94	164	57.3%	3.5%	0.3092	0.58
Use of NP, PA, and other clinical staff	29	93	31.2%	45	161	28%	3.2%	0.2983	0.59
Weather	59	96	61.5%	99	166	59.6%	1.9%	0.0841	0.77
Jobs in desired practice setting	86	98	87.8%	146	168	86.9%	0.9%	0.0401	0.84
Cost of living	63	97	64.9%	105	164	64%	0.9%	0.0227	0.88
Partnership opportunity	37	82	45.1%	66	149	44.3%	0.8%	0,0146	0.90
Jobs/Practice in desired location	94	98	95.9%	159	167	95.2%	0.7%	0.0718	0.79
Length of work day	90	98	91.8%	153	168	91.1%	0.7%	0.0459	0.83
Other factors	9	27	33.3%	17	47	36.2%	–2.9%	0.0606	0.81
Predictable work day start and end times	75	97	77.3%	137	167	82%	–4.7	0.8629	0.35
Salary/compensation	87	98	88.8%	162	168	96.4%	–7.6%	6.0595	0.01*

Sorted in order of the difference in percentage of women responding as "very important or important" compared to men (column 7).
*$P < .05$ significance.
**Since not every respondent answered every question, N is the total number of women and men responding to the question.
EM, emergency medicine; *NP*, nurse practitioner; *PA*, physician assistant.

as different career goals. Women are statistically less likely than men to consider high salary as very important and more likely to consider more non-salary factors, as listed in Tables 2A and 2B, as more important than men. The long-term financial impact of these decisions are unknown and were not considered in the analysis, but these personal priorities may contribute to the unexplained and persistent salary differences by sex.

We confirmed that salary may be impacted, but less so, based on location of practice, size of the city and the setting, with academic and large hospitals paying less than smaller, rural and community hospitals. Men were more likely to accept jobs associated with higher pay in smaller communities, non-academic settings, smaller hospitals, or exclusively EM practice consistent with at least one other study.[24] As an anticipated surplus of EPs is projected, its

Table 3. Quantile regression results (median).

Category	Characteristic	Variable	Number (percent)	Mean income difference ($)[1]	(95% confidence interval)	$P > \|t\|$	Median salary (male) ($) *	Median salary (female) ($) *
Demographics	Sex	Men	162 (62.8%)	$+30,000	(+6,929 – + 53,071)	0.01*	244,200	214,200
		Women	96 (37.2%)	reference				
	Race[2]	Under-represented	3 (1.2%)	$+3,114	(–98,750 – + 104,977)	0.95	247,313	217,313
		Non-minority	255 (98.8%)	reference				
	Ethnicity	Hispanic	12 (4.7%)	$–2,491	(–54,791 – + 49,809)	0.93	241,708	211,708
		Non-Hispanic	246 (95.3%)	reference				
	Age	Increasing age	Mean	$–1,246	(–4,535 – + 2,044)	0.46	242,954	212,954
Training	Training location[3]	International medical graduate	10 (3.9%)	$+48,096	(–9,067 – + 105,529)	0.10	292,296	262,296
		US or Canadian graduate	248 (96.1%)	reference				
	Degree type[4]	DO degree	72 (27.9%)	$+30,000	(+5,133 – + 54,867)	0.02*	274,200	244,200
		MD degree	186 (72.1%)	reference				
Job Characteristics	Work Setting	Academic	68 (26.4%)	$–24,539	(–50,226 – + 1,507)	0.07	219,840	189,840
		Non-academic	190 (73.6%)	reference				
	Organization type	For-profit	91 (43.5%)	$–1,246	(–26,631 – + 24,141)	0.92	242,954	212,954
		Nonprofit	118 (56.5%)	reference				
	Location	rural location<50,000	27 (10.5%)	$+35,605	(–475 – + 71,685)	0.05	279,805	249,805
		>50,000 in city	231 (89.5%)	reference				
	Primary job	Full time	238 (92.2%)	$+43,149	(–1349 – + 84,950)	0.04*	287,349	257,349
		Part time	20 (7.8%)	reference				
	Secondary Job	Has secondary job	70 (27.1%)	$–6,263	(–30,951 – + 18,424)	0.62	237,936	207,936
		No secondary job	188 (72.9%)	reference				

[1]Base salary only.
[2]Under-represented minority of Black, Native American, and Alaskan compared to all others.
[3]International medical graduate compared to Canadian and American schools accredited by the Liaison Committee on Medical Education and American Osteopathic Association.
[4]*DO*, osteopathic physicians, compared to *MD*, allopathic physicians.
*$P > |t|$: *P*-value in regression table: $P < .05$ significance.
**This is the median salary for males/females with all other variables set to their null value, including the continuous variable for age.
†This table shows results for 258 respondents.

impact will be felt most directly by graduating residents who are new to the job market and most closely invested in the supply and demand.[25] Of note, this survey was completed prior to the COVID-19 pandemic.

LIMITATIONS

There were several limitations to the study. The sample of 270 residents analyzed and the 258 who had complete (or imputed) data for the regression analysis represents

approximately 12% of all graduating residents in 2019; thus, while it cannot be considered a representative sample, it does provide insight into some of the factors considered by graduating residents that may be associated with their salaries. Understanding salary was not the primary purpose of the larger initiative, but the resulting dataset included salary data for respondents who had accepted a post-residency job. The analysis compared respondents' base salaries without consideration of additional income sources such as incentive payments and may not represent all anticipated income. Like all surveys relying on self-reported data, the potential exists for inaccuracies or recall bias. Survey respondents were asked to report their salaries within $10,000 ranges; so, the point values used in the analysis presume that actual salaries were evenly distributed within each salary range, which could have resulted in some inaccuracy in salary reporting.

Although there is variability in supply and demand of emergency physicians by state, our intent was a national scope; thus, analysis of the salaries and job opportunities within specific regions or states was not performed. While the original survey tool has been used widely with graduates of other specialties, validation of this survey tool was limited to content-expert comments, pilot-testing within EM, and modification based on feedback received.[1] We did not explore any numerical measures of factor loading or survey consistency.

The regression model was limited to 13 variables to address overfitting, necessitating difficult choices as to which variables to include and how best to construct dummy variables from categorical ones. Nevertheless, the results of a sensitivity analysis that found only minor changes in the results when alternative variable listings were explored suggest that the regression model was not sensitive to changes in model specification. Finally, the regression analysis used a sample that was slightly smaller than the main sample (258 vs 270) owing to missing data on some variables. It is assumed that the 258 were closely representative of the larger sample, given the small difference in numbers between the two samples.

CONCLUSION

A sample of 2019 graduating EM residents reported variance in salaries that depended on several variables. Men and osteopathic physicians were paid significantly more in their first jobs than women and allopathic physicians. In exploring possible reasons for the gap in pay between men and women, women are statistically more likely than men to consider lifestyle factors such as parental leave policy, proximity to family, job location, practice setting, and type of hospital as priorities. Men are statistically more likely to consider salary and compensation more important than women. Nevertheless, the gap in pay between men and women EM graduates is not fully explained by the factors we were able to include in our analysis, and other explanations must be sought for the portion of the gender gap that remains unexplained.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Financial support was provided by the American College of Emergency Physicians (ACEP), American Board of Emergency Medicine (ABEM), American College of Osteopathic Emergency Physicians (ACOEP), American Osteopathic Board of Emergency Medicine (AOBEM), Council of Emergency Medicine Residency Directors (CORD), Emergency Medicine Residents' Association (EMRA), and Society for Academic Emergency Medicine (SAEM). ES and LQ received funding from the American College of Emergency Physicians (ACEP), American Board of Emergency Medicine (ABEM), American College of Osteopathic Emergency Physicians (ACOEP), American Osteopathic Board of Emergency Medicine (AOBEM), Council of Emergency Medicine Residency Directors (CORD), Emergency Medicine Residents' Association (EMRA), and Society for Academic Emergency Medicine (SAEM) for the data acquisition and analysis. There are no other conflicts of interest or sources of funding to declare.

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Equity in the Early Pain Management of Long Bone Fractures in Black vs White Patients: We Have Closed the Gap

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Section Editor: David Thompson, MD
Submission history: Submitted October 27, 2023; Revision received April 19, 2024; Accepted April 26, 2024
Electronically published August 1, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18531

Introduction: Patients with long bone fractures often present to the emergency department (ED) with severe pain and are typically treated with opioid and non-opioid analgesics. Historical data reveals racial disparities in analgesic administration, with White patients more likely to receive analgesics. With the diversifying US population, health equity is increasingly crucial. In this study we aimed to evaluate the early administration of opioid and non-opioid analgesia among Black and White patients with long bone and femur fractures in EDs over different time frames using a substantial database.

Methods: We retrospectively extracted Information from 57 US healthcare organizations within the TriNetX database, encompassing 95 million patients. The ED records from 2003–2023 were subjected to propensity score matching for age and gender. We focused on four cohorts: two comprising Black and White patients diagnosed with long bone fractures, and another two with Black and White patients diagnosed solely with femur fractures. We examined analgesic administration rates over 20 years (2003–2023) at five-year intervals (2003–2008; 2008–2013; 2013–2018; 2018–2023), and further analyzed the rates for the most recent two-year period (2021–2023).

Results: Disparities in analgesic administration significantly diminished over the study period. For patients with long bone fractures (1,095,052), the opioid administration gap narrowed from 6.3% to 1.1%, while non-opioid administration disparities reduced from 4.4% to 0.3%. Similar trends were noted for femur fractures (265,181). By 2021–2023, no significant differences in analgesic administration were observed between racial groups.

Conclusion: Over the past 20 years, the gap in early administration of opioid and non-opioid analgesics for Black and White patients presenting with long bone fractures or femur fractures has been disappearing. [West J Emerg Med. 2024;25(5)809–816.]

INTRODUCTION

Background

Patients with long bone fractures routinely present to the emergency department (ED) with severe pain, requiring effective pain management strategies. Over 178 million new fractures were recorded worldwide in 2019, and approximately 60% of those were long bone fractures.[1,2] Standard management principles use non-opioid and opioid analgesics to treat the severe pain often associated with long bone fractures.[3] There have been findings suggesting that not all patients' pain was being treated equitably. A national study published in 2008 that covered a 13-year period showed that non-Hispanic White patients were 8% (31% vs 23%) more likely than Black patients to receive opioids for pain-related conditions including nephrolithiasis and long bone fractures.[4] Several subsequent studies have shown the same trend, showing that non-Hispanic White patients were more likely to be treated with pain medications than other races for long bone fractures.[4–10]

In contrast, some recent smaller studies have reported no statistically significant racial differences in analgesic prescribing for patients with long bone fractures.[11–14] For example, a study published in 2021 with 6,441 pediatric visits showed there was no significant difference in the rate of opioids prescribed to children who were Black, Hispanic, or other race vs non-Hispanic White children who were treated for long bone fractures at multiple hospitals from 2012–2019.[15]

As the population of the United States grows, its diversity is expected to increase as well. Minority groups are projected to exceed over 50% of the US population by 2044.[16] Thus, health equity and awareness of differential treatment based on race or ethnicity becomes more significant. The fundamental ideal in medicine is to ensure a healthcare system that does not produce inequitable health treatment and outcomes based on an individual's demographic characteristics.

Population Health Research Capsule

What do we already know about this issue?
Effective pain management for long bone fractures is crucial. Disparities in analgesic prescribing based on race highlight the need for health equity.

What was the research question?
Are there inequities in administration of analgesia for long bone fractures of Black vs White patients?

What was the major finding of the study?
From 2003 to 2023, the opioid administration gap narrowed from 6.3% ($P < 0.001$, CI 0.65–0.75) to 0.2% ($P = 0.78$, CI 0.98–1.03).

How does this improve population health?
Racial disparities are a significant barrier to equitable treatment, and this study helps shed light on the current state of healthcare.

Goals of Investigation

Our primary objective was to investigate potential racial inequalities in the administration of opioid and non-opioid analgesics for patients with long bone and femur fractures in the ED.

METHODS

Study Design and Setting

This study employed a propensity-matched, retrospective design to evaluate a large national database, TriNetX, over various time periods. Using the "United States Collaborative Network" within the platform, containing de-identified electronic health records of approximately 95 million patients from 57 healthcare organizations, we created two sets of cohorts on December 27, 2022. These organizations are largely tertiary academic centers and their satellite facilities. There is representation from all geographic regions of the United States.

Cohort Selection

We selected patients from all age groups. To protect patient privacy, those who were ≥90 years of age were grouped as 90 within the TrinetX database. In the first set of cohorts studied, Cohort 1.1 contained Black patients with long bone fractures, while Cohort 1.2 contained White patients with long bone fractures. Long bone fractures are defined using the International Classification of Diseases, 10th Rev, procedure coding system (ICD-10) for diagnosis of fractures of the shaft of the tibia and femur, lower end of ulna, upper end of radius, shaft of ulna and fibula, lower end of radius, forearm, and shoulder and upper arm. The ICD-10 codes are listed in Table 1. Of note, multiple fracture diagnoses may be present in one visit. In the second set of cohorts, Cohort 2.1 had Black patients with only femur fractures and Cohort 2.2 had White patients with only femur fractures. In these cohorts, patients had come through emergency department services (CPT:1013711) within the prior 20 years.

We further explored the cohorts by looking at a subgroup analysis over five-year intervals ranging from 2003–2008, 2008–2013, 2013–2018, and 2018–2023. These rounded cutoffs were chosen for ease of interpretation. We analyzed each interval from January of the starting year to January 1 of the final year. Both long bone and femur fracture cohorts

Table 1. International Classification of Diseases, 10th Rev, for fracture diagnosis in database.

Fracture diagnosis	ICD-10-CM	No. of fractures in database
Shoulder and upper arm	S42	1,073,481
Forearm	S52	1,072,733
Lower radius	S52.5	679,479
Femur	S72	597,633
Lower ulna	S52.6	346,093
Shaft of tibia	S82.2	290,731
Upper radius	S52.1	259,067
Shaft of ulna	S52.2	228,245
Unspecified shaft of fibula, initial encounter, closed	S82.409A	57,426

ICD-10-CM, International Classification of Diseases, 10th Rev, Clinical Modification.

were chosen in part to control for confounders in cases with multiple fractures, but also because femur fractures comprise a more homogeneous group that more consistently needs analgesia. Institutional review board approval was not required for this study, as TriNetX provides data that has been de-identified, which restricts access to protected health information (for users of the database).[17]

Measures

Demographics included self-reported gender race, ethnicity, and marital status, which map to Health Level 7 administrative standards. Gender was coded as male or female. Race and ethnicity were recoded into Hispanic, non-Hispanic White, and non-Hispanic Black.

Outcomes

From each cohort, two different outcomes were evaluated: treatment with opioid analgesics (VA:CN101) and treatment with non-opioid analgesics (VA:CN103). The administration data presented was binary: whether the patient had received any amount of analgesia or not. The time window was adjusted for the outcome to occur on the same day or up to one day from the index event for each cohort. Patients were excluded from the cohort if they received the outcome prior to the visit, such as those who may have had a documented acute or chronic opioid/non-opioid prescription prior to arrival.

Statistical Analysis

Using the TriNetX database, a 1:1 propensity score match was produced with linear and logistic regression. We used greedy nearest neighbor matching with tolerance of 0.1 and difference between propensity ≤0.1.[18] Balance on covariates was assessed using standardized mean difference, and absolute values of >0.1 were considered positive for residual imbalance. The TriNetX platform uses input matrices of user-identified covariates and conducts linear and logistic regression analysis to obtain propensity scores for individual subjects. TriNetX randomizes the order of rows to eliminate bias resulting from the nearest neighbor algorithms. This study methodology has been previously validated.[17]

We compared cohorts before and after propensity matching. Propensity matching was done through the "Balance Cohorts" tool in TriNetX to control for age at the diagnosis of the fracture and gender. There were statistically significant differences in the demographics for all compared cohorts prior to propensity matching. Demographics before and after propensity matching for the cohorts with long bone fractures or femur fractures in the last 20 years are shown in Table 2. Due to recent increases in societal awareness for differential treatment based on racial disparities, a second subgroup analysis was also completed on January 1, 2023, to analyze the same outcomes (opioid analgesics and non-opioid analgesics on the same day to one day after emergency care) for Black compared to White patients over the most recent two years (2021–2023).

We used the measure-of-association tool in TriNetX to perform univariate analysis where risk ratio (RR), 95% confidence interval (CI), and probability values (*P*) were

Table 2. Demographics for Black patients vs White patients from 2003–2023 before and after propensity score matching.

Long bone fractures	Black patients before	White patients before	Black patients after	White patients after
Total patients	172,411	901,998	172,411	172,411
Age at index	34.4 +/– 24.2	43.8 +/– 28.5	34.4 +/– 24.2	34.4 +/– 24.2
Female	72,411 (42.0%)	462,246 (51.2%)	72,411 (42.0%)	72,411 (42.0%)
Male	99,904 (57.9%)	430,113 (47.7%)	99,904 (57.9%)	99,904 (57.9%)
Femur fractures	**Black patients before**	**White patients before**	**Black patients after**	**White patients after**
Total patients	39,360	220,840	39,360	39,360
Age at index	45.7 +/– 25.5	62.5 +/– 24.9	45.7 +/– 25.5	45.7 +/– 25.5
Female	16,899 (42.9%)	126,750 (57.4%)	16,899 (42.9%)	16,899 (42.9%)
Male	22,441 (57%)	91,567 (41.5%)	22,441 (57%)	22,441 (57%)

calculated to show comparisons of outcomes for the time intervals corresponding to each cohort studied. The data was reported as RRs with 95% CI from the final analysis, which was completed on December 29, 2022. Statistical significance was set at a two-sided alpha <0.05.

RESULTS

Characteristics of Study Subjects

In this study we analyzed 94,990,854 patients from 57 healthcare organizations in the United States Collaborative Network database in TriNetX. There were 2,477,404 patients identified with long bone fractures (272,690 Black and 1,716,194 White) and 597,833 patients with only femur fractures (67,905 Black and 431,613 White) before restricting to ED visits. After restricting the study to the ED, 175,354 Black and 919,698 White patients were found with long bone fractures. Using the five-year intervals from the subgroup analysis of long bone fractures, the number of Black patients found were 9,917 (2003–2008); 27,294 (2008–13); 67,767 (2013–18); and 82,008 (2018–23) while the number of White patients found were 44,864 (2003–2008); 147,130 (2008–13); 340,320 (2013–18); and 459,479 (2018–23), respectively.

For patients who came through the ED in the prior 20 years with femur fractures, there were 40,084 Black and 225,097 White patients. Looking at the same five-year intervals for the subgroup analysis of femur fractures, there were 2,092 (2003–2008) 5,827 (2008–13); 15,521 (2013–18); and 19,677 (2018–23) Black patients, while there were 9,301 (2003–2008); 33,098 (2008–13); 82,390 (2013–18); and 117,103 (2018–23) White patients, respectively. We defined race as "unknown" in 19% of the patient population. The geographic distribution of patients in the cohorts of ED patients with long bone fractures was 25% from the Northeast, 20% from the Midwest, 39% from the South, and 13% from the Western US.

Main Results

Opioid analgesia for patients with long bone fractures increased for both cohorts, shifting from 14.4% of Black and 20.7% (RR 0.697, 95% CI 0.647–0.751) of White patients between 2003–2008 to 45.8% of Black and 46.9% (RR 0.978, 95% CI 0.964–0.992) of White patients between 2018–2023. Similar increases are seen with non-opioid analgesia, going from 13.1% of Black and 17.5% of White patients (RR 0.751, 95% CI 0.692–0.815) between 2003–2008 to 42.0% for Black and 41.7% of White patients (RR 1.007, 95% CI 0.991–1.024) between 2018-2023. Additional data can be found in Table 3 and Table 4. The difference between opioid analgesics prescribed for Black vs White patients with long bone fractures has overall decreased from a significant 6.3% gap to 1.1% gap from the time intervals of 2003–2008 to 2018–2023, as seen in Figure 1. For patients with long bone fractures in the ED in the prior 20 years (80% are from the most recent 10 years), 37.7% of Black patients received opioid analgesia compared to 39.8% of White patients (RR 0.947, 95% CI 0.937–0.957), while 34% of Black patients received non-opioid analgesia compared to 35.6% of White patients (RR 0.955, 95% CI 0.944–0.967).

