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JOURNAL FOCUS

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

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Attitudes, Beliefs, Barriers, and Facilitators of Emergency Department Nurses Toward Patients with Opioid Use Disorder and Naloxone Distribution

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Introduction: As opioid overdose deaths continue to rise, the emergency department (ED) remains an important point of contact for many at risk for overdose. In this study our purpose was to better understand the attitudes, beliefs, and knowledge of ED nurses in caring for patients with opioid use disorder (OUD). We hypothesized a difference in training received and attitudes toward caring for patients with OUD between nurses with <5 years and ≥6 years of clinical experience.

Methods: We conducted a survey among ED nurses in a large academic medical center from May–July 2022. All ED staff nurses were surveyed. Data entry instruments for the nursing surveys were programmed in Qualtrics, and we analyzed results R using a chi-square test or Fisher exact test to compare nurses with <5 years and ≥6 years of clinical experience. A *P*-value of < 0.05 was considered statistically significant.

Results: We distributed 74 surveys, and 69 were completed (93%). Attitudes toward naloxone distribution from the ED were positive, with 72% of respondents reporting they were "very" or "extremely" supportive of distributing naloxone kits to individuals at risk of overdose. While attitudes were positive, barriers included limited time, lack of system support, and cost. Level of comfort in caring for patients with OUD was high, with 78% of respondents "very" or "extremely" comfortable. More education is needed on overdose education and naloxone distribution (OEND) with respondents 38% and 45% "a little" or "somewhat" comfortable, respectively. Nurses with <5 years of experience reported receiving more training on OEND in nursing school compared to those with ≥6 years of experience ($P = 0.03$). There were no significant differences in reported attitudes, knowledge, or comfort in caring for patients with OUD.

Conclusion: In this single-center survey, we found ED nurses were supportive of overdose education and naloxone distribution. There are opportunities for targeted education and addressing systemic barriers to OEND. All interventions should be evaluated to gauge impact on knowledge, attitudes, and behaviors. [West J Emerg Med. 2024;25(4)444–448.]

INTRODUCTION

Opioid use disorder (OUD) is associated with a 20-fold risk of early death due to overdose, infection, trauma, or suicide.[1] Nationally, an estimated 68,000 people died of opioid-related overdose in 2020, and 2.7 million suffered from OUD.[2] The impact of non-medical opioid use and OUD can be seen in many healthcare settings, including the emergency department (ED), as opioid-related visits in the ED had an estimated cost of $1.47 billion per year between 2016–2017.[2,3]

Patients presenting to the ED for opioid-related encounters, including opioid overdose, are at high risk for negative outcomes. Emergency department-based interventions such as overdose education and naloxone distribution (OEND) can have a significant impact on opioid-related morbidity and mortality. Naloxone is an opioid receptor antagonist that is used to quickly reverse the effects of opioid overdose. In 2018, the US Surgeon General recommended increasing access to naloxone for those who are at an increased risk of an opioid overdose.[4] The American College of Emergency Physicians also recommends providing naloxone for patients at increased risk of opioid overdose, including those discharged from the ED after an opioid-related visit as well as any patient with a history of OUD.[5]

Emergency department-based take-home naloxone programs have been an effective means of distributing naloxone to patients at risk for future overdose[6,7]; and OEND from the ED has been shown to have positive impact on trained laypersons in addition to patients and their social network.[8] Large-scale OEND has been shown to be an effective public health intervention.[9] Patient education related to overdose prevention and naloxone distribution can be provided by ED nurses who routinely spend more time with patients than the treating clinician. Clinical nurse specialist-led OEND in the ED have been effective across an integrated healthcare system.[10] While much is known about the beliefs, attitudes, and barriers of prescribers toward naloxone distribution, including time, cost, and clinical decision support, less is known about nurse perspectives in the ED.[6,7,11–15] We sought to evaluate nurse attitudes, beliefs, barriers, and facilitators to naloxone distribution in an academic ED in the Midwest.

Population Health Research Capsule

What do we already know about this issue?
Emergency departments play a crucial role in caring for patients with opioid use disorder (OUD) with interventions such as overdose education and naloxone distribution.

What was the major research question?
What are attitudes of ED nurses related to caring for patients with OUD, and training in overdose education and naloxone distribution (OEND)?

What is the major finding of the study?
ED nurses have positive attitudes (72%) toward naloxone distribution. Early career nurses (<5 years) had more OEND training.

How does this study improve population health?
Results highlight opportunities for targeted nursing education, addressing barriers and facilitators to OEND in the ED, thereby improving care for patients with OUD.

METHODS

From May–July 2022 we conducted a survey of ED nurses at a quaternary-care, academic ED in the Midwest that sees approximately 60,000 patients per year. The research team, which included an emergency physician and an addiction medicine physician, created a survey tool in collaboration with survey methodology experts from the University of Wisconsin Survey Center. Most items on the survey were developed by the team, but the stigma questions were adapted from a validated mental health stigma survey.[15–17] Research coordinators in the ED distributed 74 paper surveys to full and part-time ED staff nurses at daily staff huddles during the study period. Each respondent was allowed to complete only one survey. A $5 pre-incentive was included with the survey at the time of distribution.

We used a chi-square test or Fisher exact test to assess the difference in nurse attitudes, based on relative job experience (≤5 years v ≥6 years), regarding perception, knowledge, and barriers for naloxone distribution and caring for patients with OUD. All analyses were done in R v 4.1.1 2021 (R Foundation for Statistical Computing, Vienna, Austria). A P-value of <0.05 was considered statistically significant.

Disclosures

This study was reviewed by the University of Wisconsin-Madison Minimal Risk Research Institutional Review Board and deemed exempt. None of the authors have any financial conflicts of interest to disclose.

RESULTS

Surveys were distributed to 74 ED nurses, with a 93% response rate. Respondents had a breadth of clinical experience, with 60% having been a practicing nurse for six years or more. Of that group, 21% had been a practicing

nurse for ≥16 years. The majority of the ED nurses reported completing their nursing training in the Midwest (83%). Other regions represented were the West (7.6%), Southwest (1.5%), Southeast (4.5), and Northeast (3%).

Overall, the level of training on OEND during nursing school was low, with 77% reporting no or a little education received. Nurses with 0–5 years of experience reported receiving more education compared to nurses with ≥6 years of experience ($P = 0.03$). When asked about level of comfort providing education related to naloxone for overdose prevention immediately following nursing school, 67% felt "not at all" or "only a little" prepared. Despite more recent nursing school graduates reporting more education in nursing school, there were no differences in how prepared they felt to provide OEND ($P = 0.63$).

Responses were mixed when they were asked about the perceived effectiveness of naloxone kits as a public health intervention, with 55% of all nurses reporting naloxone kits are "a little" or "somewhat" effective. However, the majority (66%) felt that naloxone kits would not increase behavior that put people at risk for overdose. Additional responses to questions about attitudes, beliefs, barriers, and facilitators to naloxone distribution from the ED are available in the Table. Responses to all questions were compared between the nurses with 0–5 years' experience to those with ≥6 years' experience, and no statistically significant differences were appreciated.

Overall comfort level for caring for patients who use non-prescribed opioids was high, with 78% of respondents very or extremely comfortable. Again, no differences were appreciated between nurses with 0–5 years' experience and those with ≥6 years' experience.