Opioid analgesia for patients with femur fractures has been increasing for both cohorts, going from 17.8% of Black and 22.6% of White patients (RR 0.786, 95% CI 0.667–0.926) between 2003–2008 to 68.1% of Black and 69.4% of White patients (RR 0.982, 95% CI 0.961–1.003) between 2018–2023. This increase is also seen in non-opioid analgesia, increasing from 16.3% of Black and 18.7% of White patients (RR 0.876, 95% CI 0.732–1.047) between 2003–2008 to

Table 3. Opioid analgesic administration for Black patients vs White patients from 2003–2023 after propensity score matching.

Long bone fractures	Black patients % (n)	White patients % (n)	RR (95% CI)
2003–2008	14.4% (997)	20.7% (1,346)	0.697 (0.647, 0.751)
2008–2013	19.5% (3,318)	24.6% (4,210)	0.792 (0.761, 0.824)
2013–2018	38.8% (14,250)	40.1% (15,392)	0.969 (0.952, 0.986)
2018–2023	45.8% (19,178)	46.9% (21,168)	0.978 (0.964, 0.992)
2021–2023	45.0% (7,223)	44.8% (7,643)	1.003 (0.981, 1.028)
2003–2023	37.7% (37,412)	39.8% (41,408)	0.947 (0.937, 0.957)
Femur fractures	**Black patients % (n)**	**White patients % (n)**	**RR (95% CI)**
2003–2008	17.8% (213)	22.6% (248)	0.786 (0.667, 0.926)
2008–2013	29.9% (839)	29.7% (806)	1.006 (0.928, 1.091)
2013–2018	54.1% (3,495)	53.0% (3,401)	1.021 (0.989, 1.055)
2018–2023	68.1% (5,196)	69.4% (5,511)	0.982 (0.961, 1.003)
2021–2023	69.6% (2,186)	70.1% (2,228)	0.993 (0.962, 1.026)
2003–2023	54.8% (9,726)	54.4% (9,777)	1.008 (0.989, 1.027)

RR, relative risk; *CI*, confidence interval; time intervals from initial Jan 1 to final Jan 1.

Table 4. Non-opioid analgesic administration for Black patients vs White patients from 2003–2023 after propensity score matching.

Long bone fractures	Black patients % (n)	White patients % (n)	RR (95% CI)
2003–2008	13.1% (886)	17.5% (1,072)	0.751 (0.692, 0.815)
2008–2013	19.0% (3,109)	23.6% (3,985)	0.807 (0.774, 0.841)
2013–2018	34.8% (12,004)	36.3% (13,774)	0.957 (0.939, 0.976)
2018–2023	42.0% (15,044)	41.7% (17,582)	1.007 (0.991, 1.024)
2021–2023	41.0% (5,473)	40.0% (6,270)	1.025 (0.996, 1.054)
2003–2023	34.0% (30,735)	35.6% (35,604)	0.955 (0.944, 0.967)
Femur fractures	**Black patients % (n)**	**White patients % (n)**	**RR (95% CI)**
2003–2008	16.3% (196)	18.7% (199)	0.876 (0.732, 1.047)
2008–2013	25.4% (695)	25.5% (722)	0.995 (0.910, 1.089)
2013–2018	45.1% (2,817)	45.0% (2,966)	1.004 (0.966,1.043)
2018–2023	58.6% (4,034)	59.0% (4,464)	0.994 (0.967, 1.021)
2021–2023	58.5% (1,668)	59.1% (1,798)	0.990 (0.948, 1.033)
2003–2023	46.3% (7,712)	45.3% (8,120)	1.023 (0.999,1.046)

RR, relative risk; *CI*, confidence interval; time intervals from initial Jan 1 to final Jan 1.

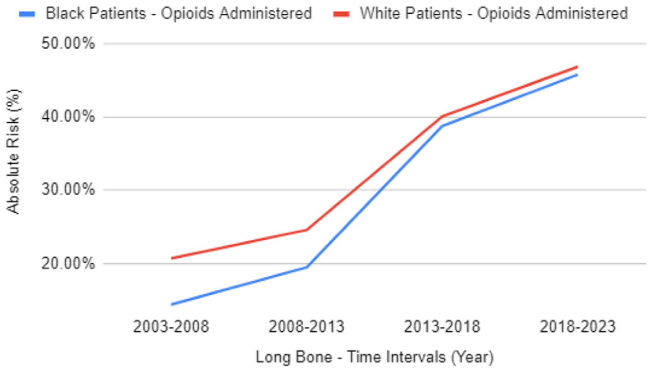


Figure 1. Rate of opioid administration for Black patients vs White patients with long bone fractures after propensity matching.

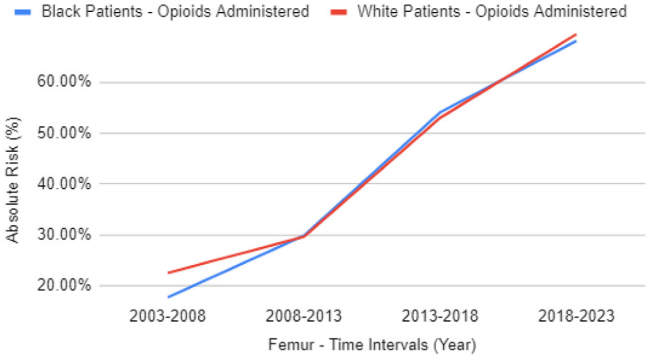


Figure 2. Rate of opioid administration for Black patients vs White patients with femur fractures after propensity matching.

58.6% of Black and 59% of White patients (RR 0.994, 95% CI 0.967–1.021) between 2018–2023. Additional data can be found in Table 3 and Table 4. The difference between opioid analgesics prescribed for Black vs White patients with femur fractures has overall decreased from a 4.8% gap to 1.3% gap from the time intervals of 2003–2008 to 2018–2023, as seen in Figure 2. For patients with femur fractures in the ED in the prior 20 years (80% are from the most recent 10 years), opioid analgesia was given to 54.8% of Black vs 54.4% of White patients (RR 1.008, 95% CI 0.989–1.027) while non-opioid analgesia was given to 46.3% of Black vs 45.3% of White patients (RR 1.023, 95% CI 0.999–1.046).

Subgroup Analysis

In the subgroup analysis performed January 5, 2023, administration of opioid analgesics and non-opioid analgesics for Black patients was compared to White patients for long bone and only femur fractures during ED visits from 2021–2023. Before propensity matching was performed, a total of 229,395 patients were identified with long bone fractures and 62,761 patients with only femur fractures during this period. After propensity matching, there were a total of 69,668 patients with long bone fractures and 18,992 patients with only femur fractures during this period. The analysis after propensity matching showed that Black and White patients were both given comparable opioid analgesics (45.0% vs 44.8%, RR 1.00, 95% CI 0.980–1.028) and non-opioid analgesics (41.0% vs. 40.0%, RR 1.025, 95% CI 0.996–1.054) for long bone fractures during this time interval. When evaluating for only femur fractures, the findings were also comparable. Black and White patients were given equivalent opioid analgesics (69.6% vs 70.1%, RR 0.993, 95% CI 0.962–1.026) and non-opioid analgesics (58.5% vs 59.1%, RR 0.990, 95% CI 0.948–1.033).

Comparison of Groups

The outcomes for prescribing of opioid analgesics and non-opioid analgesics for Black vs White patients presenting to the ED in all time intervals and subgroups were all collected on the same day or within 24 hours after the index event. During the period 2003–2008, White patients were prescribed significantly more opioid analgesics than Black patients; however, the gap has been decreasing, and between the years 2021–2023, we found no significant difference in the number of opioid analgesics prescribed for either the long bone fracture or femur fracture cohorts.

DISCUSSION

The objective of this study was to investigate the relationship between racial disparities and the administration of both opioid and non-opioid analgesics following various long bone and femur fractures, and the trend over a 20-year time span to determine whether disparities have diminished. The sample included over 2.4 million patients across the US who were evaluated for pain associated with long bone fractures. Previous studies have concluded that the pain for these fractures is undermanaged for non-White patients.[6] In the 2003–2008 cohort, the findings of previous studies were confirmed, that White non-Hispanic patients were previously administered analgesia significantly more often than other demographics.[4–8,10] The results of this study suggest that the gap between analgesia administration rates has diminished. In fact, there was no statistical significance in opioids given to Black patients with long bone fractures over White patients over the most recent years (2021–2023). Results were similar with and without propensity matching of the given populations. The cohorts of femur fractures showed similar findings; however, the gap in administration of opioids appears to have narrowed in 2008 and has remained insignificant up to 2023.

Employing propensity matching by age and gender is important in this database, given the marked differences in the epidemiology of long bone and femur fractures across races. Notably, racial disparities in fracture incidence are evident across various age groups, from preschool to 60 years of age. Black males show a significantly higher incidence of fractures up to the age of 62, while Black females experience a modestly elevated rate of fractures until the age of 40. Furthermore, fractures attributed to violence are tenfold higher among Black individuals compared to other racial groups. Interestingly, despite possessing greater bone density, Black individuals, including both children and adults, exhibit an increased susceptibility to fractures across most non-fall-related injury mechanisms. This highlights the complexity of the factors influencing fracture risks and the significance of considering age, gender, and race in the analysis.[19]

This study demonstrates that, overall, opioid administration has increased over the past 20 years. Several factors contributed to this trend, including recent misrepresentations by drug companies about the risks associated with opioids,[20] as well as policy initiatives from the Joint Commission on Accreditation of Healthcare Organizations which incentivized hospitals and physicians for more aggressive pain management. The results are consistent with a 2008 study that showed an increase in opioid use during times shortly after the launch of Joint Commission initiatives.[4] In 1997, pain standards were developed through policies developed by the Joint Commission due to a need for organized pain assessment. The policies emphasized pain as the "5th vital sign," which resulted in an upward trend for administration and prescription of opioid medications as treatment.[21]

Time to pain management became a core quality metric by which EDs were measured for multiple years and was linked to Medicare CMS reimbursement. Physicians and hospitals were evaluated based on their pain treatment practices, and financial incentives were provided for meeting certain criteria. This, in conjunction with increased societal awareness regarding disparities in healthcare, may have played a role in narrowing the gap in analgesia administration between Black and White patients. The combination of performance-based assessments and incentives, along with heightened public consciousness, likely contributed to changes in pain management practices that addressed previously existing disparities. There has been a more recent trend as a result of the opiate pandemic that shows overall opioid prescriptions are now decreasing to all patients.[14]

The results of this study have important implications for the acute management of patients with long bone fractures in the US. Inadequately treated pain has been found to be a major public health challenge in the US, and racial and ethnic minority groups have historically appeared to be at a high risk of receiving inadequate pain treatment in the ED.[4] While studies as recent as 2020 have concluded that racial and ethnic minorities are less likely to receive analgesia for acute trauma,[10] the results of this study show that the differential in treatment has disappeared. We incorporated a larger sample size that is approximately 10 times larger than any previous study on this topic, and through propensity matching some of the confounding variables were eliminated that may have skewed previous data. Future studies should aim to address other variables contributing to this decrease in disparity and incorporate more stratification of race and ethnicity to determine whether other disparities are present. Other possible relationships, such as rates of analgesic refusal by race, prehospital administration of analgesia, disparities in assessment of pain score by emergency clinicians, and language barriers should also be analyzed.

LIMITATIONS

Because this was a retrospective study, causation between racial disparities and opioid administration could not be

established. However, the size of this study – 2.4 million vs 157,000 - in conjunction with propensity matching, gave us greater power to identify differences in outcomes between groups compared to previous studies.[3,11–15]

In this propensity-matched retrospective study out of this national database, it becomes difficult to evaluate clinical details about each patient encounter such as pain scores, amount of analgesia, compliance to medications given, Emergency Severity Index acuity level, multitrauma, and information about the prescriber. This leads to lack of objectively measuring the effectiveness of the analgesia, whether additional treatment was needed after the initial analgesia, and, overall, a limitation in judging the effectiveness of the treatment itself. This study, however, was dedicated to a more short-term approach regarding the use of medications in the ED, not necessarily the effectiveness of post-encounter or medications prescribed upon discharge.

There may be an issue with granularity of the visit type and date in data collected from ICD 9/10-based systems. This difference should not be significant between the groups or lead to confounding. Approximately 80% of the patient population is from the past 10 years as many additional healthcare organizations have recently joined the TriNetX database. As a result, the dataset that includes all 20 years is skewed toward more recent patients. This effect is minimized by looking at two- and five-year periods.

Additionally, the inability to obtain insurance information for each patient may have posed a particular challenge as this can account for certain biases that affect financial access to treatment and may not be measurable on this scale.[7] Our aim was to eliminate confounding variables such as this, and further information on insurance per patient may provide data allowing us to better understand the differences being measured in these sets after propensity matching. Although propensity matching was performed for demographic information, there may be pre-existing medical conditions that impact pain severity and administration of analgesia for which the study did not control. In addition, race was not known for approximately one-fifth of the patient population.

In the TriNetX database, the identities or designations of the healthcare organizations and their respective sites are not disclosed since the data is de-identified. Consequently, we could not consider any clustering by hospital. This limitation is significant as there may be inherent differences in the population characteristics across various hospital systems or sites, which could influence the administration patterns of analgesia and potentially introduce bias into the results. Moreover, our database does not provide information that allowed us to discern whether analgesics were administered to individual patients in the prehospital setting, which may have served as an additional confounding factor. There is evidence indicating that prior to 2020, disparities existed in the administration of pain medication in the prehospital setting. This was observed in cases involving both non-traumatic and traumatic painful conditions, where the probability of Black patients receiving pain medication was lower when compared to White patients.[22]

CONCLUSION

This retrospective analysis provides evidence from healthcare centers across the US that there is no longer a significant difference in the administration of opioid and non-opioid analgesics between Black and White patients diagnosed with long bone and femur fractures.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This study was conducted with the support of the Institute for Translational Sciences at the University of Texas Medical Branch, supported in part by a Clinical and Translational Science Award (UL1 TR001439) from the National Center for Advancing Translational Sciences, National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. There are no other conflicts of interest or sources of funding to declare.

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A Cross-Sectional Review of HIV Screening in High-Acuity Emergency Department Patients: A Missed Opportunity

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Section Editor: Ioannis Koutroulis, MD, MBA, PhD
Submission history: Submitted April 17, 2023; Revision received April 24, 2024; Accepted May 3, 2024
Electronically published August 1, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18067

Introduction: Emergency department (ED) patients requiring immediate treatment often bypass a triage process that includes HIV screening. In this study we aimed to investigate the potential missed opportunity to screen these patients for HIV.

Methods: We conducted this cross-sectional study in a municipal ED over a six-week period between June–August 2019. The patient population in this study arrived in the ED as a pre-notification from prehospital services or designated by the ambulance or walk-in triage nurse as requiring immediate medical attention. Medical student researchers collected demographic data and categorized patients into three clinical groups (trauma, medical, psychiatric). They documented the patient's eligibility for HIV screening as determined by a physician and confirmed that the patient met criteria of clear mental status, controlled pain, stable vital signs, and ability to contribute to a medical history and physical examination. The student researchers did this at initial presentation and then again during the patient's ED stay of up to eight hours. The study outcomes measured the percentage of total patients within each clinical group (trauma, medical, psychiatric) able to engage in the HIV screening process upon arrival and during an eight-hour ED stay.

Results: On average, 700 patients per month are announced on arrival via overhead page, indicating that they require immediate medical attention. During the six-week study, 205 patients (approximately 20% of total) were enrolled: 114 trauma; 56 medical; and 35 psychiatric presentations. The average patient age was 53; 60% of patients were male. Niney-eight (48%) patients were eligible for HIV screening within an eight-hour ED stay; 63 (31%) were able to be screened upon initial presentation and 35 (17%) in the first eight hours of their ED visit. Within medical and trauma subgroups, there was no significant difference in the proportion (36%) of patients that could be screened upon presentation. Among the psychiatric presentations, only five (14%) were able to be screened during their hospital stay.

Conclusion: Triage protocols for high-acuity medico-surgical patients resulted in a missed opportunity to screen 48% of patients for HIV. Acute psychiatric patients represented a particular missed opportunity. We advocate for universal HIV screening, facilitated through electronic best practice advisories and a modified triage tailored to higher acuity patients. Implementing these changes would ensure that HIV screening is not overlooked in high-acuity ED patients, leading to early detection and timely interventions. [West J Emerg Med. 2024;25(5)817–822.]

INTRODUCTION

The US Centers for Disease Control and Prevention (CDC) reported 131.3 million visits to United States emergency departments (ED) in 2020.[1] In 2014, 7% of patients who visited the ED reported a lack of access to clinicians rather than seriousness of their medical condition as the reason for their last ED visit.[2] Approximately 1.2 million people live with HIV in the US, and 13% are unaware of the diagnosis.[3] This incidence of HIV infections, coupled with significant ED volume and use of the ED for primary care, continues to make the ED a critical point of engagement with the medical system and, thus, an opportunity to provide HIV screening.[4–7]

Since the CDC's 2006 recommendation for opt-out HIV screening for patients in all healthcare settings, there has been ample literature on universal HIV screening in the ED; however, acutely ill patients are often excluded from data collection.[8–10] One study focusing on HIV screening of acutely ill medical patients in the ED found that the majority of the patients diagnosed with HIV were admitted with AIDS and had an average of three previous healthcare visits prior to HIV screening.[11] When considering trauma patients in the ED, the literature reports HIV screening rates that range from 25.2–64.1%.[12–14] A recent paper comparing screening in trauma to medicine patients found that screening in trauma patients was lower than in medical patients, yet HIV rates were higher in trauma vs medical patients.[14] Both studies demonstrate that it is feasible to test these higher acuity patients and suggest that high-acuity patients may be another missed opportunity in the ED to identify previously undiagnosed HIV.

In our setting, if a patient is acutely ill or injured requiring immediate medical attention, the patient is announced via an overhead intercom and is moved to a resuscitation bay, bypassing the triage process that includes required HIV screening. Per New York State Public Health Law (PHL),[15] there are three exceptions to the required HIV testing offer: life-threatening illness; recent testing and no recent risk behaviors; and a determination by the attending that the patient does not have mental capacity. We hypothesize that our triage process of automatically excluding patients identified via overhead page presents missed opportunities to screen otherwise eligible patients.

Population Health Research Capsule

What do we already know about this issue?
While universal HIV screening in the ED is a well-known and reviewed clinical activity, acutely injured and medically ill patients are often excluded.

What was the research question?
Do patients who present emergently to an urban ED present a missed opportunity for HIV screening?

What was the major finding of the study?
Of the 205 acutely ill, injured or psychiatric patients in this study who bypassed typical HIV screening in triage, 98 (48%) were screened for HIV during their eight-hour ED stay, with 63 (31%) screened upon initial presentation.

How does this improve population health?
This study highlights a gap in HIV screening and a missed opportunity for testing HIV in ED patients.

METHODS

Design

This was a single-site, cross-sectional study. Our objective was to measure what percentage of patients deemed acute, and who thus bypassed the triage process that includes HIV screening in order to receive immediate medical evaluation, were able to be screened for HIV during their ED stay. The protocol was approved by the Albert Einstein College of Medicine and the New York City Health & Hospitals institutional review boards and was deemed exempt from requiring consent. This study is reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[16]

Setting

This study was conducted in a municipal, adult ED with Level 1 trauma designation in New York City with an annual census of approximately 73,000 and approximately 15% of patients arriving by ambulance. Enrollment occurred over a six-week period from June–August 2019. Three medical student researchers (SR) were present in the ED for approximately 13 hours per day, 5–7 days per week.

Research Workflow

The patient population in this study arrived in the ED as a pre-notification from prehospital services or was designated by the ambulance or walk-in triage nurse as requiring immediate medical attention. These patients were either Emergency Severity Index (ESI) 1 or 2, were announced via an overhead intercom system, and moved to a resuscitation bay. In real time, SRs reported to the resuscitation bay to record demographic data including age, gender, chief complaint, date, and time of presentation. They assigned patients to one of three clinical groups: trauma; medical;

or psychiatric. Psychiatric patients included those with agitation secondary to substance use, primary psychiatric presentation, or a dual diagnosis. The attending or resident physician determined whether the patient could engage in the HIV screening process, and the SRs checked that the patient met criteria of clear mental status, controlled pain, stable vital signs, and ability to contribute to medical history and physical examination.