Barriers and facilitators to naloxone distribution in the ED are varied and related to time, education, and cost concerns. Staff reported the most significant barrier was limited staff time, with 47% reporting this was an "extremely" impactful barrier. These are similar to previously described barriers and facilitators that prescribers report facing; responses are included in the Table.[14–18]

DISCUSSION

Emergency department nurses are critical to the effectiveness of ED-based OEND programs. Although there have been multiple studies looking at emergency clinician attitudes, beliefs, barriers, and facilitators to naloxone distribution, little is known about ED nurse-specific factors for OEND. Although nurses in practice for ≤5 years reported receiving more education on naloxone for overdose prevention while in nursing school, the additional education did not relate to statistically significant differences in attitudes, comfort, or perceived barriers or facilitators. Further research is needed to provide a better understanding of why receiving more education did not lead to increased

Table. Responses of emergency department nurses to questions about attitudes, beliefs, barriers, and facilitators to naloxone distribution from the ED.

		Not at all	A little	Somewhat	Very	Extremely
Attitudes	How much do you support giving naloxone kits to individuals who might be at risk for opioid overdose?	1.5% (1)	10.3% (7)	16.2% (11)	29.4% (20)	42.6% (29)
	How effective is giving a naloxone kit to people who use drugs as a public health intervention?	0.0% (0)	24.6% (17)	30.4% (21)	29.0% (20)	14.5% (10)
	How likely is giving a naloxone kit to people who use drugs going to lead to behaviors that increase risk for overdose, eg, using more opioids or using in combination with other drugs?	41.8% (28)	23.9% (16)	25.4% (17)	9.0% (6)	0.0% (0)
Comfort	Asking screening questions about non-prescribed opioid use?	0.0% (0)	2.9% (2)	10.1% (7)	47.8% (33)	39.1% (27)
	Caring for patients who use non-prescribed opioids?	0.0% (0)	1.4% (1)	20.3% (14)	46.4% (32)	31.9% (22)
	Offering a naloxone kit to be able to reverse an overdose?	1.4% (1)	5.8% (4)	33.3% (23)	31.9% (22)	27.5% (19)
	Teaching a layperson to administer naloxone?	2.9% (2)	10.1% (7)	27.5% (19)	34.8% (24)	24.6% (17)
	Providing care to a person with an opioid use disorder compared to helping a person with a physical illness?	3.0% (2)	4.5% (3)	26.9% (18)	47.8% (32)	17.9% (12)
	Educating patients about opioid overdose prevention?	0.0% (0)	5.8% (4)	36.2% (25)	44.9% (31)	13.0% (9)
	Educating patients about overdose response and naloxone administration?	4.3% (3)	15.9% (11)	29.0% (20)	37.7% (26)	13.0% (9)
	Educating patients about overdose prevention?	2.9% (2)	18.8% (13)	30.4% (21)	34.8% (24)	13.0% (9)

(*Continued on next page*)

Table. Continued.

		Not at all	A little	Somewhat	Very	Extremely
Barriers	Limited staff time?	0.0% (0)	4.5% (3)	18.2% (12)	30.3% (20)	47.0% (31)
	Lack of systems supporting it to happen in a time efficient way?	1.5% (1)	4.6% (3)	21.5% (14)	43.1% (28)	29.2% (19)
	Lack of clinical decision support to ensure consistent process?	31.% (2)	10.9% (7)	25.0% (16)	39.1% (25)	21.9% (14)
	How much of a barrier to dispensing naloxone kits from the ED is lack of insurance or limited insurance coverage leading to high costs to patients?	9.4% (6)	10.9% (7)	17.2% (11)	39.1% (25)	23.4% (15)
	Concerns about being able to identify patients at risk for overdose?	21.2% (14)	28.8% (19)	40.9% (27)	9.1% (6)	0.0% (0)
	Concerns that a layperson won't be able to administer it appropriately?	28.8% (19)	37.9% (25)	27.3% (18)	6.1% (4)	0.0% (0)
	Concerns that providing a naloxone kit will lead to more or riskier drug use?	48.5% (32)	15.2% (10)	16.7% (11)	18.2% (12)	1.5% (1)
	Concerns that patients will be offended by it being offered?	40.9% (27)	19.7% (13)	31.8% (21)	6.1% (4)	1.5% (1)
Facilitators	Funding to ensure patients don't have to pay co-pays for cost of the naloxone kit?	3.1% (2)	7.8% (5)	20.3% (13)	32.8% (21)	35.9% (23)
	Clinical decision support that makes the prescription an automated process?	0.0% (0)	9.4% (6)	26.6% (17)	48.4% (31)	15.6% (10)
	Education for staff?	1.6% (1)	3.1% (2)	43.8% (28)	35.9% (23)	15.6% (10)
	How much of a facilitator to discharging a patient from the ED with a naloxone kit is patient education materials to teach about overdose prevention and naloxone administration?	3.2% (2)	7.9% (5)	27.0% (17)	44.4% (28)	17.5% (11)

ED, emergency department.

comfort or knowledge and whether offering more targeted education can improve these metrics. Despite receiving more education, early career nurses have had less experience caring for patients with OUD, which may have contributed to the results.

Overall, most respondents were comfortable caring for patients with OUD, including asking OUD screening questions. Slightly less than half felt naloxone is a "very" or "extremely" effective public health intervention, which is an important area for future educational efforts and evaluation. Additional areas for educational foci include trainings on overdose prevention education and naloxone training for patients and their friends/family while in the ED. This data provides a baseline understanding and can be re-assessed after further educational initiatives.

We found nursing-identified barriers were similar to previously described prescriber barriers including limited time, cost, and lack of efficient system support.[18–20] Some of these barriers can be addressed with clinical decision support, including prompts to order naloxone for patients with opioid-related diagnostic codes. Providing standardized, easy-to-follow instructions on overdose prevention and naloxone administration can benefit both the patients and the staff member providing the education. Although handouts are helpful, regular education by content experts would provide continued education to ensure all staff are comfortable with overdose prevention education and naloxone use moving forward.

Overall, ED nurses were open to receiving more education, and most nurses identified this as a facilitator to expanding naloxone distribution in the ED. Using baseline surveys like the one our team used can guide ED leadership when developing educational and systems interventions for nursing staff.

LIMITATIONS

Limitations of this study include evaluating a single, academic Level I trauma center; so results may not apply more broadly to other EDs. We did not evaluate for nursing experience in areas outside the ED. Additionally, the number of ED nurses surveyed was small (69); so it is possible that the sample size was too small to enable us to identify differences between the nurses with less experience as compared to those with more experience.

CONCLUSION

Understanding attitudes, beliefs, barriers, and facilitators of naloxone distribution among ED nurses is important for successful implementation of overdose education and prevention programming. Emergency department nurses surveyed were generally supportive of naloxone distribution and comfortable caring for patients with OUD. There are opportunities for addressing systemic barriers and providing targeted education to facilitate ED-based naloxone distribution. These results show opportunities to improve care for patients with OUD, although future research is needed to determine whether education impacts knowledge, attitudes, and behaviors.