If a patient could not engage in the HIV screening process, but an appropriate healthcare proxy (HCP) was present to provide consent, the patient was considered screenable. Verbal consent of the patient or the patient proxy is required prior to ordering the HIV test in accordance with New York State PHL 2781/2781a[17]; however, asking the HCP for consent for HIV testing is not typically done in our ED. Patients who were not immediately able to participate in the HIV screening process were reassessed at four and eight hours after presentation. Eight hours was chosen since the average length of stay in this ED is approximately seven hours.

We were unable to receive HIV test results for patients who were both eligible and opted in for testing. The study period straddled a hospital-wide transition to a new electronic health record system (EHR), which included a change in the HIV testing protocol, leading to lost and canceled blood tests.

Data Analysis

The primary study outcomes were the percentages of patients in each of the clinical groups (trauma, medical, psychiatric) who were able to engage in the HIV test screening process at arrival and by or before eight hours. Mean age with standard deviation were reported for each clinical group and compared to the mean of the entire cohort. Since consent via HCP is atypical in practice, we report the number of patients and the average age of this patient subgroup.

We compared the proportion of patients in each clinical group and the proportion that could engage in the HIV screening at arrival and by or before eight hours using the trauma group as the reference group. We used χ^2 to compare proportions and the Student *t*-test to compare means with the α at .05 or less for two-tailed tests of significance. Analysis was completed in Excel 2019 (Microsoft Corporation, Redmond, WA).

RESULTS

In our ED, approximately 700 patients per month are called overhead on arrival and moved to the resuscitation bay. During the six-week study period, 205 patients were enrolled, capturing approximately 20% of overhead notifications. The average time of day the SR responded to the overhead page was 3:40 PM with 23% of patients being seen after 8 PM on the overnight shift. A mean male age of 44.7 vs a mean female age of 66.6 was statistically significant in the trauma group only ($P < .001$, Table 1). The medical and psychiatric clinical subgroups had no statistically significant difference in age by gender. The proportion of patients in the medical clinical subgroup did not differ statistically from the trauma reference group (Table 1). Eight (4%) patients were included as screenable because a HCP provided consent; average age of these eight patients was 65 with a range of 23–91.

Of the 205 patients, 98 (48%) were able to engage in HIV screening during their eight-hour ED stay. Of these 98 patients, 63 (31%) were able to be screened upon initial presentation and an additional 35 (17%) in the first eight hours of their ED visit. When categorized by presentation type, 61 (54%) of 114 trauma patients, 32 (57%) of 56 medical patients, and five (14%) of 35 psychiatric patients were able to engage in HIV screening during their eight-hour ED stay. There was no statistical difference between ability to participate in screening between trauma and medical clinical presentations (Table 2). Compared to trauma and medical patients, psychiatric notifications had a significantly lower ability to be screened by the eight-hour mark ($P < .03$). The patient's level of psychiatric acuity, being in police custody, or leaving upon sobriety were reasons that 30 (86%) of the 35 psychiatric patients were not able to be screened within eight hours in the ED.

Table 1. Patient characteristics: age, gender, clinical presentation assignment.

	Number (N)	%	*P*-value[1]	Mean age	SD (±)			
Total patients	205			53	21			
Clinical subgroup				Mean age (male)	SD (±)	Mean age (female)	SD (±)	*P*-value[2]
Trauma	114	56%		44.7	19	66.6	21	<0.001
Medical	56	27%	0.78	55.3	19	64.8	20	0.09
Psychiatric	35	17%	<0.001	41.4	12	46.8	17	0.38

[1]Medical and psychiatric clinical subtype were compared to the trauma group as a reference.
[2]Mean age by gender were compared within each clinical sub-type.

Table 2. Percentage of patients by presentation type and time who were able to be screened for HIV.

Presentation sub-type	Patients (total N = 205)	Screened at presentation (t = 0 hours)	*P*-value	Screened ≤ 8 hours	*P*-value
Trauma	114	41 (36%)		20 (18%)	
Medical	56	20 (36%)	0.97	12 (21%)	0.52
Psychiatric	35	2 (6%)	<0.001	3 (8%)	0.03

DISCUSSION

This single-site, cross-sectional study demonstrated that 36% of patients who presented with emergent medical or trauma clinical presentations, thus bypassing HIV screening in triage, were able to be screened at initial presentation. An additional 21% who presented for medical and 18% for trauma presentations were able to be screened by eight hours into their ED stay. The results were statistically consistent between patients in the medical or trauma clinical presentation groups and statistically less likely for psychiatric patients. Notably, 86% of psychiatric patients were unable to be screened within eight hours in the ED.

With 1 in 7 people, or nearly 165,000 in the United States,[18] unaware of their HIV status, universal, non-targeted HIV screening in high-volume settings like EDs remains an effective strategy. Studies from both Oakland and Chicago report that approximately 50% of new HIV diagnoses would have been missed had they used a targeted, symptom- and risk-based screening methodology.[19–23] In a randomized clinical study comparing a targeted vs a non-targeted screening approach, Haukoos et al concluded that targeted screening was not superior, although it was more efficient with fewer tests completed.[24]

In addition to the screening methodology, the location of HIV screening may influence the completion of testing. Screening for HIV can occur during triage, registration, in the waiting room with kiosks and dedicated staff, or at the bedside driven by a clinician. In Tan et al, the authors reviewed 20 HIV testing protocols.[25] They found that offer rates are highest during registration and at triage, attributed to systematic questioning, reaching 100% in some studies. The offer of testing does not, however, equate to acceptance of testing. The highest acceptance rates were found at the bedside and in the waiting room, often because the person doing the screening would also be conducting the test.[25] Screening and testing protocols differ by site and resources available, making generalizability across all ED settings difficult.

Triage is one of the most important processes in the ED. To guide clinicians with this task, triage scores are used to provide an objective measure of patient acuity to focus on the sickest patients. The Emergency Severity Index (ESI) triage score is the most used in the US[26] and is the one used in our institution. Studies report great variability with poor to moderate accuracy,[27,28] especially in high-acuity patients. The American College of Surgeons Committee on Trauma recommends an over-triage rate of 25–50% on activation of trauma teams at trauma centers, and the literature reports a range of 18–91%.[29–32] This variability may be necessary to ensure prompt treatment of life-threatening injuries and illnesses, while also reducing the number of acute patients treated at non-trauma centers.[29]

Over-triage and an emphasis on immediate intervention presumes ineligibility for HIV screening in our triage process that would typically include universal, non-targeted HIV screening. Patients with high acuity (ESI 1 and 2) were not informed of HIV screening in our study, as was the case in other studies.[15,33] The focus on identifying, stabilizing, and treating acute injury or illness sensibly supersedes the HIV screening process. A true universal HIV screening protocol should include all patients regardless of ESI and include an individual assessment to determine ability to consent, rather than presumed ineligibility. While we had the manpower to reassess patients periodically, this resource-heavy model is not likely to be broadly replicable.

Even with the ability to reassess periodically, we found that 86% of acute psychiatric patients were not able to be screened for HIV at initial presentation or within eight hours in the ED. In all stages of the HIV care cascade, the patient population that struggles with mental health is met with challenges. Mental health disorders increase the risk of HIV acquisition by 4–10 times[34,35] and, at the same time, interfere with HIV testing and learning one's HIV status.[36] The struggle with depression, anxiety, trauma, and substance use is a substantial barrier to HIV prevention methods (ie, condoms, pre-exposure prophylaxis), and adults with mental health disorders were more likely to be involved in behaviors associated with HIV acquisition or transmission than adults without mental disorders.[37,38] Struggles with mental health contribute to poor retention in care and anti-retroviral adherence.[38,39] Without the benefit of viral suppression achieved with anti-retroviral treatment, acute-care hospitalizations for patients with HIV and mental health disorders are higher than for HIV patients without mental health disorders.[39,40] Of the acute patients presenting to the ED, our findings suggest that patients with mental health presentations and, in particular, acute mental health crises may require an alternative or additional approach to HIV screening and testing.

The ED is one place to start the care cascade with universal testing. However, we see that the acute patient, and especially the patient with acute mental health presentations, may require an alternative approach, other than during initial

triage, to ensure that screening occurs. Using the EHR has been shown to optimize screening and testing and to increase identification of new HIV infections.[41,42] Building an ESI 1 and 2 order set that includes an HIV test could be one means to address HIV screening into the care of acutely ill patients. The HIV test in the order set would require the clinician to acknowledge screening eligibility and verbal consent prior to finalizing the order. A best practice advisory with scripts for clinicians to use opt-out language could be programmed to fire if patients haven't yet been screened during the current ED encounter and haven't received HIV testing in a predetermined look-back period. This strategy could address any patient who may have missed HIV screening or testing in the ED, not just our acute patients who miss our triage screening. Any new approach or combination of approaches would require implementation plans and processes and future investigation before being accepted as solutions.

LIMITATIONS

This was not a complete sample of all acute patients presenting to the ED during the study period since we did not have SRs 24 hours a day. This was a single-site study in a Level I trauma center with high volume, which contributes to problems with generalizability mainly for non-urban hospital settings. The approach to HIV screening is likely to be variable in other EDs and may not occur as part of the triage process. Differences in laws and regulations for testing and consent may also contribute to the lack of generalizability of these findings. The determination of being able to be screened is clinician-dependent, with possible bias toward HIV screening and testing in the ED and whether people should be asked. We are not able to report the disease prevalence in this small dataset. The HIV test results were not reported due to inconsistent testing and lab protocols for HIV testing as the hospital migrated to a new EHR system during the testing period. While not the focus of the study, we acknowledge that this data and collection of HIV risk factors for patients would have been a valuable addition to the study.

CONCLUSION

This study highlights a gap in HIV screening in EDs and a missed opportunity for testing for HIV in ED patients. We found that close to 48% of patients who present for emergent care and missed the HIV universal screening that occurs during triage in our institution could engage in the screening process either at presentation or during their ED stay. And we identified an already vulnerable group—psychiatric patients— that appears to be ineligible for screening within an ED stay, leaving us to consider whether these patients will determine their HIV status. Future research is needed to assess the effectiveness of electronic best practice advisories and built-in HIV screening and testing order sets in higher acuity patients, as well as approaches to meeting the needs of the acute and vulnerable psychiatric patient.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Preventive Health Services Offered in a Sampling of US Emergency Departments, 2022–2023

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Section Editor: Faith Quenzer, DO, MPH
Submission history: Submitted September 28, 2023; Revision received February 23, 2024; Accepted April 5, 2024
Electronically published July 17, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18488

Introduction: In the United States, more chronic and preventive healthcare is being delivered in the emergency department (ED) setting. Understanding the availability of preventive health services in the ED setting is crucial. Our goal was to understand the availability of a subset of preventive health services in US EDs and explore how that has changed over time.

Methods: In 2022–2023, using the National Emergency Department Inventory (NEDI)-USA, we surveyed a random 20% (1,064) sampling of all 5,613 US EDs. We asked directors of these EDs about the availability of and preference for 12 preventive health services, social worker availability, self-reported percentage of uninsured ED patients, and measures of ED crowding. We also asked about perceptions of barriers to implementing preventive health services in the ED. We used unadjusted and multivariable logistic regression models to compare service frequency in 2022–2023 to prior findings from 2008–2009 that represented a 5.7% random sampling of all EDs.

Results: Among 302 responders to the 2022–2023 survey (5.4% random sampling, 28.4% response rate), 94% reported offering at least one preventive health service, with a median of five services. The most common service offered was intimate partner violence screening (83%), while the least common was routine HIV screening (19%). Seven services (eg, intimate partner violence, alcohol risk, and smoking cessation screening) had a higher odds of being offered in 2022–2023 than in 2008–2009; findings were unchanged in sensitivity analyses. A small proportion of directors opposed offering preventive health services. However, many expressed concerns that preventive health services in the ED would lead to longer lengths of stay (56%), increased costs to their ED (58%), a diversion of staff time from providing acute care (50%), or that their patients would not have access to adequate follow-up (49%).

Conclusion: Nearly all EDs offer at least one preventive health service. Many offer multiple services; rates were higher than those identified in 2008–2009, in both unadjusted and multivariable models. Although limited by the response rate, this work provides the most recent and comprehensive snapshot of the type and frequency of a subset of preventive health services currently offered in US EDs. [West J Emerg Med. 2024;25(5)823–827.]

INTRODUCTION

A large proportion of US healthcare is delivered in the emergency department (ED) setting.[1] As an entry point into the healthcare system, EDs are providing an increasing proportion of both emergent and non-emergent (ie, chronic and preventive) care,[1,2] in part due to insufficient access to primary care, population growth, and an aging population with increasingly complex medical needs. The recent end of the Public Health Emergency for COVID-19 and subsequent unwinding of the Medicaid continuous enrollment provision likely entails greater ED utilization for both chronic and preventive healthcare needs.[3] However, it remains unclear what preventive health services are currently being offered in the ED setting and how this has changed over time. Findings from this study could help frame the changing landscape around ED reimbursements and incentive structures.

A study conducted in 2008–2009 engaged ED directors, determined the availability of a subset of preventive health services offered in a random sampling of US EDs, and characterized perceived barriers to implementing these services.[4] Our objective was to provide an updated assessment of the availability of a subset of preventive health services following the onset of COVID-19 in EDs, given the expectation that resources are increasingly allocated to preventive care. The underlying goal was to offer insight into and contribute to the knowledge base supporting efforts to improve and optimize healthcare delivery within the ED setting.

Population Health Research Capsule

What do we already know?
A large proportion of all United States (US) healthcare is delivered in the emergency department (ED); this includes a growing amount of preventive care.

What was the research question?
To understand how the provision of a subset of preventive health services in US EDs has changed over time.

What was the major finding of the study?
Nearly all EDs studied (94%) reported offering at least one preventive health service, with a median of five services.

How does this improve population health?
This work provides the most recent snapshot of the type and frequency of a subset of preventive health services currently offered in US EDs.

METHODS

We used the National Emergency Department Inventory (NEDI)-USA as a sampling framework for this study. The NEDI-USA is a comprehensive database of all non-federal, non-specialty US EDs; information available at the ED-level (eg, teaching hospital affiliation and annual visit volume) is updated annually.[5] From NEDI-USA, we generated a random list of 1,064 EDs (≈20% of all US EDs).[5] On the basis of this random list, directors were contacted up to three times (from Winter 2022 to Spring 2023) via e-mail or mail. Non-responders were contacted by trained research assistants via telephone.[4]

The instrument was a previously implemented survey (2008–2009) that characterized the availability of (and preference for) 11 preventive health services, ED-level social worker availability, self-reported percentage of ED patients who were uninsured, and measures of ED crowding in a 5.7% random sampling of US EDs (Appendix).[4] If a service was not offered, the survey asked whether it could be offered given existing resources. Directors were also asked about perceptions of barriers to implementing preventive health services in the ED. In line with updated US Centers for Disease Control and Prevention (CDC) recommendations encouraging hepatitis C screening, the 2022–2023 survey also inquired about availability of routine hepatitis screening.[6] Otherwise all other data elements, including the definition of crowding (ie, at least one of three CDC criteria: average waiting time of one hour or greater; left without being seen rate of 3% or more; or any time on ambulance diversion) were unchanged.[4]

In initial analyses, we summarized data with descriptive statistics (eg, counts, proportions, and medians with interquartile ranges [IQR]), and comparisons were conducted using statistical tests (eg, $\chi 2$ and Kruskal-Wallis tests). Logistic regression was then employed to assess the odds of preventive health services being offered more frequently in 2022–2023 than in 2008–2009. We also conducted sensitivity analyses with multivariable models adjusting for critical access hospital status. These data were summarized with odds ratios (OR) and 95% confidence intervals (CI). A two-tailed $P < 0.05$ was considered statistically significant. Analyses were completed in Stata 15.1 (Stata Corp, College Station, TX) and R Studio (https://www.R-project.org), and figures were created in R and Datawrapper release 0.4.6 (https://app.datawrapper.de/). This study was approved by the Stanford University Institutional Review Board and followed the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines for observational studies.[7]

Table. Characteristics of responders, non-responders, and the National Emergency Department Inventory-USA.

	NEDI-USA, N = 5,613%	*Responders, n = 302% (95% CI)	Non-responders, n = 762% (95% CI)	*P*-value
Median annual visit volume (IQR)	20,000 (7,300–42,350)	14,216 (5,000–37,000)	16,572 (7,300–38,000)	0.07
Hospital type				
Teaching hospital	5	6 (4–9)	5 (3–6)	0.36
Trauma center				0.85
No	83	85 (80–88)	84 (81–86)	
Basic	8	7 (5–11)	7 (6–9)	
Advanced	9	8 (5–12)	9 (7–11)	
Critical access hospital	24	41 (36–47)	32 (29–36)	<0.01
Urban influence code				<0.01
Urban	66	51 (45–57)	57 (53–60)	
Large rural	14	13 (10–17)	17 (15–20)	
Small rural	20	36 (31–42)	26 (23–29)	
US region				0.06
Northeast	11	12 (9–16)	14 (11–16)	
Midwest	27	34 (29–40)	36 (32–39)	
South	43	34 (29–39)	37 (34–41)	
West	19	20 (16–25)	14 (11–16)	

*Confidence intervals not calculated for NEDI-USA because entire US population of EDs is included; values do not rely on an estimate. The 302 responders (28.4% response rate) reflect a 5.4% random sampling of all 5,613 EDs in the US; NEDI-USA reflects ED-level information from the 2019 NEDI-USA.
CI, confidence interval; *ED*, emergency department; IQR, interquartile range; *NEDI-USA*, National Emergency Department Inventory-USA.

RESULTS

Characteristics of responders, non-responders, and NEDI-USA overall are presented in the Table. The 302 responders (28.4% response rate) reflect a 5.4% random sampling of all 5,613 US EDs. With the exception of a higher proportion of responders representing small, rural, critical access hospital EDs (compared to NEDI-USA and non-responders), ED characteristics were otherwise similar. For context, characteristics of responders in 2008–2009 and 2022–2023 are presented in Supplemental Table 1; there were a similar number of total responders in 2008–2009 (277, 5.7% random sample of all EDs). In 2022–2023, responders were similarly more often from critical access hospitals than in 2008–2009; they also reported less ED social worker availability and—in the context of the previous passage of the Affordable Care Act—were less likely to report having more than 35% of their patients being uninsured.[8]

Nearly all (94%) directors reported that their EDs routinely offer at least one of the 12 preventive health services, with a median (IQR) of 5 (3–7) services offered. The most common service offered was intimate partner violence screening, while the least common was routine HIV screening. Nearly all the preventive health services, except HIV and hypertension screening, were more frequently offered in 2022–2023 than in 2008–2009 (Figure 1). Seven of the services had higher odds of being offered in 2022–2023 than in 2008–2009; findings were unchanged after adjustment for critical access hospital status (Supplemental Table 2).

Further, among directors who reported that their ED did not offer a particular preventive health service, many still reported that resources were available to offer such services (Figure 2). When asked about their "first choice" of service they would most like to offer, alcohol risk screening, counseling, and referral was most common, while routine HIV and hepatitis screening were least common. Only a small proportion of ED directors thought that preventive health services should not be offered in the ED. However, as highlighted in the Supplemental Figure, many expressed concern (ie, strongly agreed or agreed) that offering preventive health services in the ED would lead to either longer lengths of stay (56%) or increased costs to their ED (58%), or would require a diversion of staff time from providing acute care (50%), or that their patients would not have access to adequate follow-up (49%).

DISCUSSION

Among a random sampling of US EDs, nearly all offered at least one preventive health service, many currently have the resources to offer more, and only a minority of directors

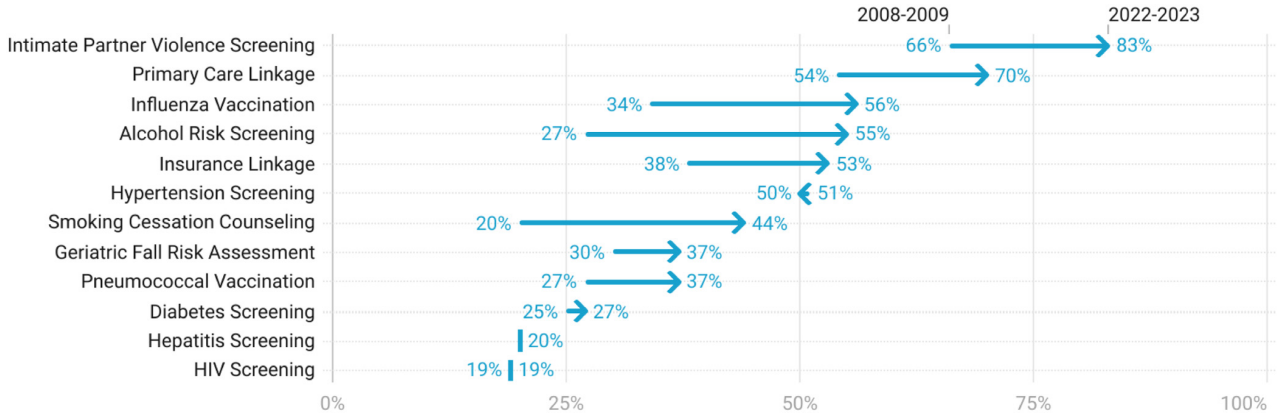


Figure 1. Availability of preventive health services, 2008–2009 and 2022–2023.
The individual preventive health services are sorted by most frequent to least frequent. Hepatitis screening was not included in the 2008–2009 study; values reflect 2022–2023 data. Nearly all the preventive health services were more frequently offered in 2022–2023 than in 2008–2009.

expressed the belief that preventive health services should not be offered in the ED setting. The results represent an increase in both the overall proportion of EDs offering at least one preventive health service and the median number of services offered per ED since 2008–2009.[4] This finding is consistent with recent work demonstrating that EDs are providing a growing amount of chronic and preventive care in the US.[1,2] A component of the results might be explained by the high proportion of responders from critical access hospitals and the unique mission these EDs have within their local communities. Reassuringly, adjustment for critical access hospitals did not materially alter the observed temporal difference.

Although we are unable to comment on the underlying reasons why (or why not) a particular ED offers a particular preventive health service, the reasons are likely multifactorial. Services that are mandated or strongly encouraged, compared to services that are neither, are likely more often offered. Further, services that are less time- and resource-intensive (eg, a series of screening questions compared to checking a hemoglobin A1c or performing a HIV antigen/antibody test) are also more likely to be offered. A component likely also depends on both the ED and its available resources, and the unique needs of the patient populations served in these EDs.

The observed changes occurred in the setting of the recent unwinding of Medicaid's continuous enrollment provision, with the prospect that millions of Americans will lose—or have already lost—Medicaid coverage.[3] This loss will likely translate into increased rates of ED utilization for both emergent and non-emergent (eg, chronic and preventive) care across the country. Given the staffing, crowding, and

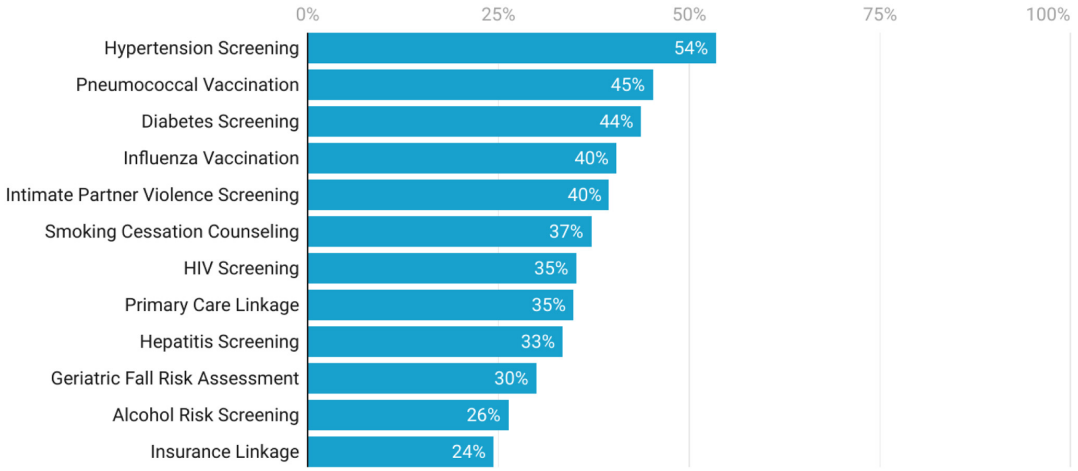


Figure 2. Ability to offer preventive health services with existing staff and funding in 2022–2023.
Emergency department directors were asked whether they had a system in place to routinely provide a particular preventive health service. Those who reported "no" (ie, did not offer a particular service) were further asked whether they could already offer that service routinely given existing staff and funding. The individual preventive health services are sorted by most to least frequently reported as being possible to offer.

boarding crises in EDs, which were exacerbated by the COVID-19 pandemic, ED resources are expected to be further strained.[9]

LIMITATIONS

Our work has several important limitations, among them our survey-based approach and response rate. A survey is the only feasible means to study this topic; these services are not typically billed for or trackable in any systematic national sample of US EDs. Reassuringly, our goal of obtaining a similarly sized random sampling of EDs as in 2008–2009 was met, and our response rate is consistent with recent work demonstrating survey-fatigue among healthcare workers during COVID-19 and lower survey response rates.[10] For context, we provide detailed comparisons of how responders compare to non-responders, NEDI-USA, and to 2008–2009 responders. Given this limitation, and that both timepoints reflect distinct random samplings, we intentionally avoided formal pairwise comparisons between 2008–2009 and 2022–2023 responders. Instead, we incorporated a conservative approach using descriptive statistics and conducted regression to demonstrate that adjustment for critical access hospital status did not materially change our findings.

Second, we can only comment on availability for the preventive health services we considered; neither could we comment on the fidelity, comprehensiveness, or effectiveness of any of the preventive health services studied. Our objective was to provide an updated assessment of the availability of a subset of preventive health services in the ED setting, with the goal of highlighting the increasing amount of non-emergent care being provided. Third, given our goal of using the same survey vehicle to facilitate comparisons against prior work we cannot comment on the extent of, or ED-level differences in, these services. These issues are important and merit future investigation but are beyond the scope of the current work. These issues, and work focused on cost effectiveness, reimbursements, and financial incentives of preventive health services offered in ED settings, are the focus of current and future efforts by our group. Despite these limitations, our findings represent the most current and comprehensive snapshot of the availability and frequency of preventive health services currently offered in US EDs.

CONCLUSION

Nearly all. EDs in the United States offer at least one preventive health service. Many EDs offer multiple services, and rates were higher than those identified in 2008–2009 in both unadjusted and multivariable models. Although limited by the low response rate, this work provides the most recent snapshot of the type and frequency of a subset of preventive health services currently offered in US EDs.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Exploring Medical Student Experiences of Trauma in the Emergency Department: Opportunities for Trauma-informed Medical Education

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Section Editor: Andrew Phillips, MD, MEd
Submission history: Submitted October 6, 2023; Revision received March 20, 2024; Accepted March 25, 2024
Electronically published June 28, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18498

Purpose: During the third-year emergency medicine (EM) clerkship, medical students are immersed in traumatic incidents with their patients and clinical teams. Trauma-informed medical education (TIME) applies trauma-informed care (TIC) principles to help students manage trauma. We aimed to qualitatively describe the extent to which students perceived the six TIME domains as they navigated critical incidents during their EM clerkship.

Methods: We employed a constructivist, modified grounded theory approach to explore medical students' experiences. We used the critical incident technique to elicit narratives to better understand the six TIME domains as they naturally appear in the clerkship. Participants were asked to describe a traumatic incident they experienced during the clerkship, followed by the clerkship's role in helping them manage the incident. Using the framework method, transcripts were analyzed 1) deductively by matching transcript excerpts to relevant TIME domains and 2) inductively by generating de novo themes to capture factors that affected students' handling of trauma during critical incidents.

Results: Twelve participants were enrolled and interviewed in July 2022. "Safety" was the most frequently described TIME domain, whereas "Gender, Cultural, and Historical issues" and "Peer Support" were discussed least. Inductive analysis revealed themes that hindered or supported their ability to manage traumatic experiences, which were grouped into three categories: 1) student interactions with the learning environment: complex social determinants of health, inequalities in care, and overt discrimination; 2) student interactions with patients: ethically ambiguous care, witnessing acute patient presentations, and reactivation of past trauma; and 3) student interactions with supervisors: power dynamics, invalidation of contributions, role-modeling, and student empowerment.

Conclusion: The six TIME domains are represented in students' perceptions of immediate, stressful critical incidents during their EM clerkship, with "Safety" being the most commonly described; however, the degree to which these domains are supported in students' experiences of the EM clerkship differ, and instances of inadequately experienced domains may contribute to student distress. Understanding the EM clerkship through the specific lens of students' experiences of trauma may be an effective strategy to guide curricular changes that promote a supportive learning environment for students in the emergency department. [West J Emerg Med. 2024;25(5)828–837.]

INTRODUCTION

Over recent years, emergency departments (ED) across the United States have served as points of care for victims of widening health disparities, increasing sociopolitical unrest, the COVID-19 virus, and increasing numbers of mass shootings. The ED workplace also serves as a clinical learning environment for learners across multiple health professions, routinely exposing them to trauma that is intrinsic to emergency medicine (EM) practice and care delivery in the US. Medical students are at high risk for sustaining psychological and emotional trauma from their encounters with patients and interactions with members of their ED care teams— often for the first time in their professional careers.[1–3]

Students have previously reported that their undergraduate medical education (UME) training has not adequately prepared them to cope with such stressful events.[2] An inability to positively cope with stress can negatively impact students' health, contribute to anxiety, depression, and/or detachment.[4–6] Not only can this stress have a psychological impact on well-being, but it can also impact students' ability to advocate for themselves, their peers, and their patients over the course of their training.

Research suggests that the impact of stressful events on students can be lessened or amplified by structural support embedded in formal curriculum. Frameworks, such as trauma-informed medical education (TIME), have outlined what structural support may look like in UME. Trauma-informed medical education represents an approach that applies trauma-informed care (TIC) principles to UME to help students recognize and address trauma in real time.[7] It aims to create a learning culture guided by six trauma-informed domains: safety; trust and transparency; peer support; collaboration and mutuality; empowerment, voice, and choice; and cultural, historic, and gender considerations (Table 1).[8]

Population Health Research Capsule

What do we already know about this issue?
Medical students are immersed in traumatic incidents when they rotate through the ED during the emergency medicine (EM) clerkship.

What was the research question?
To what extent do medical students perceive the domains of trauma-informed medical education (TIME) as they navigate the ED clinical environment?

What was the major finding of the study?
The degree to which TIME domains are supported in students' experiences of trauma differ, and instances of inadequately experienced domains may contribute to student distress.

How does this improve population health?
Better identifying opportunities for trauma-informed education in the EM clerkship can support students and their well-being.

Table 1. Trauma-informed medical education domains.

Domain	Areas explored
Safety	Could the student express their thoughts about the situation openly? Did the student wonder if they would be negatively impacted if they voiced their opinion?
Trust and transparency	Was the student briefed about the situation before they experienced it?
Peer support	Were any of the student's peers in the situation, too? How did the student interact with these peers?
Collaboration and mutuality	Was the student able to interact with their faculty? Did the student witness a lack of professionalism? What happened? How was this lack of professionalism responded to?
Empowerment, voice, and choice	If the student had feedback for your clerkship and/or other people, how did they deliver this feedback? If the student needed to take time away from the situation or clerkship, was there room in their schedule to do so? How could they request this time if they needed it?
Cultural, historic, and gender considerations	Were there others in this situation who had a similar racial, ethnic, or gender identity as the student? Were there others whose racial, ethnic, or gender identities were different from the student's?

While some medical colleges have incorporated TIME domains into their curriculum,[9] the extent to which TIME domains inform the third-year EM clerkship curriculum remains unclear and unexplored. By better understanding the student experience of the third-year EM clerkship, educators could take practical steps to adequately prepare learners for the challenges posed by the ED clinical learning environment. In this qualitative study, we aimed to describe specific TIME domains students experience as they are naturally immersed in the clinical environment. Specifically, we aimed to identify to what extent students perceived TIME domains to be present within the third-year EM clerkship curriculum to support their ability to navigate high-stress critical incidents in the ED.

MATERIALS AND METHODS

We took a modified constructivist grounded theory approach to collect, describe, and analyze third-year medical students' perceived stressful incidents during their EM clerkship in their third-year of medical training. We employed the critical incident technique (CIT), a data collection method that guides participants to disclose vivid descriptions of a "critical incident." Formally, per CIT a critical incident is defined as "any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act."[10] As part of our CIT method, participants were asked to recount and describe a specific, stressful critical incident that they experienced during their EM clerkship. It is important to note that two study investigators have considerable experience with qualitative research methods (SD, DP), and one study investigator has extensive experience with the CIT method (DP). Also, one research team member (SD) is a trained trauma counselor with an extensive TIC background. The study protocol was approved by the institutional review board of Thomas Jefferson University, and data was collected in July 2022.

Population and Sampling Strategy

Because we sought to understand the experiences of medical students in the EM clerkship, we intentionally and exclusively sampled third-year medical students. We recruited third-year medical students who had completed their EM clerkship at an urban, academic, tertiary-care medical center at Thomas Jefferson University Hospital in Philadelphia, Pennsylvania. Two study investigators (KR, DP) are faculty in this department and are familiar with the practice environment.

Student participants were identified through purposive convenience sampling. In July 2022, the study team sent recruitment emails to student listservs at our respective medical schools. Criteria for inclusion were that the participant was a third-year medical student and had successfully completed the required EM clerkship during the study period. Participants were enrolled through targeted emails describing the study and assurance that participation was voluntary. Study participants and their respective narratives were de-identified using an internally developed coding scheme.

Data Collection

The study consisted of a series of critical incident interviews with third-year medical students, each 30–45 minutes long, that were conducted in August 2022. Informed consent was obtained from recruited students. After a brief demographic electronic questionnaire was completed, interviews were scheduled with participants. Each interview was conducted virtually using video conferencing software (Zoom Video Communications, Inc, San Jose, CA) with two members of the research team who were trained in eliciting critical incidents through interviews. Participants were compensated $75 for their participation in the study.

Interviews were conducted using a detailed interview protocol with questions that were informed by the TIME framework (Appendix). The interview protocol was developed by the study investigators and was piloted with two medical students to optimize interview questions. Pilot interview data were included in the analysis. Student participants were asked to describe a key incident during their EM clerkship when they experienced a significant trauma. An audio recording from each Zoom interview was transcribed using automated transcription software, which was then manually reviewed by members of the study team for transcription accuracy. Transcripts were de-identified.

Analysis

Data for each participant's transcript was reduced to capture a critical story. For each transcript, the participant's narrative was re-organized chronologically into a coherent, re-storied narrative. By taking a constructivist and modified grounded theory approach, we inductively analyzed re-storied critical incidents. Through a series of several iterative conversations, and per CIT best practices, we manually developed assertions (organized in Excel [Microsoft Corp, Redmond WA]) about the meaning of each incident as it related to the research question. To organize overarching themes from assertions, we conducted a series of virtual card-sorting activities that were facilitated through several virtual Google Jamboard activities. Iterative cross-incident analyses with the study team informed connections, associations, and relationships for themes that emerged from the assertions. This allowed our team to generate an overarching framework of observed themes and relationships.

To ground our inductive findings and more directly assess the degree to which students' perceived TIME domains during their clerkship, we undertook a deductive approach in which excerpts from each participant's narrative were matched with the most relevant TIME domain discussed

(ie, a vivid description of the impact the ED learning environment had on a student's ability to openly express their opinions was matched to the TIME domain of "Safety"). For critical incidents where multiple TIME domains were identified, we selected the most dominant TIME domain. To ensure internal validity of data interpretation, the entire team of investigators met to review all inductive assertions and deductive categorizations. Discrepancies were resolved through iterative conversations over the 10-month study period.

RESULTS

We identified and interviewed 12 student participants. Study size was informed by data saturation, information power, and analytical and data sufficiency.[11] The average age of participants was 25.5 years old; 50% identified as male and 50% as female. The majority of participants identified as White (8 of 12 participants) (Table 2). Participants' critical incidents aligned with deductive codes borrowed from the TIME framework (Table 3). Participants described elements of "Safety," whether psychological or physical, most frequently across all 50 interviews, whereas "Gender, Cultural, and Historical issues" and "Peer Support" were discussed the least (13 each).

Analysis of critical incidents with cross-case comparisons revealed that themes were classified into three categories: 1) student interactions with the ED clinical learning environment; 2) student interactions with their supervisors; and 3) student interactions with their patients (Table 4).

Table 2. Demographics of participants.

Characteristic	N = 12
Age	
21–24	4 (33%)
25–27	5 (42%)
27+	3 (25%)
Gender	
Man	6 (50%)
Woman	6 (50%)
Race	
Asian/Native Hawaiian/Pacific Islander	3 (25%)
White	8 (67%)
Hispanic	1 (8%)

Student Interactions with the ED Clinical Learning Environment

Navigating Social Determinants of Health

Students struggled with having to navigate and reconcile the complex social determinants of health (SDoH) for patients seeking care in the ED. This was often accompanied by intense emotion and stress in students.

> So, I obviously was a little stressed out because patients crying obviously is not something I have experienced . . . That's just something that I hadn't done on my own yet. And so being in the patient's rooms with them crying and me just trying to be like, "What do I do? Do I want to fix it right away?" So I was like, "Maybe I should go get someone. Maybe he wants to talk about why he's feeling this way." I wasn't really told how to deal with that.

Students experienced uncertainty when navigating overt patient suffering, psychosocial factors that further complicated care plans, and having conversations with their patients. Consequently, students desired more support during these encounters in the form of greater preparation for the patient encounter, emotional support, and effective role-modeling from their supervisors. They also expressed an interest in opportunities to debrief and make sense of these challenging encounters.

Responding to Observed Inequities in Care

Students experienced hesitation and distress when navigating instances of perceived care inequities with their treatment teams (eg, when the reason why two patients with similar presentations receiving different treatments was unclear).

> And this patient looks exactly the same. . . . And I was sort of like, What's the difference? They were like, "You could tell this one's [the patient's] uncomfortable." I thought the other one looked uncomfortable, but whatever. We ended up doing just a lot more for her, and I couldn't really identify any difference between the two cases. I thought they were both the same . . . "Hey, did that just happen, though?" I thought it happened. Or like, "Am I hallucinating?"

Inequity in care is a concept repeatedly introduced in the preclinical years; however, students felt unprepared to navigate discussions with their colleagues when they recognized inequity directly influencing the care they were delivering. Moreover, a third-year medical student's relative lack of experience in the clinical realm and unfamiliarity with the unique environment of their rotation (eg, team dynamics, patient population, location), added further ambiguity to the situation. Students felt unable to communicate their concern and advocate for their patients.

Navigating Race, Gender, and Socioeconomic Discrimination

Discrimination (ie, racial, cultural, and/or gender-based) in the workplace hindered the psychological safety of students belonging to minority groups that were

Table 3. Frequency of deductive themes.