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Pragmatic Emergency Department Intervention Reducing Default Quantity of Opioid Tablets Prescribed

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Introduction: The opioid epidemic is a major cause of morbidity and mortality in the United States. Prior work has shown that emergency department (ED) opioid prescribing can increase the incidence of opioid use disorder in a dose-dependent manner, and systemic changes that decrease default quantity of discharge opioid tablets in the electronic health record (EHR) can impact prescribing practices. However, ED leadership may be interested in the impact of communication around the intervention as well as whether the intervention may differentially impact different types of clinicians (physicians, physician assistants [PA], and nurse practitioners). We implemented and evaluated a quality improvement intervention of an announced decrease in EHR default quantities of commonly prescribed opioids at a large, academic, urban, tertiary-care ED.

Methods: We gathered EHR data on all ED discharges with opioid prescriptions from January 1, 2019–December 6, 2021, including chief complaint, clinician, and opioid prescription details. Data was captured and analyzed on a monthly basis throughout this time period. On March 29, 2021, we implemented an announced decrease in EHR default dispense quantities from 20 tablets to 12 tablets for commonly prescribed opioids. We measured pre- and post-intervention quantities of opioid tablets prescribed per discharge receiving opioids, distribution by patient demographics, and inter-clinician variability in prescribing behavior.

Results: The EHR change was associated with a 14% decrease in quantity of opioid tablets per discharge receiving opioids, from 14 to 12 tablets ($P = <.001$). We found no statistically significant disparities in prescriptions based on self-reported patient race ($P = 0.68$) or gender ($P = 0.65$). Nurse practitioners and PAs prescribed more opioids per encounter than physicians on average and had a statistically significant decrease in opioid prescriptions associated with the EHR change. Physicians had a lesser but still significant drop in opioid prescribing in the post-intervention period.

Conclusion: Decreasing EHR defaults is a robust, simple tool for decreasing opioid prescriptions, with potential for implementation in the 42% of EDs nationwide that have defaults exceeding the recommended 12-tablet supply. Considering significant inter-clinician variability, future interventions to decrease opioid prescriptions should examine the effects of combining EHR default changes with targeted interventions for clinician groups or individual clinicians. [West J Emerg Med. 2024;25(4) 449–456.]

INTRODUCTION

The opioid epidemic is a major cause of morbidity and mortality in the United States, including in California.[1] Opioid prescriptions initiated in the emergency department (ED) and other clinical care settings can increase the incidence of opioid use disorder (OUD) in a dose-dependent manner—the more tablets prescribed, the greater the risk of future development of OUD.[2–4] In addition, the presence of excess opioid tablets in the home is linked to diversion and overdose.[5] Decreasing the total quantity of tablets prescribed from the ED may help decrease the risk of these harms.

Many interventions attempt to decrease and alleviate the risks of opioid prescriptions in ED settings, from electronic clinical decision support alerts to co-prescription of naloxone, but most existing ED interventions focus on decreasing prescription rates rather than decreasing the quantity of opioid tablets prescribed when ED patients are discharged with opioids.[6–8] Prior research has shown that decreasing the default quantity of tablets prescribed in the electronic health record (EHR) without announcing the change to clinicians can decrease the number of opioids per prescription given at discharge. In these studies, clinicians were not notified of altered EHR default prescriptions either for convenience or to test the effect of a default change alone, or due to concern that clinicians would consciously override the defaults.[9–13]

Because protocol changes in the ED are commonly arrived at by consensus and are usually implemented transparently rather than unannounced, studying the effect of an announced EHR change more closely mirrors real-world scenarios. An announcement about the change may have the added benefit of educating clinicians about opioid prescribing guidelines, the risks of prescribing opioids, and signals what other clinicians are thinking about opioid prescriptions. Further, there is evidence that nurse practitioners (NP) and physician assistants (PA) are more likely than physicians to prescribe opioids in primary care settings,[14] but the relationship between clinician type and opioid-prescribing behavior in the ED setting remains unknown. In addition, prior work has not shown whether these different types of clinicians respond similarly to default-directed attempts to decrease opioid prescribing.

To address these gaps, we implemented a quality improvement (QI) intervention decreasing EHR default quantities of commonly prescribed opioids at a large, academic, urban, tertiary-care center. Our goal was to determine whether this EHR change was associated with decreased opioid prescribing and whether this association varied by clinician type.

Population Health Research Capsule

What do we already know about this issue?
Emergency department opioid prescriptions increase the incidence of opioid use disorder in a dose-dependent manner, potentially exacerbating the opioid epidemic.

What was the research question?
This study evaluated the impact of a quality improvement intervention decreasing default opioid quantities in the EHR from 20 pills to 12, on average opioids prescribed at discharge.

What was the major finding of the study?
The EHR change was associated with a 14% decrease in quantity of opioid tablets per discharge receiving opioids ($P < .001$), driven mostly by nurse practitioners' and physician assistants' changes.

How does this improve population health?
We demonstrate a simple intervention other emergency departments can immediately implement to reduce the burden opioid prescribing has on the opioid epidemic.

METHODS

Design

We implemented a single-site, QI intervention at a large, academic, urban tertiary-care ED altering the default quantity of six commonly prescribed opioids. This was a prospective QI study where data was pulled from chart review and analyzed both during study design and continuously during implementation. We collected pre-intervention data on all ED discharges receiving these six opioids at discharge from January 1, 2019–March 28, 2021, and compared this with post-intervention data from March 29, 2021–December 5, 2021. This work was considered QI activity according to the University of California, San Francisco institutional review board policy. As a result, the requirement for individual research HIPAA authorization and signed consent forms was waived for all subjects as the research presented no more than minimal risk of harm to the subjects' privacy.

Intervention

We decreased the pre-populated ED discharge dispense quantities in the EHR from 20 tablets to 12 tablets for the following six commonly prescribed opioids: oxycodone 5 milligrams (mg); oxycodone-acetaminophen 5–325 mg; oxycodone 10 mg; tramadol 50 mg; hydrocodone-acetaminophen 5–325 mg; and hydrocodone-acetaminophen 10–325 mg. Changes were made at the system level and applied to all ED patients and clinicians. Clinicians decided

for whom to prescribe opioids and could choose any quantity by altering the default setting. Clinicians in the ED were informed of the study and quantity changes using two communication methods: by two email announcements sent to all physicians, PAs, and NPs; and by two in-person announcements during the weekly all-staff ED meetings attended by 10–12 total physicians, PAs, and NPs. The email and weekly all-staff announcements were made over a period of two weeks prior to the intervention.

Participants

We included ED patient encounters in which patients were discharged from the ED with a prescription for one of the six opioid medications included in the intervention. We also recorded the total number of patients discharged from the ED each month during the period of our study, regardless of whether they were given a prescription at the end of their visit. Each encounter was recorded as an observation, regardless of whether these patients had other ED visits.

Outcomes

From all ED encounters that had an opioid medication prescribed at discharge, we extracted the following data from the EHR: date of visit; patient demographics (race, age, gender, insurance type); acuity (based on the assigned Emergency Severity Index score in the EHR), chief complaint, prescribing clinician type, opioid medication prescribed and quantity of tablets. Insurance type was categorized as Medicaid, Medicare, commercial, self-pay, or other. Chief complaints were classified into the four most common chief complaints seen in our ED over the study period (back pain, abdominal pain, flank pain, falls), with the remaining chief complaints grouped as "other." Prescribing clinician types were categorized as physician, NP, or PA.