TIME domain	Representative quote(s)	Frequency table (as number of instances across all transcripts)	Percentage of all instances (%)
Safety	"I made an appointment with school counseling services. I felt fine. I kind of thought I was going to have, like, weird dreams or feel weird. And I was totally unaffected, but I don't know. You never know. I don't think I've ever seen someone . . . been there when they pronounce someone dead. It was kind of my first experience and even then, I was still periphery. [Counseling] was like, 'I was going to reach out to you anyway. We made a list of those people who came up at the school counseling center's meeting.' I was feeling fine, so it wasn't like, 'Wow, that's great!'; but it was kind of nice for someone to be, 'It's okay that you feel fine. You shouldn't feel bad that you're not, like, haunted by this,' if that makes sense."	51	34
Empowerment, voice, choice	"So I read the attending a little bit on edge, listening to what they're saying, and then they say, 'Yeah, like you didn't even look into their mouth. And yeah, it just was not, not organized.' And I was like in my head, like thinking, "Wait, what? Like I 100% did a neuro exam, and I had him open up his mouth and say, check for nine and ten. And then I had him point his tongue out to, to the right and left." And then I was like, 'Okay, what do I do now? Do I contradict my attending? Or just say, 'Sure?'"	30	20
Collaboration and mutuality	"The physician brought the event up quickly. Once he was on the phone, consulted surgery and then hung up and he said, 'It's really important that we take ownership of what happened here. Instead of lying and/or making excuses, we take ownership and say what happened.' But then he still had to go do other things, and then I was the one who initiated [more conversation about the event], which I think was appropriate from my sense and from the attending sense, a conversation about the event, mostly for a learning experience for me to talk about what happened."	25	17
Transparency and trustworthiness	"I think it would have been nice to have some acknowledgment because like, part of the frustration is feeling like you're the only person who sees it this way, you know? And it's like, it would have been nice if my attending turned to me and was like, 'Hey, like that was kind of problematic. I hope you don't think that we all think that way because we don't like that kind of thing.' I think it would have counteracted a little bit of the disillusionment I feel towards medicine in general."	18	12
Gender, cultural, and historical issues	"I think there's always that feeling, especially like as a young female trainee, I feel like I kind of have to put on a brave face and not show that much emotion. I don't know. Like it's good to appear invested in your patients, but it's not good to be like, 'Oh, like this is the worst thing that's ever happened, blah, blah, blah.' Because obviously all these people have seen worse. So, no, I don't think that anyone would have written me a bad review if I was showing that I was upset. But I do think it subconsciously impacts what people think of you. Like, you know, maybe she's not cut out for this field or something."	13	8.7
Peer support	"And so, I think that made me feel like I had to be the one responsible for ensuring that this woman was able to get home and avoid further intimate partner violence. I really felt like I was the one who decided, like, whether she would be undergoing more violence that night."	13	8.7

TIME, trauma-informed medical education.

Table 4. Framework of inductive themes.

Overarching grouping	Individual themes
Students' interactions with patients	Reactivation of past trauma
	Emotional discomfort associated with navigating ethics and uncertainty
	Emotional discomfort when witnessing high acute patient care for the first time
Students' interactions with supervisors	Power dynamics diminishing student clinical autonomy
	No validation for student clinical contributions
	Role-modeling as a means to support students
	Empowerment and feedback as a means to create psychological safety
Students' interaction with the ED clinical learning environment	Navigating social determinants of health
	Responding to observed inequities in care
	Navigating race, gender, and socioeconomic discrimination

ED, emergency department.

discriminated against—even when these acts were not directed to students (eg, at staff or patients belonging to the student's minority group).

> It's also disappointing because I felt like my attending didn't really say anything to go against that. He wasn't agreeing with her, but he was like, "Oh yeah." He kind of just dismissed it and didn't engage too much.

A discriminatory experience coupled with silent complacency (ie, a lack of acknowledgment of such events from clinical team members, particularly faculty and supervisors who were tasked with advocating, teaching, and protecting students) complicated students' responses to such events and marginalized their role in the clinical workplace. Importantly, students of color (as in the above case) felt less empowered on the team, especially when being their team's only member of color.

Student Interactions with Supervising Residents and Attendings

Power Dynamics Diminishing Student Clinical Autonomy

Power dynamics interfered with students' ability to advocate for their patients and contributed to their stress when immersed in the clinical environment. These power dynamics hindered their ability to clarify complex medical and social cases because they feared being perceived as unknowledgeable. Furthermore, they were less likely to ask for a discussion and/or debriefing to resolve their feelings surrounding patient encounters as they did not want to be perceived as emotional or "weak":

> I felt sad and kind of disappointed that other physicians weren't taking it seriously, that we needed to get her out of there and we could at least provide resources, or we could do more to acknowledge that she's here for intimate partner violence-related concerns and that no one really cared about what happened after she left.

Students often found themselves torn between the desire to invest more time in caring for and advocating on behalf of their patients and the need to maintain efficiency, subordination, and a strong performance for evaluators who assessed their clinical skills, often overlooking unassessed yet equally vital interpersonal skills (ie, demonstrating empathy, advocating for patients).

> And I didn't really feel like I could explain to the physician, "Hey, this is something that is really important to me that I think should be handled differently." I just didn't feel that was my place with someone who had a lot of control over my grade. It was this war between what I feel was best for my future grades and what I felt was morally right.

No Validation for Student Clinical Contributions

A lack of acknowledgment of students' contributions to the care team, either in real time or on their evaluation, caused students to experience distress. In complex clinical situations where students felt they had meaningfully contributed to patient care, a lack of validation of the student's composure, adaptability, and/or judgment hindered their ability to assimilate to the care team and triggered dissociation from and disillusionment toward the clerkship experience.

> You get an evaluation for every single stuff you work on. My EM evaluation didn't say anything about [the mass shooting event]. It wasn't like I needed anyone to be "Wow, she didn't freak out" or "She was calm." It didn't have to be that. And my evaluation wasn't bad,

> it was fair . . . Just to me, that's kind of a large event that happened. It just felt kind of weird that that context was missing.

Role-Modeling to Support Students

Modeling of integrity, professionalism (ie, accountability), and debriefing by supervisors helped students process poor clinical performance and gain closure during iatrogenic complications.

> The physician brought the event up quickly. Once [he[hung up after talking with surgery, he said, "It's really important that we take ownership of what happened here. Instead of lying and or making excuses, we take ownership." Then he personally addressed my feelings and my potential blaming of myself for the situation and reassured that it wasn't my fault. And these things he said, which is admirable, and how you take full, full ownership for the complication.

Participant narratives suggested that taking ownership over a stressful or traumatic incident offered a sense of agency and opened opportunities for positive clinical learning, instead of leaving the student feeling powerless to speak or act on the event. The negative impact of performing a clinical error was mitigated based on how next action steps were framed.

Empowerment and Feedback to Create Psychological Safety

As students worked through a variety of clinical encounters during their rotation, one factor that was often described as supporting students' psychological safety was feeling empowered by their team and receiving timely feedback before, during, and/or after a clinical situation.

> Them putting that trust in me . . . made me want to try to do the best that I could in this situation with a limited number of experiences.

In this particular incident, the student found themselves in an emergent encounter with a patient in cardiac arrest and was tasked with intubating the patient. Although the student felt uncertain, the team's trust and empowerment to perform a critical role improved their sense of agency and security and helped motivate them to perform the task.

Student Interactions with Patients

Reactivation of Past Trauma

Clinical situations involving patients who were victims of domestic violence reactivated trauma in students with similar experiences.

> [Listening to her disclosure] was definitely hard because I've had not as extreme but similar experiences. I resonated with her, and I think that made it a lot more challenging. We could at least provide resources or do more to acknowledge that she's here for intimate partner violence-related concerns. No one really cared about what happened after she left, or people were not even totally aware of it.

The clerkship curriculum did not prepare this student to manage the guilt associated with treating domestic abuse victims (or a sense of "not doing enough"). The student felt disappointed that other members of the clinical team were not acknowledging concerns for future domestic violence risk. Consequently, the student did not feel they could openly express themselves with their superiors who had control over their summative assessment (ie, grade).

Emotional Discomfort Associated with Navigating Ethics and Uncertainty

Ethically ambiguous situations abound in medicine. However, these ethically challenging situations—such as instances in which patients were physically/chemically restrained, procedures that were performed on patients with altered mental states, or critical medical decisions that were made by patient surrogates—caused students to experience emotional discomfort that made it difficult to navigate these situations in real time.

> [The facial laceration] needed to be repaired. But the patient, understandably, who was confused really didn't want us touching her and didn't want it done . . . What we ended up doing is holding the patient down while the resident repaired the facial laceration. And during the entire time, she was obviously very unhappy, kept on telling us to stop, and told the resident that she would get her fired. We were able to successfully complete the procedure, which was our goal.

Emotional Discomfort Witnessing High-Acuity Patient Care for the First Time

The educational experience of the EM clerkship is primarily based on clinical encounters. However, witnessing acute manifestations of patients' conditions, such as physical disfigurement or inability to communicate, overwhelmed students and impeded their ability to effectively manage the concerns of their patients. In the example below, while physical disfigurement was expected, the student felt stunted by a lack of preparation on how to navigate an encounter with a patient with alternative methods of communication and was overall unprepared for the effect that the patient's physical disfigurement would have on their own composure.

I have never seen someone disabled for a while; I feel like we do have proper training on that. But then when I see, "Oh, my God, he wasn't like this a tiny bit ago, and now he is because of disease. They used to be fully able and now they're not." I was trying to walk a line of the best way to communicate, which was a different experience than I ever had before. It was really hard to see a person in that state, especially when you're not expecting it. I'll remember what he was like forever.

DISCUSSION

Student experiences explored in this study reinforce prior literature's understandings of the ED as a stressful environment and the EM clerkship as an educational setting that may expose students to trauma that exceeds their existing coping abilities. The deductive and inductive analyses undertaken in this study reveal insights about the nature of these stressors through the lens of students' experiences during their third-year EM clerkship. The deductive approach matched incidents shared within 12 students' narratives to the six TIME domains, whereas the inductive approach of this qualitative data generated a novel group of 10 overarching themes.

Overall, the deductive analysis demonstrated that TIME domains were represented in students' perceptions of EM clerkship educational structures (eg, mentors, policies, types of patient interaction) as they navigated critical incidents. However, there are differences in the frequency of and ways in which certain domains are represented and supported in the students' perception of existing curricular structures. "Safety" was by far the most frequently matched TIME domain to excerpts within students' narratives (34% of all identified instances), followed by "Empowerment, Voice, and Choice" and "Collaboration and Mutuality" (20% and 17% of instances, respectively).

In contrast, the TIME domains of "Transparency and Trustworthiness," "Gender Cultural, and Historical Issues," and "Peer Support" were less commonly identified as dominant domains across students' critical incidents (12%, 8.7%, and 8.7% of instances, respectively). Excerpts that were matched to these TIME domains often described instances in which these domains were discussed but not positively reinforced in the current clerkship curriculum (Table 3). For example, an excerpt matched to "Safety" may have expressed an experience in which a student felt unable to voice their opinions openly due to perceived negative consequences. In contrast, other excerpts in student narratives reflected instances in which a particular TIME domain may have been well represented and supported by their clerkship experience. For instance, as described in Table 3, an excerpt that was matched to "Collaboration and Mutuality" demonstrated how this domain was supported by a supervisor's role-modeling of professionalism.

Often, instances where TIME domains were positively reinforced resulted in stronger student resilience and handling of critical incidents, whereas the lack of positive reinforcement of TIME domains resulted in student distress. The prevalence of "Safety" as a domain identified across incidents (often as a domain that was not well supported) may indicate that students experience "Safety" as one of the most salient domains that affects their ability to manage stressful situations compared to other domains.

The inductive approach generated 10 de novo themes that describe students' perceptions of trauma during the EM clerkship and can be broadly organized and understood as emerging from three types of student interactions: with the clinical environment; with supervisors; and with patients (Table 4). "Students' interaction with the clinical learning environment" describe the immutable contextual environment of the clerkship experience (eg, social, racial, and/or cultural factors) that influence students' interactions with others and includes navigating SDoH, acting on perceived inequities, and handling discrimination in the ED. In contrast, "Students' interactions with supervisors" captures the themes of power dynamics, distress from invalidated contributions to the team, role-modeling, feedback, and empowerment.

Finally, the third category, "Students' interactions with patients," encompasses themes of emotional discomfort with ethical ambiguity, emotional distress from acute patient care conditions, and reactivation of previous personal trauma. Overall, these three families of themes paint a picture of the third-year EM clerkship in which students perceive themselves to be at the center of the complex learning environment of the ED, continuously interfacing with patients and supervisors in a pre-existing, fixed, socioeconomic, political, and cultural context that shapes the learning experience. The 10 themes that describe this complex setting have potential to either "enable" or "disable" effective student management of their critical incidents.

When comparing the inductively generated framework with the TIME framework in how they capture students' experiences of the third-year EM clerkship, both frameworks demonstrate a considerable degree of overlap but differ in how they categorize students' responses to critical incidents. Both frameworks describe the influence of power structures, debriefs, transparency of expectations, gender and cultural issues on students' experiences. However, where the TIME framework categorizes these ideas based on the type of stressor, the inductive framework categorizes the same ideas based on whom the student was interacting with. Thus, one of the largest differences to emerge between the deductive and inductive analysis was not the content of themes but the overall principles by which the approaches organized and understood the content of student narratives.

We felt that the TIME framework yielded a broader, less specific picture of students' experiences with critical incidents that were not as effective at capturing the nuances and complexities of students' experiences and specific stressors (eg, SDoH, patient disfigurement, inequities in patient care, ethical dilemmas, lack of autonomy and validation) as the inductive framework. This discrepancy may stem from the fact that the TIME domains are not based specifically on the third-year EM clerkship but instead on general ideas found throughout UME. In addition, the TIME domains as envisioned by Brown et al draw on structures, such as institutional policies, counseling services, and self-care techniques, that extend beyond the structures (ie, mentors, patients) that students actively interact with when critical incidents occur.[7]

By comparison, because our findings originate entirely from student experiences during these incidents, this framework may be better able to capture a more detailed and student-informed understanding of the trauma-informed structures in the third-year EM clerkship that most significantly impact their ability to navigate acute stress. Accordingly, our observed themes may offer a more relevant lens to assess for educational and environmental structures specific to the third-year EM clerkship that hinder or promote students' responses to critical incidents, while TIME domains may offer non-specific relevance in capturing experiences of trauma across various clerkships.

LIMITATIONS

Several limitations of this study are worth noting. As this study was conducted as an interview series using convenience sampling at one institution, the findings may not be fully generalizable. However, the findings of our study may serve as a foundation for future studies, which may be able to better assess the generalizability of their findings in the context of this study's. Our limited sample size raises concerns about the extent to which our findings are generalizable across EM clerkships in the US or to a broader population of medical students across various geographic locations.

Some degree of recall bias also likely affected our study as participants were more likely to remember the most salient elements, positive or negative, of their experiences in the ED while omitting descriptions of other factors that aided or impeded their ability to manage the situation. We attempted to limit the effect of recall bias by using a critical incident technique-guided questionnaire that asked participants to actively recall as many elements of the situation as possible (eg, location, time of day, surroundings, involved people, etc) to avoid omission. Also, the degree of safety that participants felt in disclosing their true feelings to the interviewer may have affected disclosure of traumatic incidents across our participant pool, which might have been reduced by a neutral, third-party interviewer not affiliated with our academic institution. Future studies might employ a cross-sectional qualitative approach in which representative sites across the country can be sampled.

CONCLUSION

At present, students experience all six TIME domains during their third-year EM clerkship, with some domains experienced more than others. The domains of "Safety," "Empowerment, Voice, and Choice," and "Collaboration and Mutuality" are frequently described in student accounts of responding to immediate, stressful critical incidents during the clerkship. The inadequate perception of certain TIME domains in EM undergraduate medical education during critical incidents may contribute to student distress and hinder students' ability to respond to their perceived trauma. Considering the findings laid forth by this study, the specific nature of students' experiences of trauma during the EM clerkship may be an effective tool to guide curricular changes that improve students' ability to manage immediate stressors in the clinical environment.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. Funding for this study was provided through the Society for Academic Emergency Medicine (SAEM) Foundation through the SAEMF/RAMS Medical Student Research Grant, which was awarded to Ms. Giselle Appel (mentor, D. Papanagnou). There are no other conflicts of interest or sources of funding to declare.

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Drowning Among Children 1–4 Years of Age in California, 2017–2021

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Section Editor: Cristina M. Zeretzke, MD
Submission history: Submitted March 17, 2024; Revision received July 8, 2024; Accepted August 23, 2024
Electronically published September 9, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.20356

Background and Objectives: Drowning, the leading cause of unintentional injury death among California children less than five years of age, averaged 49 annual fatalities for the years 2010–2021. The California Pool Safety Act aims to reduce fatalities by requiring safety measures around residential pools. This study was designed to analyze annual fatality rates and drowning incidents in California among children 1–4 years of age from 2017–2021.

Methods: We identified fatalities, injury hospitalizations, and emergency department (ED) visits from California state vital statistics death data and state hospital and ED discharge data using the EpiCenter California Injury Data Online website.

Results: Over the five-year study period, 4,166 drowning incidents were identified: 234 were fatalities, 846 were hospitalizations, and 3,086 were ED visits. The observed difference in fatality rates from 2017 to 2021 failed to achieve statistical significance ($P = 0.88$). Location-based analysis of the 234 fatal drowning incidents revealed that pools were the most common injury site, accounting for 65% of the cases.

Conclusion: Drowning remains the leading cause of unintentional, injury-related death among California children 1–4 years of age, as the annual rate of fatality over the five-year study period did not decline. While the EpiCenter California Injury Data Online website is excellent for analyzing annual rates of drowning incidents among California residents over time, it is limited in providing insight into modifiable risk factors and event circumstances that can further inform prevention. The development of robust integrated fatal and non-fatal local, state, and national systematic data collection systems could aid in moving the needle in decreasing pool fatalities among young children. [West J Emerg Med. 2024;25(5)838–844.]

INTRODUCTION

Drowning is the leading cause of unintentional, injury-related death among children 1–4 years of age in the US and California, and the second leading cause of unintentional, injury-related death among children 5–9 years of age.[1,2,3] For the years 2010–2021, there was an average of 49 child fatalities among those less than five years old. California's population is nearly 40 million living in 58 counties.[4] The California Department of Public Health (CDPH) EpiCenter online database reveals that drowning has been the leading cause of injury death among California residents 1–4 years of age for nearly 25 years.[4] Among children who survive

drowning, a large number experience lifelong disabilities that range from minor to severe. The California Department of Developmental Services 2022 Client Development and Evaluation Report documents a caseload of more than 700 persons who require lifelong services as a result of nonfatal drowning.[5]

California is one of four states that address the prevention of residential pool drowning through state legislation. The first California Pool Safety Act went into effect on January 1, 1997, and was updated in 2017. In part, the California Pool Safety Law increased the number of required safety features around residential pools from one to two, expanded allowable safety devices, and expanded the inspection process.[6] The law covers pools and spas at private, single-family residences at the time of sale, transfer of property, or remodel.

Population Health Research Capsule

What do we already know about this issue?
Drowning is the leading cause of unintentional, injury-related death among children 1–4 years of age in the US and California.

What was the research question?
We examined recent fatality rates and characterized drowning incidents among California children 1–4-years of age.

What was the major finding of the study?
Annual drowning fatality rates (2017–2021) did not decline ($P = 0.88$), and 65% of fatalities occurred in pools.

How does this improve population health?
This study offers a new perspective on the need for robust data collection systems that aid in moving the needle in decreasing pool fatalities among young children.

Purpose of Analysis

The purpose of this data analysis was to examine the annual fatality rates and characterize drowning incidents among California children 1–4 years of age (University of California Irvine IRB #1735.)

METHODS

We obtained the data for this study from the EpiCenter California Injury Data Online website. This is a comprehensive source of injury data limited to California residents. EpiCenter data includes fatalities, injury hospitalizations, and emergency department (ED) visits.[4] Drowning fatalities were identified from the CDPH using International Classification of Diseases, 10th Rev, Clinical Modification (ICD-10-CM) cause-of-death codes appearing in the underlying cause-of-death field as follows: W65–W74; X71; X92; Y21; W65–W74; X71; X92; and Y21. We calculated fatality rates from the California Department of Finance Report P-3: Complete State and County Projections Dataset (Baseline 2019 Population Projections; Vintage 2020 Release).[4]

Injury hospitalizations and ED visits were identified from the California Department of Health Care Access and Information (HCAI) Patient Discharge Dataset (PDD) and the ED dataset, respectively. The PDD includes records of inpatient discharges from California-licensed hospitals, including general acute care, acute psychiatric, chemical dependency recovery, and psychiatric health facilities. The ED data includes records of patient face-to-face encounters with clinicians at hospitals licensed to provide emergency medical care. If an ED encounter resulted in a same-hospital admission, the ED encounter would be combined with the PDD record and only appear as a hospitalization. We identified drowning hospitalizations and ED visits using ICD-10-CM codes appearing in any of 25 diagnosis fields and 12 external cause-of- morbidity fields.[7] On the EpiCenter interactive website, we selected "drowning/submersion" under the Injury Mechanism drop-down menu for deaths, hospitalizations, and ED visits. This included unintentional, intentional, and undetermined intent drownings.

Consistent with California Health and Human Services De-Identification Guidelines, EpiCenter does not provide data for results with fewer than 11 cases. Because of the de-identification guidelines, we were only able to determine that less than 4% of fatal cases were intent unknown or intentional. Less than 1% of hospitalized and ~0.3% of ED cases were classified as intentional.

We looked at the overall incidence of cases among California children 1–4 years of age for the years 2017–2021 and the rates of fatalities, hospitalizations, and ED visits. Data elements reviewed included age in years, sex of child, race/ethnicity, location of incident, outcome (fatal, hospitalization, ED visit), disposition, and length of stay. Incident location is defined as the body of water, based on ICD-10/ICD-10-CM code descriptions (eg, pool, bathtub, or open body of water). Race/ethnicity is categorized as follows: Hispanic; White; Asian; Black; multiracial; and Pacific Islander. We calculated incidence rates and 95% confidence intervals assuming a Poisson distribution of drowning data. *P*-values were calculated based on the chi-square test by exact calculation method. We used Stata 17.0 SE (StataCorp LLC, College Station TX) for statistical analysis.

RESULTS

Incidence

During the study period, 2017–2021, a total of 4,166 drowning incidents were documented. Table 1 shows the annual incidence of drowning by fatality, hospitalization, and ED visit. Table 2 shows the incidence rate (IR) of drowning by age and sex. The incidence of drowning was highest among the 2-year-old age group ($P < 0.01$). Table 3 shows the IR of drowning per month and day of the week during 2017–2021. Drowning was most prevalent in June and July and least prevalent in December and January ($P < 0.001$). Similarly, drowning was more prevalent on weekends compared to weekdays ($P < 0.001$).

Drowning incidents among 234 (5.62%) cases were fatal. Of the nonfatal cases, 2,438 (58.52%) patients were treated and released from the ED; 628 (15.07%) required hospitalization for less than a day or overnight; 136 (3.26%) stayed in the hospital for 2–4 days; 82 (1.97%) had hospital stays exceeding four days; and 648 (15.55%) were either transferred from the ED or had unknown dispositions.

Fatality

The fatality rates varied from 2.2 per 100,000 population in 2017 to 2.5 per 100,000 in 2021, but the observed difference failed to attain statistical significance ($P = 0.88$). This is contrary to the decrease in ED visits and hospitalization during the same period. The case fatality ratio for the 1-year-old age group stood at 7.86% (6.32–9.64%), which was higher than for other age groups ($P < 0.001$). Similarly, the case fatality ratio for males was 6.48% (5.52–7.54%), exceeding the fatality ratio for females, which was 4.47% (3.56–5.53%) ($P = 0.005$). The analysis of fatal drowning incidents among 234 children aged 1–4 years, based on the location, showed that pools were the most common site, accounting for 65% (152 cases). Bathtubs followed at 14% (32 cases), natural bodies of water at 11% (27 cases), and 10% (23 cases) occurred at other or unspecified water sources.

Fatal drowning rates by race/ethnicity were highest among Black and multiracial children (3.3/100,000), followed by White children (3.0/100,000), Hispanic children (2.1/100,000), and the lowest rate was among Asian children (1.8/100,000).

DISCUSSION

Drowning remains the leading cause of death among California children 1–4 years of age. The annual rate of fatality over the five-year study period did not decline.

Incidence

Over the five-year study period (2017–2021), 4,166 drowning incidents were reported among California children 1–4 years of age, an annual average of 833 incidents. Of

Table 1. Annual drowning rates of California children 1–4 years of age: 2017–2021.

	Fatalities (N = 234)		Hospitalizations (N = 846)		ED visits (N = 3,086)		Total (N = 4,166)
Year	N	Crude rate*	N	Crude rate*	N	Crude rate*	Population
2017	44	2.2	220	11.1	876	44.1	1,986,642
2018	53	2.4	219	11.1	709	36.0	1,967,438
2019	44	2.2	157	8.2	619	32.2	1,923,620
2020	47	2.4	118	6.3	389	20.9	1,864,194
2021	46	2.5	132	7.2	493	27.1	1,821,672

*Rate: Incidence rate per 100,000 person-year.
ED, emergency department.

Table 2. Demographics of the drowning incidence of California children 1–4 years of age: 2017–2021.

		Fatalities (N = 234)			Hospitalizations (N = 846)			ED visits (N = 3,086)			Total (N = 4,166)	
		N	%	Rate*	N	%	Rate*	N	%	Rate*	N	Rate*
Age (years)	1	84	7.9%	3.7	227	21.2%	9.9	758	70.9%	33.0	1069	46.6
	2	75	5.3%	3.2	283	19.9%	12.0	1061	74.8%	44.9	1419	60.1
	3	48	4.4%	2.0	223	20.4%	9.2	820	75.2%	33.8	1091	45.0
	4	27	4.6%	1.1	113	19.3%	4.6	447	76.1%	18.1	587	23.8
Sex	Male	154	6.5%	3.2	506	21.3%	10.5	1717	72.2%	35.8	2377	49.5
	Female	80	4.5%	1.7	340	19.0%	7.1	1369	76.5%	28.7	1789	37.5

*Rate: Incidence rate per 100,000 person-year.
ED, emergency department.

Table 3. Timing of the drowning incidence in California children 1–4 years of age: 2017–2021.

		Fatalities (N = 234)		Hospitalizations (N = 846)		ED visits (N = 3,086)		Total (N = 4,166)
		N	%	N	%	N	%	N
Month	1	7.75*	9.1%	20	23.6%	57	64.8%	88
	2	13	11.5%	28	24.8%	72	63.7%	113
	3	7.75*	5.4%	31	21.6%	105	71.4%	147
	4	24	7.5%	70	22.0%	224	70.4%	318
	5	28	6.8%	97	23.6%	286	69.6%	411
	6	38	4.3%	172	19.7%	664	76.0%	874
	7	43	4.5%	168	17.4%	754	78.1%	965
	8	29	4.9%	118	19.8%	448	75.3%	595
	9	17	5.4%	57	18.0%	242	76.6%	316
	10	7.75*	4.6%	39	23.0%	123	71.1%	173
	11	7.75*	7.7%	25	24.8%	68	65.4%	104
	12	11	14.7%	21	28.0%	43	57.3%	75
Day of week	Sunday	37	4.2%	183	20.6%	669	75.3%	889
	Monday	24	4.8%	105	21.1%	368	74.0%	497
	Tuesday	34	7.6%	98	21.9%	316	70.5%	448
	Wednesday	30	6.7%	79	17.7%	338	75.6%	447
	Thursday	32	7.4%	87	20.1%	313	72.5%	432
	Friday	38	7.8%	101	20.8%	346	71.3%	485
	Saturday	39	4.0%	193	19.9%	736	76.0%	968

*The number of incidents was recorded as "<11," and we arbitrarily replaced them with 7.75, contributing to the grand total of 4,166.
ED, emergency department.

these, nearly 6% were fatal and 94% were nonfatal drownings. The highest IR was among children two years of age. Incidents in the summer months (June and July) and on weekends were most prevalent. Racial/ethnic rates are only available for fatalities due to 2019 modifications to race and ethnicity coding in the HCAI hospital discharge and ED visit data. Fatality rates were highest among Black and multiracial children. The highest rates among Black children have been documented in other studies as well, indicating the need to address disparities.[3,8,9,10,11,12]

Fatal

A previous analysis found that annual rates of unintentional fatal drownings from 1999–2020 among California children 1–4 years of age at all locations and at swimming pools did not decline significantly.[13] For the years 2017–2021, of the 234 fatalities among children 1–4 years of age, 65% occurred at pools, similar to the findings in other studies. The coding does not differentiate the location of pools (eg, residential or community), which are governed by different regulations. However, it is well documented that fatal incidents among young children are most common at residential pools. The National Center for Fatality Review and Prevention (NCFRP) reported that 52% of fatal drownings occurred in a home or residential pool. The Consumer Product Safety Commission Pool or Spa Submersion 2023 Report also revealed that among the fatalities, 84% were at a residential pool.[2,3,11,12,14] This data highlights the need to prioritize prevention efforts that target pool drownings. For nonfatal cases, we could not determine whether the location was a pool or other body of water because of the large proportion of T75.1 ICD-10-CM codes corresponding to "Unspecified effects of drowning and nonfatal submersion."

Fatal/Nonfatal

For every fatality among the 1–4-year age group in this study, there were 18 nonfatal incidents. This finding highlights the need to include and compare fatal and nonfatal incidents to better understand the circumstances and modifiable risk factors, such as submersion time before rescue and initiation of cardiopulmonary resuscitation at the site.[15,16,17,18] The current California pool safety law is SB-442 Public Health: Pools: Drownings 2017.[6] Based on its provisions, coverage, and inspection requirements, we would not expect to see a reduction in a drowning fatality because

1) fatality is a rare event; 2) we have no documentation of the degree to which pool owners remain compliant after the one-time inspection; and 3) although two "safety features" are required, only one of the options is a best practice — an enclosure that isolates the pool from access to the home meeting California Building Standards Code specifications.

Addressing Data Gaps

Based on these findings, robust integrated fatal and nonfatal local, state, and national systematic data collection systems that enhance our understanding of the epidemiology and modifiable risk factors including regional differences are necessary to move the needle in decreasing pool fatalities among young children. Comprehensive surveillance systems would also include all portals of data entry, beginning with first responders such as lifeguards, emergency medical services, and law enforcement. Standard definitions and coding using ICD-10 and IC1-10-CM, data source linkages, real-time electronic data entry, timely analysis and reporting, and state-of-the-art technology to improve data variable capture will increase our knowledge and fill data gaps.[19,20,21] Preliminary results from the Drowning Death Scene Investigation and the Child Death Review (CDR) Project of the NCFRP also indicate that the widespread use of a standardized tool will fill a significant data gap in knowledge to inform prevention.[22]

Local CDR, a process that allows for a multidisciplinary comprehensive review of child fatalities using data collected from multiple sources, has been used effectively for both surveillance and to inform prevention.[23,24,25] The Haddon Matrix model as applied to drowning captures the multiple layers of protection and interventions to interrupt the progression to a death by drowning and can be integrated into case fatality review.[9,26] The Injury Equity Framework theoretic model provides further guidance on systematic data collection and analysis that can be considered in the local child death review process.[27]

In addition to pediatricians (child abuse, intensivists, primary care), local CDR teams ideally include representatives from the county child protective social services, law enforcement, public health and school nursing, and the coroner's or medical examiner's offices. The coroner's office (and often law enforcement) conducts detailed investigations in cases of unexpected child death, especially those who die without being transported to hospitals. Other team members may also have additional interaction with the child or family.[28] The availability of guidelines on the type of information to gather in fatal drowning cases should improve data capture by CDR team members.

Physician involvement in improving the quality and quantity of data in health record documentation and the subsequent CDR process further details the circumstances and provides insight into future prevention recommendations. Further, reporting to county child protective services if there are concerns for lack of appropriate supervision or safeguards can result in additional resources or services for the family to prevent future incidents. Child death review as a surveillance tool with action recommendations is effective.[23,24,25] Pediatricians can advocate for integrating non-fatal drowning into the fatality review.

The American Academy of Pediatrics (AAP) strongly recommends that states establish systematic reporting on the circumstances of drowning.[9] A robust statewide data collection and analysis system provides information to develop best practices, community interventions, and relevant public policies. The California Legislature found a solution to the statewide drowning data collection gap in reporting fatal and nonfatal incidents when California Senate Bill 855 (Newman, Ch. 817, Stat. 2022: Child Drowning Data Collection Pilot Program) was chaptered into law. Implementation of a data collection system by the CDPH moves us closer to the AAP recommendation that states establish systematic reporting. Strengthening our county CDR teams in reviewing drowning cases and including nonfatal cases for analysis should contribute to a robust statewide surveillance system and can be a model for other states.[9,10,29]

LIMITATIONS

There are several limitations to this study. The CDPH EpiCenter online publicly available database, based on vital statistics and hospital/emergency discharge data, enables an analysis of annual rates of drowning incidents only among California residents over time. Children who visit California and our popular tourist attractions are not counted if they sustain a fatal or nonfatal drowning. Moreover, the database is limited in identifying modifiable risk factors and event circumstances that can further inform data-driven prevention strategies and policies.

The ratios of fatal to hospitalization to ED visits may include double counts as some ED encounters may also be included in the hospital data. We do not have exposure data. Additionally, we could not determine the extent of unreported incidents. As Koon pointed out, the CDPH publicly accessible data related to drowning was not designed for research.[14] Finally, a significant data gap relates to the location of the pool for hospital and ED visits due to ICD-10-CM coding variability.

CONCLUSION

Drowning remains the leading cause of unintentional, injury-related death among California children 1–4 years of age, as the annual rate of fatality over the five-year study period did not decline. While the EpiCenter California Injury Data Online website is excellent for analyzing annual rates of

drowning incidents among California residents over time, it is limited in providing insight into modifiable risk factors and event circumstances that can further inform prevention. Currently, inconsistent and incomplete data hamper the identification and monitoring of trends, risk factors, and prevention recommendations. Incorporating data elements in the context of the injury equity framework will further guide interventions.[27] Systematic child death review, combined with all child drowning incident investigations can inform evidence-based best practices, community interventions and the implementaton of effective and impactful public policies.

ACKNOWLEDGMENTS

Thank you to Orion Stewart, PhD, research scientist, California Department of Health, Injury and Violence Prevention Branch for reviewing and contributing to this study. We also thank the California Kids' Plates Program, California Department of Public Health Injury and Violence Prevention Branch for supporting this project with partial funding.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. This study was supported by partial funding from the California Kids' Plates Program, California Department of Public Health Injury and Violence Prevention Branch. The California Kids' Plates Program, California Department of Public Health Injury and Violence Prevention Branch had no role in the design and conduct of the study. There are no other conflicts of interest or sources of funding to declare.

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ChatGPT's Role in Improving Education Among Patients Seeking Emergency Medical Treatment

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Section Editor: Chris Baker, MD
Submission history: Submitted December 21, 2023; Revision received June 21, 2024; Accepted June 21, 2024
Electronically published August 13, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18650

Providing appropriate patient education during a medical encounter remains an important area for improvement across healthcare settings. Personalized resources can offer an impactful way to improve patient understanding and satisfaction during or after a healthcare visit. ChatGPT is a novel chatbot—computer program designed to simulate conversation with humans— that has the potential to assist with care-related questions, clarify discharge instructions, help triage medical problem urgency, and could potentially be used to improve patient-clinician communication. However, due to its training methodology, ChatGPT has inherent limitations, including technical restrictions, risk of misinformation, lack of input standardization, and privacy concerns. Medicolegal liability also remains an open question for physicians interacting with this technology. Nonetheless, careful utilization of ChatGPT in clinical medicine has the potential to supplement patient education in important ways. [West J Emerg Med. 2024;25(5)845–855.]

INTRODUCTION

Effective communication and counseling between clinicians and patients is crucial for high-quality healthcare, particularly in the emergency department (ED) where time constraints and evolving diagnostics can complicate discussions about current and post-hospital care. This makes patient education an important gap to address. The urgency and complexity of emergency cases often hinder comprehensive information delivery, leaving patients' questions unanswered. Inquiries about their condition, treatment options, and prognosis are vital for patient understanding and engagement in decision-making. A systematic review examining the factors that influence the patient experience in the ED highlighted physician-patient communication as the most common factor affecting patient satisfaction.[1] Addressing these concerns not only boosts satisfaction but also empowers patients, improving health outcomes.

Effective discharge instructions are essential for a patient's post-emergency care, as ambiguity or inadequate explanation can result in confusion, noncompliance, and subsequent readmission.[2,3] A recent study revealed that 24% of patients do not fully understand their follow-up plan, 64% struggle to comprehend their return-to-ED instructions, and 42% do not receive complete discharge instructions.[3] Improving discharge communication can enhance transition to follow-up care, thereby improving patient care outcomes and reducing avoidable readmission. In addition to communication challenges, patients may struggle to identify the most appropriate type of care for their conditions. The ED often sees cases that could be more effectively managed in primary care or urgent care settings. About 13–27% of all ED visits are considered non-urgent in nature, resulting in approximately $4.4 billion annual cost.[4] Identifying factors that contribute to unnecessary emergency care utilization can aid the development of targeted interventions and educational initiatives aimed at redirecting patients to more appropriate avenues of treatment.

Furthermore, increasingly diverse patient populations bring language barriers to the forefront of care in the ED. Patients with limited English proficiency often face obstacles in understanding their diagnoses and treatment plans. One

studied showed only 52% of non-English speakers were satisfied with their ED visit, compared to 71% of English speakers.[5] Strategies to reduce the inequitable impact of language barriers has obvious benefits for patient safety and outcomes in the ED.

One method to address these limitations could be clinical application of a machine learning (ML) large language model (LLM), such as ChatGPT (OpenAI, LP, San Francisco, CA). An ML-based chatbot can learn from a vast array of training data and user interactions to improve performance and efficacy of its delivered communication. In recent performance evaluations, ChatGPT scored above the national average on publicly available renditions of Step 1, Step 2-Clinical Knowledge, and Step 3 of the United States Medical Licensing Exam (USMLE).[6] The model's USMLE performance continues to improve with new updates, such as GPT-4, which additionally offers image-analysis capabilities.[7] Models are also being used to train medical students and prepare them for clerkships.[8–10] These benchmarks demonstrate ChatGPT's fluency with basic medical information at the knowledge level of a medical school graduate.

Patients often undertake an internet search of medical topics before or after speaking with a physician. However, with a vast array of information and misinformation available on the internet, physicians and other healthcare professionals remain an important interface to source reliable medical knowledge. Here, we evaluate the potential role that LLMs like ChatGPT could have as a personalized educational resource for patients seeking emergency medical treatment.

Population Health Research Capsule

What do we already know about this issue?
Current patient education in the ED is inadequate, often leading to misunderstanding and noncompliance with post-care instructions.

What was the research question?
How can the chatbot ChatGPT improve patient education in the ED setting?

What was the major finding of the study?
ChatGPT helps triage, clarify discharge, and provide care instructions.

How does this improve population health?
ChatGPT can enhance patient education, improving comprehension and adherence to follow-up care, reducing unnecessary ED visits and enhancing overall outcomes.

CHATGPT: HOW IT WORKS

ChatGPT is a text-based chatbot that facilitates user interaction through natural language. The ML model for the publicly available versions, GPT-3.5 and GPT-4, were trained on written text drawn from a vast spectrum of online databases. Pretraining enables the models to construct a robust linguistic framework. Further conditioning includes assignment-specific adjustments, human feedback that can bolster its conversational abilities, and rigorous testing to ensure resilience against challenging user queries. This process is critical for aligning the model's output with nuanced human dialogue, enhancing its capacity to provide precise and contextually appropriate responses.[10]

GPT-4 is the latest iteration of this LLM, with an enhanced architecture that not only understands and generates textual content but also interprets and responds to visual input.[11] Furthermore, while experimental features in GPT-4 include the potential for current internet data, such capabilities have not been broadly released to users. The broader implications of this limitation, including the balance between model autonomy and the necessity for human oversight, are examined further in the section on technical restrictions. Nevertheless, the current capabilities of ChatGPT are an important leap toward a collaborative role that humans and AI systems will share in navigating complex real-world applications.[12]

PATIENT EDUCATION BENEFITS

The ED is a setting with a particularly high demand for efficient and clear patient education at discharge given the potential reappearance or sequelae of conditions requiring emergent evaluation. However, the ED also often imposes a high degree of constraint on patient-clinician interaction time. Even in the setting of low-acuity conditions, an observational study showed the combined amount of time physicians, nurses, and technicians spent with patients once they are assigned to a bed was about 25% of total patient length of stay.[13] The factors underlying limited interaction time are multifactorial, but often-cited contributing reasons include patient volume and high load of documentation requirements. Offering a resource that is adaptive and responsive to patient concerns relevant to their specific situation is an important gap in the ED. ChatGPT can provide an interactive modality that is personalized to meet this gap for the healthcare education needs of patients and their clinicians.