Our primary outcome measure was the difference in mean number of opioid tablets prescribed at discharge before and after our intervention. Our secondary outcomes included differences in this measure given the patient's self-reported race and self-reported gender, as well as prescribing clinician type for the encounter (physician, NP, PA). We also tested the difference in mean morphine milligram equivalents (MME) prescribed at discharge before and after our intervention.

Analysis

We calculated MMEs using the conversion factors provided by the US Centers for Disease Control and Prevention (CDC).[4] Frequency tables were generated for categorical variables. Median and interquartile range were generated for age and means, and standard deviations were calculated for all other continuous variables. We performed two sample *t*-tests to compare mean opioid tablets prescribed before and after our intervention and calculated 95% confidence intervals (CI). Given the effect of the COVID-19 pandemic on the volume of ED discharges during our pre-intervention data collection, we performed sensitivity analyses restricting the study period to different start times, including after the start of the COVID-19 pandemic (in March 2020). We performed chi-square tests of independence for age, race, insurance type, and acuity before and after intervention, and the Fisher exact test for gender. Two-way analysis of variance (ANOVA) was performed to analyze the interaction between clinician type and intervention on mean opioid tablets prescribed. P values < 0.05 were reported as significant. We performed all analyses using Python 3 (Python Software Foundation, Wilmington, DE).

RESULTS

There were 3,575 ED discharges with an opioid prescribed during the study period, of which 3,274 (91.6%) had prescriptions for one of the six opioids targeted by our intervention, including 2,666 discharges pre-intervention and 608 discharges post-intervention. **Opioids not targeted** by our intervention included morphine (2.5%), hydromorphone (1.4%), **oxycodone** (1.3%), hydrocodone (<1%), codeine (<1%), **tramadol** (<1%), methadone (<1%), and fentanyl (<1%). The patient population seen in the ED pre- and post-intervention had similar distributions of discharge diagnoses, age, gender, self-reported race, acuity, insurance type, and prescribing clinician type (Table 1). There were no statistically significant differences in prescriptions between individuals with different self-reported races (chi-squared $P = 0.68$) or between genders (Fisher exact $P = 0.65$) before and after implementation of our intervention.

The number of ED encounters associated with an opioid prescription upon discharge was proportional to the total number of discharges from the ED throughout the study period, although both experienced a precipitous decline at the start of the COVID-19 pandemic (Figure 1).

Decreasing the EHR default quantity of commonly prescribed opioids was associated with a decrease from 14.01 to 12.00 tablets per discharge prescription with opioids from the ED, a difference of 2.01 tablets (95% CI 1.44–2.58) (Table 2). Sensitivity analysis showed there was a statistically significant difference in tablets prescribed regardless of how many months were included in the pre-intervention dataset (Supplemental Table 1). This decrease in tablets is mirrored by an 11.0 MME decrease per discharge prescription with opioids (95% CI 5.74–16.22) from 94.25 to 83.27 (Table 2).

For 2,666 pre-intervention encounters in the dataset, physicians wrote 47.6% of study prescriptions, NPs wrote 26.8%, and PAs wrote 25.6% of study prescriptions. For the 608 post-intervention encounters in the dataset, physicians wrote 50% of study prescriptions, NPs wrote 24.3%, and PAs wrote 25.7% of study prescriptions. All clinician types prescribed significantly fewer opioids per encounter after the intervention compared to prior, with PAs and NPs affected

Table 1. Patient demographics of opioid prescriptions in the emergency department.

Patient demographics	All	Pre	Post	*P* value
Age, median (IQR)	48 (27)	48 (27)	48 (29)	0.88
Gender, n (%)				0.65
Female	1,707 (0.522)	1,395 (0.5242)	312 (0.514)	
Male	1,561 (0.478)	1,266 (0.4758)	295 (0.486)	
Race, n (%)				0.69
White	1,719 (0.525)	1,393 (0.5225)	326 (0.536)	
Black	423 (0.129)	353 (0.1324)	70 (0.115)	
Asian	467 (0.143)	382 (0.1433)	85 (0.14)	
Other	665 (0.203)	538 (0.2018)	127 (0.209)	
Acuity, n (%)				0.29
Emergent	286 (0.087)	243 (0.0912)	43 (0.071)	
Urgent	2,013 (0.615)	1,618 (0.6071)	395 (0.65)	
Less urgent	947 (0.289)	781 (0.2931)	166 (0.273)	
Non-urgent	27 (0.008)	23 (0.0086)	4 (0.007)	
Insurance, n (%)				0.53
Commercial	1,448 (0.442)	1,172 (0.4396)	276 (0.454)	
Medicaid	801 (0.245)	662 (0.2483)	139 (0.229)	
Medicare	702 (0.214)	571 (0.2142)	131 (0.216)	
Self-pay	167 (0.051)	140 (0.0525)	35 (0.058)	
Other	156 (0.048)	121 (0.0454)	27 (0.044)	
Clinician, n (%)				0.42
Physician	1,573 (0.481)	1,269 (0.476)	304 (0.5)	
NP	862 (0.263)	714 (0.268)	148 (0.243)	
PA	839 (0.256)	683 (0.256)	156 (0.257)	
Discharge diagnosis, n (%)				0.38
Abdominal pain	425 (0.130)	345 (0.129)	80 (0.131)	
Back pain	324 (0.0990)	258 (0.0968)	66 (0.109)	
Flank pain	292 (0.0892)	248 (0.0930)	44 (0.0724)	
Fall	190 (0.0580)	41 (0.0559)	149 (0.0674)	
Other	2,043 (0.624)	1,666 (0.624)	377 (0.620)	

IQR, interquartile range; *NP*, nurse practitioner; *PA*, physician assistant.

the most (Figure 2, Table 3). A two-way ANOVA of the clinician type and intervention confirmed statistically significant effects of the intervention, clinician type, and interaction between intervention and clinician type on the number of tablets per discharge prescription with opioids ($P < 0.001$).

DISCUSSION

We implemented an announced decrease in EHR default quantities of six commonly prescribed opioids at a large, academic, urban, tertiary-care ED. The analysis of our primary outcome showed that this QI intervention was associated with a statistically significant decrease in opioid tablets per discharge prescription with opioids from the ED, from 14 to 12 tablets, and a corresponding 11-point decrease in mean MMEs prescribed. While no studies have precisely quantified the clinical significance of this level of decrease, prior literature and CDC guidelines note a dose-dependent relationship between prescriptions and risk of developing OUD, suggesting that every pill matters at a population level.[2–4] Further, given that this center's pre-intervention mean tablets per ED discharge opioid prescription was only 14, the maximum expected decrease from a default change to 12 was only a decrease of two tablets per discharge prescription. However, these interventions might confer a larger clinical significance at other institutions with a higher

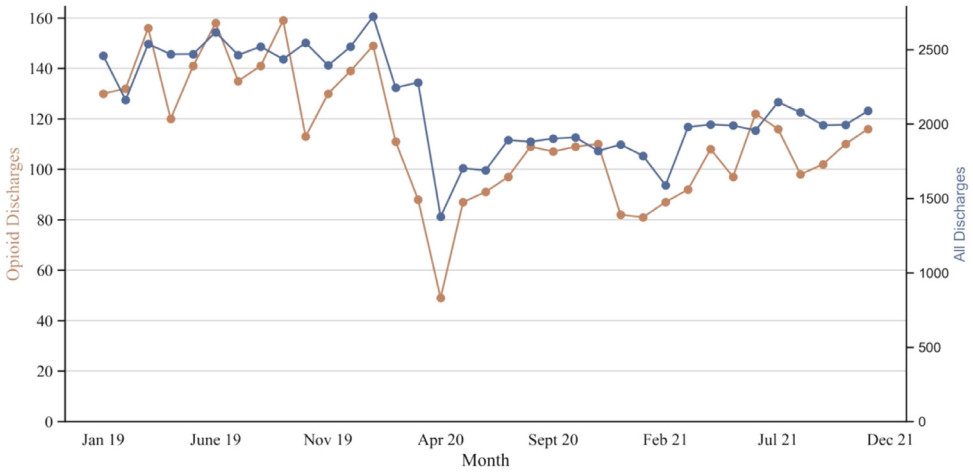

Figure 1. Decreasing default opioid quantities in the electronic health record is associated with lower ED prescription of opioids in the emergency department. Number of total discharges (blue) and discharges in which opioids were prescribed (orange) over the study timeline. The intervention began on March 19, 2021.

Table 2. Tablets and morphine milligram equivalents per discharge prescription with opioids.

Opioid prescriptions	All Mean (SD)	Pre Mean (SD)	Post Mean (SD)	Δ (95% CI)	*P* value
Tablets per opioid discharge	13.63 (6.54)	14.01 (6.75)	12.00 (5.22)	−2.01 (−2.58, −1.44)	<.001
MME per opioid discharge	92.21 (59.60)	94.25 (62.18)	83.27 (45.60)	−11.0 (−16.22, −5.74)	<.001

CI, confidence interval; *MME*, morphine milligram equivalent.

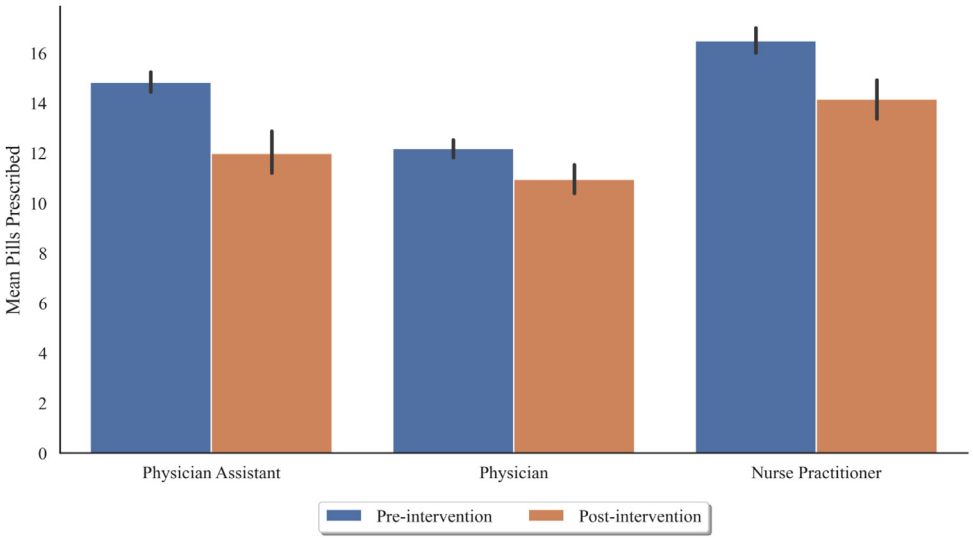

Figure 2. Clinician type is associated with opioid prescription quantities in the emergency department. Average number of tablets per discharge in which opioids were prescribed, grouped by clinician type and intervention time (blue = pre-intervention, orange = post-intervention).

Table 3. Number of tablets per discharge prescription with opioids, by clinician type.

Clinician type	All	Pre	Post	Δ (Post minus Pre)	95% CI
NP	16.09	16.49	14.16	−2.33	(−3.40, −1.08)
Physician	11.93	12.17	10.95	−1.22	(−2.08, −0.46)
PA	14.30	14.83	11.99	−2.84	(−3.80, −1.88)

NP, nurse practitioner; *PA*, physician assistant; *CI*, confidence interval.

starting mean tablets per discharge. Importantly, we observed that NPs and PAs in the ED setting are more likely than physicians to prescribe higher levels of opioids at baseline, consistent with previous results in primary care settings.[14]

Our results suggest that a universal default change is associated with decreased opioid prescriptions across all clinicians, with larger decreases for NPs and PAs compared to the change observed for physicians. The higher rates of opioid prescriptions among NPs and PAs could be due to a variety of factors, including differences in the acuity or types of illnesses and injuries evaluated. Additionally, even after the intervention, the high average opioids prescribed in the NP group was driven by a few clinicians still far exceeding the default (Supplemental Figure 1). The existence of inter-clinician variability in prescriptions may provide opportunities for more targeted future interventions, such as NP- or PA-specific interventions in conjunction with EHR-driven interventions.

We chose to analyze the average number of tablets prescribed per encounter in which opioids were prescribed rather than per ED visit or per month. Average number of tablets aligns more directly with our intervention, which was aimed at reducing the quantity of opioids prescribed after a clinician had already determined a need for opioid analgesia. Additionally, the number of tablets prescribed per opioid encounter is less impacted by temporal and seasonal variation in prescribing patterns and visit acuity, including the effect of the COVID-19 pandemic.

In most prior studies, clinicians were not notified of altered EHR default prescriptions either for convenience or to test the effect of a default change alone, or due to concern that clinicians would consciously override the defaults.[9–13] However, we found that decreasing default EHR opioid quantities to 12 tablets coupled with informing clinicians of the EHR change resulted in a decrease in the total number of opioids prescribed at ED discharge. We observed decreases in the average number of tablets prescribed per patient and the average MME of tablets prescribed per patient. This suggests that transparency with clinicians regarding best practices in opioid prescribing does not negate the effect of altering EHR defaults. It is possible that an announcement to clinicians about the EHR change and the rationale behind it may serve as an educational feedback component to the intervention. Clinicians who appreciate the purpose of the default change may be more likely to use the default, go lower than the default, or even write fewer prescriptions as they see fit for each clinical scenario, consistent with prior work demonstrating that audit and feedback approaches can decrease opioid prescribing.[15]

Because prior work has demonstrated the existence of racial disparities in opioid prescribing, we investigated whether clinicians' opioid prescribing behavior differed based on patient demographics.[16] Our analysis showed that there was no statistically significant disparity in opioid prescription amounts based on patient demographics, including age, race, and gender, for both the pre- and post-intervention data.

It is also important to note that the COVID-19 pandemic started during our pre-intervention phase, which resulted in an overall decrease in ED utilization.[17] However, our outcome is somewhat insulated from changes in ED volume, as tablets per prescription should not be dependent on the number of patient discharges. The COVID-19 pandemic may have led to other more subtle changes in prescribing behavior secondary to changing patient populations seen, but the major chief complaints did not differ in the pre- and post-intervention period, and the results of our sensitivity analysis confirmed that the effect seen was still present even after restricting our data to an entirely post-COVID-19 timeframe.