Care-Related Questions

ChatGPT may offer multiple benefits for patients in the ED. It can quickly give personalized responses to queries on a wide range of healthcare topics. For example, the software

can provide purpose- and risk-based information about procedures a patient or their family member may undergo during an ED encounter (Figure 1A). ChatGPT offers background information about the procedure and refers to the care team for further encounter-based questions and concerns. The information provided about a procedure, such

Figure 1A: General Medical Care Questions

Input

I am currently in the emergency department and my doctor says my husband needs a CT-angiogram. What is that and why does he need it? Is it risky?

GPT-3.5 Response	GPT-4 Response
A CT angiogram, also known as a computed tomography angiogram, is a medical imaging test that uses X-rays and a special dye to create detailed images of the blood vessels in the body, including those in the heart and lungs. This test is often used to help diagnose or evaluate conditions that affect blood flow, such as blood clots, aneurysms, or pulmonary embolism. Your doctor may have recommended a CT angiogram for your husband if he suspects that your husband may have a condition that affects the blood vessels, or if he needs further evaluation to confirm a diagnosis. The test may also be used to monitor the progress of treatment for certain conditions, such as aneurysms. A CT angiogram is generally considered safe, but like any medical procedure, there are some risks involved, including exposure to radiation and an allergic reaction to the contrast dye. However, the benefits of the test usually outweigh the risks, especially when used to diagnose or treat serious medical conditions. Your doctor will provide you with more information about the procedure and what to expect, including any risks or potential complications. If you have any questions or concerns, be sure to discuss them with your doctor or the medical staff before the test.	I'm sorry to hear that your husband is in the emergency department, and I hope he receives the best possible care. A CT angiogram is a medical imaging test that combines a CT scan with an injection of a contrast material to produce detailed images of blood vessels and tissues in a part of your body. "CT" stands for computed tomography, which is an advanced form of X-ray that takes multiple images from different angles and then uses a computer to create cross-sectional views of the inside of the body. When these images are focused on the body's blood vessels, it's known as an angiogram. Doctors may order a CT angiogram for a variety of reasons, including but not limited to: 1. **Diagnosing aneurysms** (outpouchings of a blood vessel wall that can be at risk of rupture) 2. **Identifying blockages or other abnormalities in blood vessels** that could be responsible for conditions like stroke, ischemia, or other forms of vascular disease. 3. **Evaluating blood vessels after surgery** to ensure they are functioning as intended. 4. **Detecting tumors** in certain parts of the body, since they often have a distinct blood supply. 5. **Evaluating the condition of blood vessels in patients with trauma**, to detect injury or bleeding. Regarding risks, CT angiograms are generally safe, but as with any procedure, there are some risks and considerations: 1. **Allergic Reaction to Contrast Dye**: Some people may have an allergic reaction to the iodine-based contrast dye used in the procedure. It's important to tell your doctor if your husband has had a prior reaction to contrast material or has severe allergies in general. 2. **Kidney Function**: The contrast dye can sometimes cause kidney damage, particularly in people who already have kidney problems. Your husband's doctors will likely check his kidney function before proceeding with the test. 3. **Radiation Exposure**: CT scans involve exposure to radiation, which is a concern, especially if someone has had multiple scans over time. However, the diagnostic benefits often outweigh the risks, especially in emergency situations. 4. **Pregnancy**: CT angiography is usually not recommended for pregnant women due to potential risk to the unborn baby from radiation exposure. The decision to proceed with a CT angiogram is based on a careful consideration of risks versus benefits. In an emergency setting, if a doctor recommends a CT angiogram, it is often because they believe that the immediate benefits of diagnosing a potentially serious or life-threatening condition outweigh the risks associated with the procedure. I hope this explanation helps you understand why this test might be necessary. Please do ask the medical team any questions you have; they are there to help and support you both through this. If you have any concerns about your husband's health condition or the procedures being recommended, don't hesitate to discuss them with the medical staff.

Figure 1B: General Medical Care Questions

Follow Up Question

The doctor said my wife has heart failure and needs to start a medicine called milrinone, what does that mean?

GPT-3.5 Response	GPT-4 Response
Milrinone is a medication used to treat heart failure. Heart failure occurs when the heart cannot pump enough blood to meet the body's needs, and milrinone works by improving the heart's ability to contract and pump blood. Milrinone is typically given through an intravenous (IV) Infusion in a hospital setting, it can improve the symptoms of heart failure, such as shortness of breath, and increase the amount of blood pumped by the heart. It's important to follow your doctor's instructions for taking milrinone and to attend all scheduled appointments to monitor your wife's condition and adjust the treatment plan if necessary. It's also important to be aware of potential side effects of the medication, such as low blood pressure or an irregular heartbeat, and to notify your doctor if any occur.	I'm not a doctor, but I can provide you with some general information about heart failure and the medication milrinone. It's important to consult with your wife's healthcare provider for specific guidance and information tailored to her condition. Heart failure is a medical condition where the heart is unable to pump blood effectively to meet the body's needs. This can lead to symptoms such as shortness of breath, fatigue, fluid retention, and difficulty with physical activities. Heart failure can have various causes, and it's typically classified into different types, including systolic and diastolic heart failure. Milrinone is a medication that falls into a class of drugs called "phosphodiesterase inhibitors." It is used in the treatment of heart failure, particularly in cases of acute decompensated heart failure or when other treatments may not be sufficient. Milrinone works by increasing the strength of the heart's contractions and relaxing blood vessels to improve blood flow. Here are some key points to understand about milrinone: 1. **Inotropic Medication**: Milrinone is known as an inotropic medication because it enhances the heart's contractility. This can help the heart pump blood more effectively in cases of heart failure. 2. **Vasodilator**: Milrinone also acts as a vasodilator, which means it widens the blood vessels. This helps reduce the workload on the heart and improves blood flow. 3. **Short-term Use**: Milrinone is typically used for short-term treatment in a hospital setting, especially for patients with acute heart failure. It's often administered intravenously (through an IV) and monitored closely by healthcare professionals. 4. **Side Effects**: Like any medication, milrinone can have side effects. Common side effects may include low blood pressure, irregular heartbeats, and changes in potassium levels. Your wife's healthcare provider will monitor her for these side effects. 5. **Individualized Treatment**: The use of milrinone and the specific dosing will depend on your wife's condition, medical history, and the judgment of her healthcare provider. It's crucial for her to follow her healthcare provider's guidance and take the medication as prescribed. 6. **Regular Follow-up**: Managing heart failure often involves ongoing medical care and lifestyle changes. Regular follow-up with her healthcare provider is important to adjust her treatment plan as needed. It's essential for you and your wife to have a detailed discussion with her healthcare provider about her diagnosis, the reasons for starting milrinone, how to take the medication, and what to expect in terms of managing her heart failure. They will provide you with the most accurate and personalized information to ensure her well-being.

Figure 1. (A–B) Selected Q&A relating to medical care. Inputs are human questions and outputs were generated by ChatGPT.

as computed tomography angiography in this example, describes an initial depth of response that is likely adequate for a layperson's introduction. In contrast to conducting a general internet search for the purposes and risks of this procedure, ChatGPT summarizes the pertinent information in a conversational format that is easily accessible to the user.

Another example demonstrates ChatGPT's sensitivity to slight alterations of meaning when asked about medical conditions and medications. The user first asks a question about the purpose of the medication milrinone for a stated condition of heart failure (Figure 1B). The software's response explains a short summary for both the condition and the medication.

Given the same set of prompts, there are several differences between GPT-3.5 and GPT-4 outputs. GPT-4 outputs are lengthier, with clearer structure to the answer approach. In these examples, there appears to be a tendency toward itemizing lists. There is also an observed empathetic bent with apparent self-anthropomorphization by starting sentences with "I." While further study on the end-user impact of this model iteration is warranted, GPT-4 appears to offer more comprehensive information than GPT-3.5 for select healthcare-associated queries (Figure 1).

Discharge Instructions

Discharge instructions for patients leaving the ED are important for patient safety and satisfaction. However, studies show that patients often do not fully understand the after-care instructions provided to them.[2,14,15] Poor adherence to medical advice or follow-up may be attributable in part to a gap in medical understanding. Personalized efforts to increase patient adherence to discharge instructions have focused on staff follow-up via phone call or SMS messaging, but these interventions bear relatively high time and monetary requirements, and do not always provide positive results.[16–18] ChatGPT can be used to improve patient understanding of instructions given by a clinician. Its natural-language interface allows patients to ask questions as if they were conversing with a human (Figure 2A, 2B). Similar tendencies are observed comparing the GPT-4 model to GPT-3.5, with longer answers, increased list creation, and greater use of first- or second-person writing style.

Seeking Care

Navigating the US healthcare system to determine the appropriate entity from which to seek care is often a significant challenge for patients. The ED remains one of the only settings in which relatively timely evaluation and care is available and is often used as a safety net for patients with no health insurance. However, even patients with insurance and a designated primary care physician sometimes opt for an ED visit due to barriers accessing their physician. Benefits of comprehensive evaluation and services, with imaging, labs, and pharmacy provided in one location is a competitive convenience for patients.[19,20] Due in part to these factors, annual ED utilization rates continue to rise disproportionate to demographic factors, increasing burden on ED resources for conditions that are better addressed in preventive-care settings.[21]

ChatGPT can provide guidance in seeking urgent vs emergent care. In one example, a patient with symptoms typical of a urinary tract infection asks if a visit to the emergency room is advisable (Figure 3A). The response indicates that care should be sought but suggests urgent care or primary care settings for first-line evaluation, given the stated symptoms. The response also provides examples of more serious symptoms that indicate need for emergent evaluation. Guiding a patient's decision matrix in a personalized, interactive manner may be an impactful way to encourage them to seek an appropriate level of care. Reducing instances of ED utilization for low-acuity health concerns assists efforts to reduce ED crowding, which can have wide-ranging benefits for healthcare systems by improving patient outcomes.[22] Future study could examine the usefulness of ChatGPT in triage scenarios, compared to current modalities such as nurse advice phone lines.

ChatGPT can also offer guidance during prehospital emergencies, detailing step-by-step instructions to responders and advising how to seek an appropriate level of care. For example, ChatGPT describes recommended actions upon encountering a syncopal patient (Figure 3B). Prehospital-intervention education geared toward laypersons has been a key focus in public health, particularly for conditions such as cardiac arrest, stroke, and major hemorrhage. While certain practices are best taught in a hands-on demonstration setting, ChatGPT may be a valuable reference resource for laypersons acting in the capacity of an emergency responder.[23]

Patient Communication

ChatGPT can offer real-time translation for languages including English, Spanish, French, German, Italian, Portuguese, Chinese, Japanese, Korean, Arabic, Dutch, Polish, Russian, and more. While real-time translation is of crucial importance for ED history-taking, translator services are becoming ubiquitous due to the growing popularity of tele-health consultation devices. The benefits of using software with translation capability to address patient questions is apparent in prehospital and post-disposition settings. For example, ChatGPT offers the same response for a question asked first in English, and then in Spanish (Figure 4). Compared to GPT-3.5, GPT-4's English response takes a more cautious approach to providing medical guidance. However, GPT-4's Spanish response appears more like GPT-3.5 in the unhedged encouragement for further medical care. This difference may be due to a variety of

Figure 2A: Discharge Instructions **Input**	
Why do I need to take antibiotics for my lung infection?	
GPT-3.5 Response	**GPT-4 Response**
Antibiotics are prescribed for lung infections when they are caused by bacteria. Bacterial lung infections, such as pneumonia, are treated with antibiotics because they can help to kill the bacteria causing the infection and prevent it from spreading further. Antibiotics work by targeting and killing the specific bacteria causing the infection. They are often effective in treating bacterial infections, but they do not work for viral infections, such as the common cold or the flu. In fact, taking antibiotics for viral infections can actually be harmful, as it can lead to antibiotic resistance and increase the risk of side effects. It's important to note that not all lung infections require antibiotics. Some may be caused by viruses or other organisms that cannot be treated with antibiotics, and in those cases, other treatments such as rest, hydration, and over-the-counter medications may be recommended. If you are experiencing symptoms of a lung infection, such as cough, fever, chest pain, or difficulty breathing, it's important to see a healthcare provider for proper diagnosis and treatment.	Taking antibiotics for a lung infection is a common and essential medical treatment, but the specific reasons for using antibiotics in your case depend on the type of infection you have. Antibiotics are prescribed to treat lung infections when the cause is suspected to be bacteria. Here are some common reasons why antibiotics may be necessary for a lung infection: 1. Bacterial Infection: If your healthcare provider suspects that your lung infection is caused by bacteria, antibiotics are prescribed to target and kill the bacteria responsible for the infection. Common bacterial lung infections include bronchitis, pneumonia, and certain types of chronic obstructive pulmonary disease (COPD) exacerbations. 2. Preventing Complications: Bacterial lung infections, if left untreated, can lead to severe complications. For example, untreated pneumonia can progress and lead to respiratory failure, sepsis, or other life-threatening conditions. 3. Shortening the Duration of Illness: Antibiotics can help reduce the duration and severity of symptoms associated with a bacterial lung infection. They work by inhibiting the growth and reproduction of the bacteria, allowing your immune system to more effectively fight the infection. 4. Preventing Spread: Taking antibiotics as prescribed can help prevent the spread of bacterial lung infections to others. Many respiratory infections are contagious, and treating them promptly can reduce the risk of transmission. 5. Preventing Antibiotic Resistance: It's important to take antibiotics exactly as prescribed and for the full duration of the treatment course. This helps prevent antibiotic resistance, which occurs when bacteria become resistant to the drugs. Incomplete or inappropriate use of antibiotics can contribute to the development of antibiotic-resistant bacteria. 6. Specific Antibiotic Selection: The choice of antibiotic depends on the suspected or identified type of bacteria causing the infection. Different antibiotics are effective against different types of bacteria. Your healthcare provider will select the most appropriate antibiotic for your specific infection. It's crucial to follow your healthcare provider's instructions regarding the antibiotic treatment. This includes taking the medication as directed, even if you start feeling better before the full course is completed. Stopping antibiotics prematurely can lead to the survival of bacteria that are more resistant and potentially more difficult to treat in the future. If you have concerns or questions about your antibiotic treatment, it's important to discuss them with your healthcare provider. They can provide you with specific information about your condition, the prescribed antibiotic, potential side effects, and any other relevant details related to your lung infection and its treatment.

Figure 2B: Discharge Instructions **Follow Up Question**	
What would happen if I don't take the antibiotics?	
GPT-3.5 Response	**GPT-4 Response**
If you have a bacterial lung infection and do not take the prescribed antibiotics, the infection may continue to worsen and lead to potentially serious complications. The bacteria causing the infection could spread to other parts of the body, leading to conditions such as sepsis, which can be life-threatening. In addition, not completing a full course of antibiotics as prescribed can also contribute to antibiotic resistance. This means that the bacteria causing the infection may become resistant to the antibiotic, making it more difficult to treat future infections. It's important to follow your healthcare provider's instructions for taking antibiotics, including taking them for the full course of treatment, even if you start to feel better before the medication is finished. If you have concerns about taking antibiotics or experience side effects, speak with your healthcare provider before making any changes to your treatment plan.	If you have a bacterial lung infection and you don't take the prescribed antibiotics, several potential consequences can occur: 1. Worsening of Infection: Bacterial lung infections can progress and become more severe if left untreated. Symptoms such as cough, fever, and difficulty breathing may worsen, and the infection can spread to other parts of the lung or body. 2. Complications: Untreated bacterial lung infections can lead to complications, which can vary depending on the type and severity of the infection. Complications may include pneumonia, abscess formation (pus-filled cavities in the lung), pleurisy (inflammation of the lining around the lung), or even lung abscesses. 3. Respiratory Distress: As the infection progresses, it can cause increasing inflammation and damage to lung tissue, making it more difficult for your lungs to function properly. This can lead to respiratory distress, making it harder for you to breathe. 4. Systemic Illness: Bacterial lung infections can sometimes lead to systemic illnesses, including sepsis, which is a life-threatening condition where the infection spreads throughout the body and can affect multiple organs. 5. Transmission: Some bacterial lung infections are contagious, and not taking antibiotics can increase the risk of spreading the infection to others, especially if you are in close contact with family members, friends, or coworkers. 6. Prolonged Illness: Without treatment, your body's immune system may struggle to clear the infection, leading to a more prolonged illness. This can result in persistent symptoms, discomfort, and a longer recovery time. 7. Antibiotic Resistance: Failing to complete a prescribed course of antibiotics can contribute to the development of antibiotic resistance. This means that the bacteria causing the infection may become more resistant to antibiotics in the future, making them more challenging to treat. It's essential to take prescribed antibiotics as directed by your healthcare provider to effectively treat the bacterial lung infection, prevent complications, and reduce the risk of antibiotic resistance. If you have concerns about the medication or experience side effects, discuss them with your healthcare provider rather than stopping the treatment on your own. They can provide guidance and potentially adjust the treatment plan if necessary. Your healthcare provider's goal is to help you recover from the infection safely and efficiently while minimizing potential risks.

Figure 2. (A–B). Selected questions relating to discharge instructions and ChatGPT output.

factors: model language training; translation filters; or underlying differences in training data itself. Further discussion of technical limitations is discussed in the section on technical restrictions. Future studies should investigate the accuracy of ChatGPT translations and compare the results to alternative modalities like certified medical translators, or other text-only modalities like Google Translate, in a clinical healthcare environment.[24,25]

Figure 3A: Triage Recommendations	
Input	
I just started having burning when I pee, and peeing frequently and feeling a strong and sudden urge. Should I go to the emergency room?	
GPT-3.5 Response	**GPT-4 Response**
It is recommended that you seek medical attention as soon as possible for these symptoms, but it may not necessarily require a trip to the emergency room. You could start by contacting your primary care physician or an urgent care center. They can evaluate your symptoms and recommend the appropriate course of action. In some cases, they may refer you to an emergency room if they believe it is necessary. If you experience severe pain or bleeding, have trouble urinating, or have a fever, these could be signs of a more serious condition, and you should seek immediate medical attention at an emergency room.	I'm not a doctor, but I can offer some general guidance on your symptoms. It sounds like you may be experiencing symptoms of a urinary tract infection (UTI) or another urinary condition. While I can't provide a definitive diagnosis, I can offer some suggestions: 1. UTI: The symptoms you described, including burning during urination, frequent urination, and a strong and sudden urge, are common signs of a UTI. UTIs can be uncomfortable and, if left untreated, may lead to more severe infections. 2. Other Possible Causes: Your symptoms could also be related to other conditions, such as a urinary tract or bladder infection, kidney stones, or interstitial cystitis. It's important to consult a healthcare professional to determine the underlying cause. 3. Seek Medical Advice: It's a good idea to seek medical advice and evaluation. While it might not necessarily require a visit to the emergency room, you should contact your primary care doctor or visit an urgent care facility for an initial assessment. 4. When to Go to the ER: In some cases, you may need to go to the emergency room if you experience severe pain, blood in your urine, high fever, or if your symptoms rapidly worsen. These could be signs of a more serious condition or complications. 5. Stay Hydrated: While waiting for a medical evaluation, make sure to stay hydrated by drinking water. Adequate hydration can help flush out bacteria and potentially ease some of the discomfort associated with a UTI. It's crucial to seek timely medical attention to receive an accurate diagnosis and appropriate treatment. Your healthcare provider can perform tests, such as a urine culture, to confirm the presence of an infection and prescribe antibiotics or other medications as necessary. Untreated urinary issues can lead to more severe health problems, so it's important to address your symptoms promptly.