Ultimately, we recognize that opioids remain first-line treatments for certain indications such as short-term pain relief for acute fractures and cancer pain and are often necessary at discharge from the ED. However, given the risks of diversion, overdose, and OUD associated with discharging patients with large quantities of opioid tablets, it is important to encourage emergency clinicians to discharge patients with a clinically appropriate yet safe quantity of tablets. It is also important to use discretion as opioids are often not indicated for certain other causes of pain in patients presenting to the ED, including the common chief complaints of abdominal pain and lower back pain.[18] Recommendations for acute pain suggest discharging patients with a three-day supply of opioid medications, which corresponds to 12 tablets or less.[19] Our approach is a pragmatic, transparent, and scalable intervention that offers a tool that can be implemented in

the 42% of EDs nationwide that currently have defaults exceeding 12 tablets.[19]

LIMITATIONS

Our study design of a single-site, pre/post study does not allow for a causal interpretation and limits generalizability. Much of the project occurred during the COVID-19 pandemic, in which opioid prescribing increased nationwide; however, patterns for ED discharge prescriptions have not been studied.[20] Our design did not allow us to measure associated harms or benefits, such as whether pain control was adequate or whether diversion decreased.[21] Neither did our design allow us to test for differences in whether patients were prescribed opioids, which is also an important consideration for opioid stewardship. Additionally, the 12-tablet default quantity was chosen to approximate a three-day supply, but this length may vary based on the frequency prescribed of a given opioid, and there is limited evidence to support the optimal time course of opioids at discharge.[22]

Finally, the study design did not allow us to measure the precise number of clinicians who were exposed to the clinician-facing announcement, differentiate whether the effects observed were attributable to the EHR changes alone, the clinician-facing announcement alone, or a combination of the two.

CONCLUSION

We demonstrated that a quality improvement intervention coupling decreased default opioid quantities in the electronic health record with informing clinicians of the EHR change was associated with a decrease in the total number of opioids prescribed from the ED. While all clinician types (NPs, PAs, and physicians) decreased their quantities of opioids prescribed per discharge following the default change, NPs and PAs prescribed more opioids than physicians initially and experienced a larger decrease in opioid prescriptions. Future interventions seeking to address ED opioid prescribing should measure the total quantity of opioids leaving the ED over longer periods of time, use a robust, patient-centered metric for pain management follow-up, and attempt to correlate ED opioid prescriptions with negative opioid-associated outcomes in both individual patients and their communities.

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Accessibility of Naloxone in Pharmacies Registered Under the Illinois Standing Order

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Introduction: To expand access to naloxone, the state of Illinois implemented a standing order allowing registered pharmacies to dispense the drug without an individual prescription. To participate under the standing order, pharmacies were required to opt in through a formal registration process. In our study we aimed to evaluate the availability and price of naloxone at registered pharmacies.

Methods: This was a prospective, de-identified, cross-sectional telephone survey. Trained interviewers posed as potential customers and used a standardized script to determine the availability of naloxone between February–December, 2019. The primary outcome was defined as a pharmacy indicating it carried naloxone, currently had naloxone in stock, and was able to dispense it without an individual prescription.

Results: Of 948 registered pharmacies, 886 (93.5%) were successfully contacted. Of those, 792 (83.4%) carried naloxone, 659 (74.4%) had naloxone in stock, and 472 (53.3%) allowed purchase without a prescription. Naloxone nasal spray (86.4%) was the formulation most commonly stocked. Chain pharmacies were more likely to carry naloxone (adjusted odds ratio [aOR] 3.16, 95% confidence interval [CI] 1.97–5.01, $P < 0.01$) and have naloxone in stock (aOR 2.72, 95% CI 1.76–4.20, $P < 0.01$), but no more likely to dispense it without a prescription. Pharmacies in higher population areas (aOR 0.99, 95% CI 0.99–0.99, $P < 0.05$) and rural areas adjacent to metropolitan areas (aOR 0.5, 95% CI 025–0.98, $P < 0.05$) were less likely to have naloxone available without a prescription. Associations of naloxone availability based on other urbanicity designations, overdose count, and overdose rate were not significant.

Conclusion: Among pharmacies in Illinois that formally registered to dispense naloxone without a prescription, the availability of naloxone remains limited. Additional interventions may be needed to maximize the potential impact of a statewide standing order. [West J Emerg Med. 2024;25(4)457–464.]

INTRODUCTION

The rise of opioid-related overdose has had a devastating effect on communities across the United States. In 2020 alone, over 68,000 people died from opioid-related overdose, of which almost 3,000 occurred in the state of Illinois.[1,2] The rapidly evolving drug market, with the introduction of fentanyl, fentanyl analogues, and xylazine into the illicit drug supply, has contributed to the increasing opioid overdose fatality rates, with 64% of US drug overdose deaths during May 2020–April 2021 involving illicitly manufactured fentanyl.[3–5]

In response to the opioid overdose epidemic, a multi-pronged approach has been enacted to reduce morbidity and mortality. Among these are several harm reduction strategies, including syringe service programs, infectious disease screening, drug checking (eg, fentanyl test-strip distribution), supervised consumption sites, and distribution of naloxone. Multiple studies have demonstrated naloxone's ability to be used effectively and appropriately by people with no formal medical training.[6] For example, Enteen et al found that of the 24% of patients who returned for naloxone refills over a six-year period, 11% of those reported using naloxone during an overdose event, with an 89% success rate of overdose reversal.[7] Further, studies have shown that naloxone distribution does not lead to increased opioid consumption and may even lead to decreased use.[7,8] Recognizing its safety and efficacy, the US Surgeon General issued an advisory notice in 2018 encouraging its use and availability.[9] Despite widespread support by leading healthcare organizations and federal agencies, naloxone access remains limited, and opportunities to help individuals at risk for overdose are frequently missed.[10,11]

As of 2017, all 50 states had passed legislation expanding public access to naloxone.[12] In addition to legislation protecting against civil, criminal, or professional liability for both prescribers and lay administrators of naloxone, some states have introduced policies to increase the accessibility of the life-saving drug. Studies have demonstrated that pharmacists are willing to provide naloxone to the public under a standing order or other similar process (Stewart et al, 2018; Nielsen et al, 2016; Green et al, 2017). To expand access to naloxone, the Illinois Department of Public Health (IDPH) implemented a statewide standing order in 2017 (Public Act 99–0480), allowing registered pharmacies to distribute naloxone to patients without an individual prescription in their name. To register under the Illinois Naloxone Standing Order, licensed pharmacies must participate in a pre-approved training and agree to report any dispensed naloxone to the Illinois Prescription Monitoring Program.[13]

Illinois is now one of 49 states that allow pharmacists to dispense naloxone without a patient-specific prescription from a clinician, 44 of which use a standing order.[14] Despite this, studies from other states have shown limited uptake of these new protocols and wide variations in availability of naloxone at registered pharmacies.[15–22] In this cross-sectional study we aimed to evaluate the accessibility of naloxone at pharmacies registered under the statewide standing order by determining which pharmacies reported routinely carrying naloxone, which pharmacies had naloxone currently in stock, which pharmacies were willing to dispense naloxone without a prescription, which formulations were carried, and the out-of-pocket cost of naloxone. Our primary outcome was to determine which pharmacies had naloxone available without a prescription on the day of the inquiry. We further compared pharmacies' naloxone availability by pharmacy type (chain vs non-chain), urbanicity, population of ZIP Code, and opioid overdose rates in the pharmacies' surrounding region. This study expands on the existing literature by using a sample that included all pharmacies that opted in to registering under the Illinois Naloxone Standing Order. We also analyzed factors that may affect the likelihood that a pharmacy had naloxone available without a prescription, which was rarely done in previous studies.

Population Health Research Capsule

What do we already know about this issue?
Most states offer naloxone at pharmacies without a prescription, but uptake is limited.

What was the research question?
Which pharmacies registered under the Illinois Naloxone Standing Order had naloxone available without a prescription?

What was the major finding of the study?
Only 53.3% of registered pharmacies (1/8th of all Illinois pharmacies) had naloxone in stock and available without a prescription.

How does this improve population health?
Statewide standing orders are an important but insufficient step toward widespread naloxone possession. More effort is needed to improve participation.

METHODS

Study Design

A prospective, anonymous, cross-sectional "secret-shopper" telephone survey sampling all Illinois pharmacies

that had registered under the state-level standing order was performed by six trained callers. The list of pharmacies registered under the standing order was accessed on February 17, 2019 (Chicago) and May 23, 2019 (remainder of Illinois) via the IDPH Opioid Data Dashboard.[2] The list of pharmacies, their cities, and their contact numbers were transposed from the dashboard into an Excel document (Microsoft Corp, Redmond, WA) for tracking purposes. For each pharmacy, we obtained a ZIP Code and evidence of continued operation via Google searches. If a pharmacy was found to no longer be in existence, the pharmacy was marked as unable to contact.

Data Collection

Six study personnel (one attending physician, one resident physician, three medical students, and one master's level research associate) underwent three hours of training consisting of reviewing the call script, discussing the logic behind each question, discussing specific language to use, and conducting at least three pilot calls to pharmacies not included in the study sample. Pilot calls were debriefed as a group.

The callers posed as potential customers and used a standardized script to ask targeted questions. Callers followed automated prompts or requested to be connected to the pharmacy. Callers spoke with whichever pharmacy staff first answered the call and continued to use the script if the call was transferred to other pharmacy staff. If placed on hold, the caller waited up to 10 minutes before terminating the call. If the call was interrupted or the pharmacy was unreachable on the initial attempt, the pharmacy was contacted up to two additional times. If a pharmacy was unreachable three times, it was considered inactive and not included in our analyses. Calls were completed from February–December 2019. Data was collected either directly into REDCap 9.5.35 LTS (Research Data Capture hosted at University of Chicago Medicine) or into Microsoft Excel and later transposed into REDCap.

The script for the calls was created using an iterative process by the group of investigators. We designed the script to address the study questions while maintaining the appearance of a lay caller. The generic name of the medication (naloxone) was used initially. If staff seemed uncertain of the medication in question, the brand name of Narcan was used after first repeating the generic name. See Appendix 1 for the script for the secret-shopper telephone survey of pharmacies that are registered under the Illinois Naloxone Standing Order.

Measures

We collected characteristics for each pharmacy based on pharmacy type, urbanicity, population of pharmacy ZIP Code, and the overdose rate in the pharmacy ZIP Code. Pharmacies were classified as "chain" if they had four or more locations under shared ownership, and "non-chain" if they had fewer than four locations.[15,16] We defined urbanicity using the US Department of Agriculture 2013 Rural-Urban Continuum Codes (RUCC) that assign counties a score on a scale of 1-9 based on county population size and adjacency to a metropolitan area.[17] As commonly practiced elsewhere in the literature, we divided this continuum into three groups: 1) urban; 2) rural adjacent to a metropolitan area; and 3) rural and nonadjacent to a metropolitan area.

We used ZIP Codes corresponding to each pharmacy to analyze the data using overdose rates and population. Number of combined fatal and non-fatal opioid-related overdose events in 2018 by ZIP Code was obtained from the IDPH Opioid Dashboard.[2] We obtained population by ZIP Code for 2018 from the US Census Bureau.[18] Using the population size and the number of overdoses, we calculated a 2018 rate of combined fatal and non-fatal opioid-related overdose per 10,000 people for each ZIP Code in our sample.

Statistical Analyses

We performed bivariate analyses to determine whether differences in naloxone availability on the day of the call were significantly different based on the following covariates: pharmacy type; urbanicity using RUCC code; population of pharmacy ZIP Code; and the 2018 overdose count and overdose rate per 10,000 residents in the pharmacy ZIP Code. We analyzed data using STATA MP v17 statistical software release 15 (StataCorp, LLC, College Station, TX). This study was reviewed by the University of Chicago Investigational Review Board and determined to be exempt from review.

RESULTS

We identified 948 pharmacies registered under the Illinois Naloxone Standing Order and successfully contacted 886 (93.5%) (Figure 1). Of the 886 pharmacies that were successfully contacted, 806 (91.0%) were chain pharmacies and 80 (9.0%) were non-chain. Of the 886 contacted pharmacies, 807 (91.1%) were located in urban ZIP Codes, 57 (6.4%) in rural ZIP Codes adjacent to a metropolitan area, and 22 (2.5%) in rural ZIP Codes that were nonadjacent to a metropolitan area. Additionally, of the contacted pharmacies, 792 (89.4%) reported carrying naloxone, with 659 (74.4%) reporting the medication to be in stock at the time of the call, and 472 (53.3%) responding that the caller did not need a prescription from a doctor to purchase the naloxone. The 472 pharmacies (53.3%) that carried naloxone, had naloxone in stock, and offered naloxone without requiring a prescription were considered positive for the primary outcome. Pharmacy characteristics are summarized in Table 1.

Figure 2 displays the cascade of naloxone availability by pharmacy type and RUCC. Pharmacies in urban RUCC

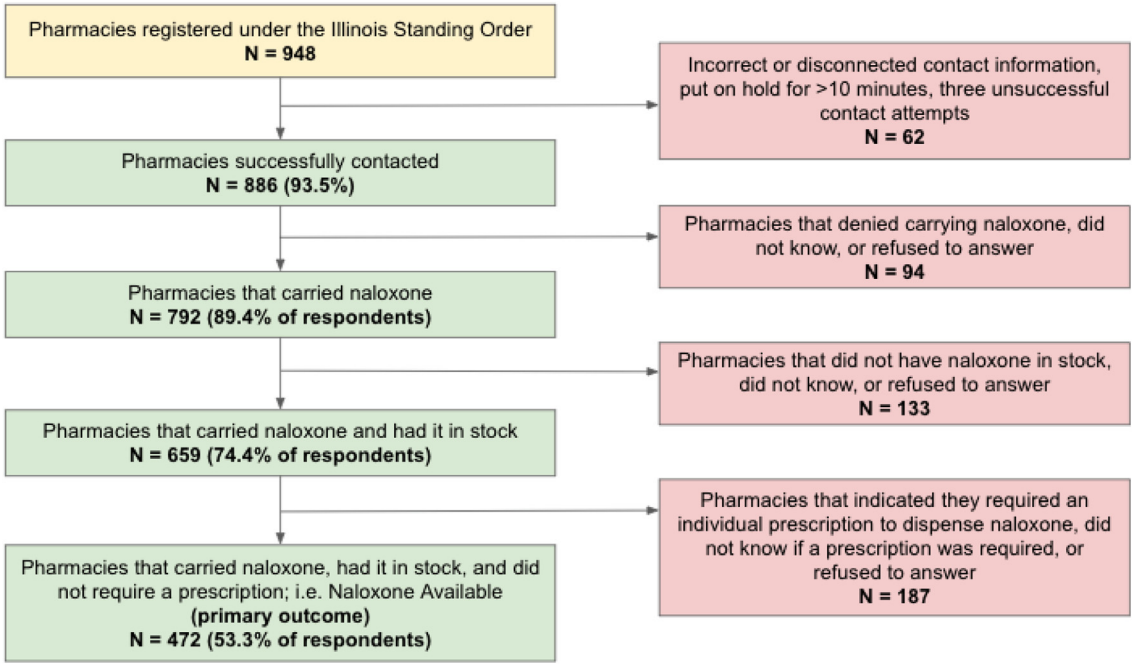

Figure 1. Availability of naloxone and need for a prescription in Illinois pharmacies registered under the Illinois Naloxone Standing Order.