Figure 3B: Triage Recommendations	
Input	
My wife passed out, what should I do?	
GPT-3.5 Response	**GPT-4 Response**
If your wife has passed out, there are several steps you should take to ensure her safety and wellbeing: 1. Call for emergency medical assistance: The first thing you should do is call your local emergency services or go to the nearest emergency room. This is especially important if your wife is unconscious for more than a few seconds or if she has any other symptoms such as chest pain, difficulty breathing, or seizures. 2. Check her breathing and pulse: If your wife is unconscious, check to see if she is breathing and has a pulse. If she is not breathing or does not have a pulse, start performing CPR immediately and continue until medical professionals arrive. 3. Make her comfortable: If your wife is breathing and has a pulse, try to make her as comfortable as possible. Place her in a safe and comfortable position, such as on her side with her head supported. Loosen any tight clothing or jewelry that may be restricting her breathing or circulation. 4. Stay with her. Stay with your wife until medical professionals arrive. If possible, have someone else call for emergency assistance while you attend to your wife. Remember, passing out can be a sign of a serious medical condition, and it's important to seek medical attention right away. Stay calm and take the necessary steps to ensure your wife's safety and wellbeing.	I'm not a medical professional, but I can offer some general guidance on what to do if someone passes out. If your wife has lost consciousness, it's important to take the following steps: 1. Check for Safety: Ensure that both you and your wife are safe. Make sure there are no immediate dangers, such as a fall hazard or ongoing medical emergency. 2. Assess Responsiveness: Gently try to wake your wife by calling her name and tapping her shoulder. Check if she responds to verbal or tactile stimuli. If she doesn't respond, she is unconscious. 3. Call for Help: If your wife is unconscious or if she regains consciousness but seems confused or disoriented, call 911 (or the emergency number in your country) immediately to request emergency medical assistance. It's important to have professional medical help on the way. 4. Monitor Breathing: Check if your wife is breathing. If she's not breathing or if her breathing is irregular, you may need to start CPR if you are trained to do so. If you are not trained in CPR, the emergency dispatcher can guide you through it. 5. Positioning: If your wife is breathing normally, place her in a safe and comfortable position, lying on her back with her legs elevated slightly if possible. This can help improve blood flow to the brain. 6. Recovery Position: If your wife is breathing but you're concerned about vomiting, you can gently roll her onto her side in a recovery position to help prevent choking. Keep her head supported and her airway clear. 7. Stay Calm: Try to remain as calm as possible during the situation. Stress and panic can make the situation more challenging. 8. Provide Information: When medical professionals arrive, be prepared to provide them with information about your wife's medical history, any medications she's taking, and any recent events or symptoms leading up to her passing out. It's crucial to let healthcare professionals assess your wife's condition, as there could be various causes for loss of consciousness, including but not limited to dehydration, low blood sugar, heart issues, seizures, or neurological problems. Timely medical evaluation is essential to determine the underlying cause and provide appropriate treatment. Please remember that this advice is not a substitute for professional medical guidance. Always follow the instructions of trained medical personnel during an emergency.

Figure 3. (A–B). ChatGPT input and output. Top output demonstrates ChatGPT triage recommendations and bottom output signifies urgent response instructions.

Costs

ChatGPT is currently easily accessible and offers a no-cost user account for the public. A subscription-based upgrade is also offered, which provides quicker response times and early access to new features.[7] Utilization of ChatGPT to assist patient education for various aspects of care, including understanding health conditions, discharge instructions, and when to seek emergency medical care may save hospital time, money, and resources. Emergency departmemt spending is a growing financial concern on a national level but may be

Figure 4: Multiple Languages	
Input	
I am having pain in my chest, back, and neck. I have a history of diabetes. Should I go to the emergency room?	
GPT-3.5 Response	**GPT-4 Response**
Yes, chest, back, and neck pain can be symptoms of a serious medical condition, such as a heart attack, especially if you have a history of diabetes. It's always better to err on the side of caution when it comes to chest pain, as delaying treatment can lead to serious complications. Therefore, it is recommended that you go to the emergency room or call your local emergency services immediately for further evaluation and treatment.	I'm not a doctor, but I can provide some general guidance based on your description. If you are experiencing chest pain and have a history of diabetes, you should take your symptoms seriously, as they could potentially be related to a cardiac issue or other medical concerns. Chest pain can have various causes, some of which may be life-threatening. It's essential to err on the side of caution and seek immediate medical attention if you're unsure about the cause of your symptoms. Here are some factors to consider: 1. Chest Pain: Chest pain can be a symptom of a heart attack or other cardiac problems. While chest pain can also be caused by other conditions, it's important not to dismiss it, especially if it's accompanied by other symptoms. 2. Diabetes: Having a history of diabetes can increase your risk of cardiovascular issues, so any chest pain should be taken seriously. 3. Other Symptoms: Pay attention to any additional symptoms you may be experiencing, such as shortness of breath, dizziness, nausea, sweating, or pain radiating down your arm. These symptoms could indicate a cardiac event. 4. Medical Evaluation: Given your symptoms and medical history, it is advisable to seek medical evaluation promptly. It's generally safer to go to the emergency room for chest pain, as they can perform necessary tests and diagnostics to rule out serious conditions. 5. Do Not Drive Yourself: If you don't have someone to drive you, consider calling an ambulance or emergency services for transportation to the hospital. It's safer than attempting to drive yourself. It's crucial not to delay seeking medical attention when you experience chest pain, especially if you have a history of diabetes or other risk factors for heart disease. While the symptoms could be due to a non-cardiac issue, it's important to rule out any serious conditions and receive appropriate care. Please consult with a healthcare professional or call 911 for immediate assistance.

Input	
Tengo dolor en el pecho, la espalda y el cuelo. Tengo antecedentes de diabetes. ¿Debo ir a la sala de emergencias?	
GPT-3.5 Response	**GPT-4 Response**
Sí, el dolor en el pecho, la espalda y el cuello puede ser un síntoma de una afección médica grave, como un ataque cardíaco, especialmente si tiene antecedentes de diabetes. Si experimenta este tipo de dolor, es mejor ser precavido y buscar atención médica inmediata en la sala de emergencias o llamar a los servicios de emergencia locales para una evaluación y tratamiento adecuados. Es importante no ignorar los síntomas y recibir atención médica lo antes posible.	Lamento escuchar que estás experimentando dolor en el pecho, la espalda y el cuello, y entiendo que tienes antecedentes de diabetes. Es importante tomar estos síntomas en serio, ya que podrían estar relacionados con problemas cardíacos u otras condiciones médicas. El dolor en el pecho puede tener varias causas, algunas de las cuales podrían ser potencialmente graves. Aquí hay algunos factores a considerar: 1. Dolor en el Pecho: El dolor en el pecho puede ser un síntoma de un ataque al corazón u otros problemas cardíacos. Debido a tus antecedentes de diabetes, debes prestar especial atención a este síntoma. 2. Antecedentes de Diabetes: La diabetes puede aumentar el riesgo de problemas cardiovasculares, por lo que es importante tomar en serio cualquier dolor en el pecho. 3. Otros Síntomas: Observa si tienes otros síntomas adicionales, como dificultad para respirar, mareos, náuseas, sudoración o dolor que se irradia hacia el brazo. Estos síntomas podrían indicar un evento cardíaco. 4. Evaluación Médica: Dados tus síntomas y antecedentes médicos, es aconsejable buscar evaluación médica de inmediato. Por lo general, es más seguro acudir a la sala de emergencias en caso de dolor en el pecho, ya que allí pueden realizarse pruebas y diagnósticos necesarios para descartar condiciones graves. 5. No Te Conduzcas a Ti Mismo: Si no tienes a alguien que pueda llevarte, considera llamar a una ambulancia o a servicios de emergencia para que te transporten al hospital. Es más seguro que intentar conducir por ti mismo. No debes demorar la búsqueda de atención médica cuando experimentas dolor en el pecho, especialmente si tienes antecedentes de diabetes u otros factores de riesgo para enfermedades cardíacas. Aunque los síntomas podrían deberse a una afección no cardíaca, es importante descartar cualquier condición grave y recibir la atención adecuada. Consulta a un profesional de la salud o llama al 911 para recibir asistencia inmediata.

Figure 4. ChatGPT responses in English (top) and Spanish (bottom).

alleviated by reducing the frequency of presentations for preventable causes and avoidable visits.[26] By providing personal guidance on when to seek emergency care, ChatGPT has the potential to make important contributions to lowering hospital burden.

RISKS AND LIMITATIONS OF CHATGPT

Technical Restrictions

Using ChatGPT in emergency medicine carries certain risks. One major concern is that the model can provide different responses to the same or similar questions, which affects its reliability and usefulness. Because ChatGPT is based on a ML algorithm, it may generate different responses to similar questions depending on a variety of factors, such as the order or context of words used as input. In a recent study on ChatGPT's responses, identical questions regarding cirrhosis and hepatocellular carcinoma were submitted twice and independently graded. ChatGPT was able to produce two similar responses 90.48% of the time. Although this number may be regarded as high reproducibility, it raises

concerns over the potential consistency of offering medical advice to laypersons. Although most instances will provide the user with the same information, ChatGPT's responses are based on probability.[27] Future studies should analyze this variability to determine the impact on response appropriateness for the user.

In addition to output variability, there is also a potential for differences in user comprehension. This underscores another risk: the potential for differences in comprehension and interpretation of the information provided to laypersons. Although this limitation is common among many different technologies, these differences in comprehension can lead to potentially adverse outcomes for patients. Given these considerations, it is crucial to exercise caution and apply critical thinking when using ChatGPT as a source of information in healthcare interactions. It is essential to be aware of the potential for developing overconfidence in ChatGPT's recommendations, and the risk for anchoring on a specific diagnosis or impression for both patients and clinicians.

Response variability and interpretation of responses can impact the consistency and reliability of this model. It is important for clinicians and patients to be aware of these risks, and to use ChatGPT as a supplementary tool rather than a primary source of information. Therefore, ongoing improvements in the technology and continued training of the algorithm should be pursued. Efforts to incorporate current medical literature into the training data could enhance the reliability and relevance of ChatGPT's responses. However, it remains essential to recognize the dynamic nature of clinical practice and the importance of relying on evidence-based guidelines to ensure patient safety and well-being.

Misinformation

Ensuring accurate and truthful information is crucial when using ChatGPT, as misinformation can have serious consequences for patient care. ChatGPT's training data is limited to information available before 2021. Medical knowledge and practices have evolved since this knowledge cutoff point, and ChatGPT may reference information that is outdated or no longer applicable to current medical practices. According to the ChatGPT study for cirrhosis and hepatocellular carcinoma, ChatGPT's answers contained a mix of correct and incorrect information. The percentage of responses that were classified as having both correct and incorrect or outdated answers was 22% in basic knowledge, 33% in diagnosis, 25% in treatment, 18% in lifestyle, and 50% in preventive medicine.[28] However, while this study highlights potential limitations of ChatGPT's accuracy in responding to questions about hepatocellular carcinoma, it is important to recognize that further research is needed to comprehensively evaluate the accuracy of ChatGPT's responses across all medical domains. Physicians and patients must remain cautious when using ChatGPT and seek confirmation from other reliable sources before making decisions based on the information provided.

Another concern is the model's opaque algorithm, which can generate plausible sounding but inaccurate or nonsensical answers, a phenomenon known as "hallucinations".[29] Evidence of this can be seen in fabricated sources when ChatGPT is asked to provide references for a given response.[30] ChatGPT's training may have included scientific literature citation datasets, but its generative algorithm does not allow for one-to-one data source matching, resulting in a response that provides completely fabricated sources. Patients may be less likely to question the accuracy of ChatGPT's responses if they are presented with a source and simply assume that the information has been verified. This can ultimately lead to patients making decisions that are not in their best interest and may even result in harm.

There is currently unavoidable risk of misinformation when using ChatGPT for patient education in emergency medicine. To mitigate this risk, it is important to manage expectations and risk thresholds. Physicians and patients should be advised of the risks and benefits of this technology. Additionally, regular evaluation and improvement of the model will help minimize the risk of inaccuracies and misunderstandings.

Privacy and Security

Ensuring patient privacy and security is another concern when using ChatGPT for patient encounters. Unauthorized access to protected health information (PHI) can lead to identity theft, insurance fraud, and other types of harm to the patient. For physicians, unauthorized disclosures violate the Health Insurance Portability and Accountability Act (HIPAA) and can lead to disciplinary action, loss of licensure, and legal liability. OpenAI, the creators of ChatGPT, have stated that data used with ChatGPT will remain secured by default, with an opt-out option to share data for research and quality improvement. Nevertheless, major corporations such as Verizon and JPMorgan & Co. have restricted employees from accessing ChatGPT due to concerns over possible data breaches.[31] Sensitive healthcare information could be at a similar risk.

While the public availability of the ChatGPT application programming interface makes it easy to integrate into websites and applications, it also raises concerns about the security and privacy of patient information. As the use of artificial intelligence (AI) chatbots become more widespread, it is increasingly important to ensure that these technologies are used in a way that protects patient privacy and complies with regulations such as HIPAA. Integrating ChatGPT into a HIPAA-compliant framework may help address these concerns. Healthcare technology leaders must take necessary measures to protect PHI.

Medicolegal and Other Ethical Consideration

Integration of ChatGPT into emergency medicine presents a complex landscape of medicolegal and ethical implications.[32] We have previously discussed limitations with the software: potential for misdiagnosis and delayed treatment is a significant concern. Artificial intelligence systems, while advanced, may not always accurately interpret patient symptoms, which is dependent upon the quality of user input and the software's understanding. This has potential to influence patient outcomes, and there are numerous situations that could do the same.

Consider the following hypothetical, ethical scenarios:

- ChatGPT recommends against seeking care, which results in a harmful or life-threatening patient outcome.
- ChatGPT provides false information to a patient.
- Patients inadequately advised on the risks/benefits of ChatGPT misinterpret its analysis.
- Patient PHI is accessed during a data breach or during the performance improvement process.
- ChatGPT provides information that is not up to date or conflicts with current guidelines.

In the unfortunate circumstance where one or more of these events occur and legal action is taken, who should be held responsible—OpenAI, clinicians, or both? This is a current challenge that necessitates further interdisciplinary discussion between stakeholders.[33] Nonetheless, there are steps that must be taken to help minimize risk for all parties involved. For example, there should be restrictions placed on LLMs prior to official implementation in the field. Whether through legislation or an independent body, ChatGPT must adhere to regulatory standards that ensure HIPAA-compliance and informed consent.[34] Physicians and OpenAI must also work toward education on potential risks of the software. Physicians and other healthcare professionals should also implement legal forms and liability waivers into the care process to ensure protection in instances where these regulations fail.

TRANSITIONING INTO CLINICAL STUDIES

The next major step that must be taken is to validate ChatGPT's efficacy and safety in clinical settings.[32] One of the major barriers that researchers may face is the ever-changing updates to the software, which is also a limitation of this paper. Not only is ChatGPT continually being updated, but the protocols by which fine-tuning, updates, and further training occur are confidential.[10] This inherently makes ChatGPT difficult to study. However, potential future studies with ChatGPT are many and should assess the accuracy, safety, readability, and semantic analysis of the software. One such future study could consider the efficacy of patient triage for ChatGPT and triage nurse phone calls. Future studies should also investigate the cost benefit of implementing such a system into ED workflow, either for triage, discharge instructions, or both. This should be corroborated by examining potential algorithm bias in the real world.[32,34,35]

THE PHYSICIAN'S ROLE IN CHATGPT

As stated previously, ChatGPT cannot replace a physician. Although OpenAI has made significant strides in developing a software that communicates in a more human-like, empathetic manner compared to previous chatbots, current technology still lacks the oversight and nuance offered by a human. This technology cannot replace an in-depth history, physical exam, or clinical reasoning. However, given the current rate of progress on these technologies, it would be naive to consider a future independent of technology-assisted patient encounters. For this reason, physicians and healthcare professionals must be involved in research and development oversight to ensure accurate data is available on these platforms, and that these technologies are being developed with the right intentions. Physicians should also continue to be informed on AI developments, so that they can play a proactive role in educating patients on the benefits, limitations, and liability of the software. Further studies must also examine the legal implications for physicians, patients, and OpenAI, as ChatGPT and healthcare continue to intersect.

CONCLUSION

This paper describes the use of ChatGPT as an educational resource for patients seeking emergency medical treatment. Although limitations such as technical issues, misinformation risk, lack of input standardization, and privacy concerns exist, this software offers compelling benefits for patient education. The software can answer questions specific to patients and their presentations, allowing for a personalized educational resource. ChatGPT can also clarify discharge instructions, help triage urgent vs emergent conditions, and it can respond in multiple languages. Physicians must understand these benefits and limitations to best guide patients and conduct further research in new AI technologies.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Comments on "A Shorter Door-in-Door-out Time Is Associated with Improved Outcome in Large Vessel Occlusion Stroke"

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Section Editor: Mark I. Langdorf, MD, MHPE
Submission history: Submitted January 3, 2024; Revision received March 21, 2024; Accepted March 25, 2024
Electronically published June 28, 2024
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.18668

Dear Editors:

We read with great interest, "A Shorter Door-in-Door-out Time Is Associated with Improved Outcome in Large Vessel Occlusion Stroke," by Sigal et al.[1] Firstly, we would like to congratulate the authors on their *WestJEM* publication that highlights important concepts for management of patients with ischemic stroke from large vessel occlusion (LVOS) in the emergency department (ED). However, we had a few comments regarding their conclusions about door-in-door-out (DIDO) time and stroke outcomes. Notably, the title states that shorter DIDO time correlates to improved stroke outcomes, but their multivariable logistic regression analysis demonstrated that DIDO was not statistically significant (Table 4, OR 1.13, 95% CI 0.99–1.30). While the univariate analysis suggested that ED patients with good outcome had shortened DIDO, this conclusion should not be made when their multivariate regression suggested otherwise.

The authors' findings and discussion also suggest that ED DIDO times are not relevant to stroke outcomes. This is controversial because there were also conflicting reports from previous studies.[2,3] In this present paper, the authors looked at specific time intervals for DIDO thresholds (≤60 minutes, >60 minutes, ≤90 minutes, >90 minutes, ≤120 minutes, >120 minutes), which they included in their univariate analysis but not their multivariable logistic regression analysis. By categorizing continuous variables, the authors risked losing the granularity of the variables and perhaps statistical power; however, it is unknown whether these intervals would have shown significance on multivariable logistic regression analysis, as opposed to assessing DIDO solely as a continuous variable in the logistic regression.

On the other hand, the authors reported that they calculated 90-day modified Rankin Scale (mRS) via electronic health records (EHR) and also retrospectively calculated 90-day mRS values for 77 (18%) of their patients. However, retrospective calculations of mRS are inherently biased, as clinicians tend to score a patient's disability as higher than what was experienced by the patient, and their quality of life lower.[4,5] Therefore, it is possible that outcome measures were more subjective and could affect the authors' analyses.

Additionally, data from our comprehensive stroke center (CSC), for which patients with LVOS and thrombectomy undergo prospective 90-day mRS assessment as part of the clinical care for all stroke patients, reported that different time intervals are associated with improved outcome for patients with LVOS. We analyzed the data of 203 patients with LVOS who presented to our CSC via our critical care resuscitation unit (CCRU) between January 2019–May 2021 for thrombectomy, using a machine learning algorithm (classification and regression tree [CART]). The CART algorithm uses recursive partitioning to identify important predictors and assign these predictors with relative variable importance (RVI). The most important predictors would be given a RVI of 100%; other predictors would subsequently be assigned RVI values as percentage of the most important factor.

Similarly to Sigal et al's study, our analysis found that while National Institutes of Health Stroke Scale and age were significant factors associated with patient outcomes (Appendix 1), the ED DIDO time was also a significant factor

with a RVI of 27.6% (Appendix 1). Furthermore, the DIDO time at our CSC's resuscitation unit was also an important factor with a RVI of 62.7%. All the time intervals in our analysis were entered in the CART as continuous variables. Nevertheless, we hypothesize that the lack of significance in the authors' multivariable logistic regression may be because their patients' 90-day mRS values were obtained via EHR, in contrast to our data, which resulted from prospectively collected 90-day mRS values. However, the result that the CCRU's DIDO was a significant factor with higher RVI values than ED DIDO for patients' outcome could also provide another possible explanation for the findings in Sigal et al and Scheving et al that ED DIDO might not be a significant factor. It could be that what was delayed in ED DIDO time was later made up by the teams at the CSC once patients were transferred from the EDs. However, further studies are necessary to confirm or refute our observation.

Despite our concerns, we wholeheartedly agree with the authors that clinicians need to expedite patients who have LVOS to undergo thrombectomy, regardless of where they are during the critical time period.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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