Table 1. Pharmacy type, urbanicity, and naloxone availability of pharmacies registered under the Illinois Naloxone Standing Order that were successfully contacted (n = 886).

	Successfully contacted, n = 886 (Col %)	Carry Naloxone n = 792 (Row %)	Carry Naloxone, in stock n = 659 (Row %)	Naloxone available without a Rx, n = 472 (Row %)
Pharmacy type				
Chain (CVS, Walgreens)	806 (91.0%)	728 (90.3%)	611 (83.9%)	432 (70.7%)
Non-chain (Independent)	80 (9.0%)	64 (80.0%)	48 (75.0%)	40 (83.3%)
RUCC				
Urban	807 (91.1%)	720 (89.2%)	599 (83.2%)	433 (72.2%)
Rural adjacent to a metropolitan area	57 (6.4%)	52 (91.2%)	43 (82.7%)	28 (65.1%)
Rural and nonadjacent to a metropolitan area	22 (2.5%)	20 (90.9%)	17 (85.0%)	11 (64.7%)

Rx, prescription; *RUCC*, Rural-Urban Continuum Codes.

codes had the highest naloxone availability without a prescription (63.7%). A larger proportion of chain pharmacies carried naloxone (90.3%) compared to non-chain pharmacies (80.0%) ($P < 0.01$). Of the 772 pharmacies that stocked naloxone and provided a response to the type of naloxone, 624 (78.8%) carried naloxone nasal spray (see Table 2).

In the adjusted analyses, we found that chain pharmacies had greater odds of carrying naloxone (adjusted odds ratio [aOR] 3.16, 95% confidence interval [CI] 1.97–5.01, $P < 0.01$) and having naloxone in stock (aOR 2.72, 95% CI 1.76–4.20, $P < 0.01$) compared to non-chain pharmacies (Table 3). However, there were no differences between pharmacy type and naloxone availability without a prescription. With regard to RUCC, rural adjacent to a metro area had lower odds compared to urban areas of providing naloxone without a prescription (aOR 0.50, 95% CI 0.25–0.98, $P = 0.05$). We also observed that more densely populated ZIP Codes were less likely to have naloxone available without a prescription (aOR 0.99, 0.99–0.99, $P < 0.01$). Neither overdose (OD) count nor OD rate were associated with naloxone availability.

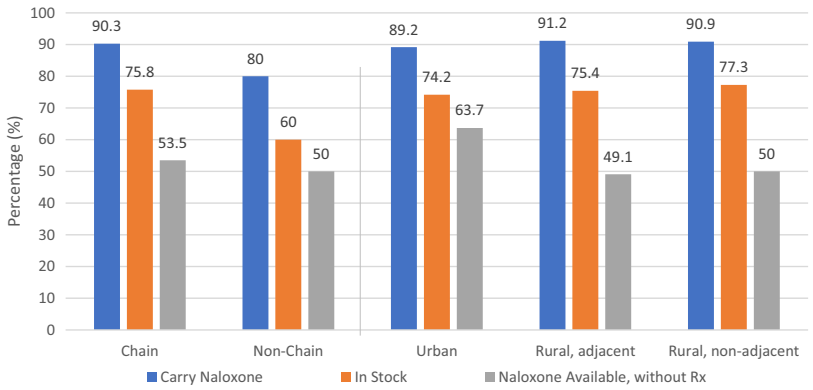

Figure 2. Pharmacy type, county urbanicity, and naloxone availability of pharmacies registered under the Illinois Naloxone Standing Order that were successfully contacted.
Rx, prescription.

Table 2. Of those who carry naloxone, available formulations of naloxone and median price.

Naloxone types	N = 722 (%)	Median price [IQR]
Naloxone nasal spray	624 (86.4)	$135.99 [$89.99, $4,500]
IM vials	71 (9.8)	$39.50 [$21.99. $239.00]
Naloxone autoinjector	27 (3.8)	$4,000 [$399.59, $6,000.00]

IQR, interquartile range; *IM*, intramuscular.

DISCUSSION

Standing orders are an important step toward reducing opioid-related mortality, but our findings suggest this legislation has not had the desired effect in state residents' access to naloxone. In 2019, two years after the implementation of the order, there was an average of 3,861 licensed pharmacies statewide.[19] Of these, only 948 (24.6%) were registered under the standing order at the time of our study. We successfully contacted 91% of the registered pharmacies and found that just over half (53.3%) had naloxone available on the day of contact and appropriately offered it without requiring a prescription. Given that all pharmacies on our contact list underwent pre-approved training to register with IDPH as a naloxone distribution site under the standing order, our findings indicate there is substantial room for improvement.

Studies from other states with comparable statewide naloxone access policies have shown limited uptake with wide variations in availability of naloxone. Across California, Texas, Pennsylvania, Massachusetts, and New York, the proportion of pharmacies that had naloxone in stock ranged from 23.5–70%, with some variation based on state and the specific sample of pharmacies studied.[20–24] Few studies have analyzed specific characteristics that may affect an individual pharmacy's likelihood of having naloxone available.[22,25] In Pennsylvania, Graves et al found that chain

Table 3. Association between predictors and carry naloxone, in stock, and no prescription needed.

	Carry Naloxone		In stock		No Rx	
	aOR (95% CI)	*P-value*	aOR (95% CI)	*P-value*	aOR (95%CI)	*P-value*
Pharmacy type						
Non-chain	*Ref*		*Ref*		*Ref*	
Chain	**3.16 (1.97, 5.01)**	**<0.01**	**2.72 (1.76, 4.20)**	**<0.01**	0.45 (0.20, 1.00)	0.05
RUCC						
Urban	*Ref*		*Ref*		*Ref*	
Rural adjacent to a metro area	1.77 (0.79, 3.98)	0.17	1.27 (0.69, 2.36)	0.44	**0.50 (0.25, 0.98)**	**0.05**
Rural, nonadjacent to a metro area	1.16 (0.41, 3.30)	0.78	1.15 (0.47, 2.82)	0.75	0.48 (0.17, 1.36)	0.17
Population by ZIP Code	1.00 (0.99, 1.00)	0.61	1.00 (0.99, 1.00)	0.40	**0.99 (0.99, 0.99)**	**0.003**
OD count	1.00 (0.99, 1.00)	0.74	1.00 (0.99, 1.00)	0.42	0.99 (0.98, 1.00)	0.09
OD rate	0.99 (0.98, 1.00)	0.16	0.99 (0.99, 1.00)	0.36	0.99 (0.98, 1.00)	0.27

Bold, $P \leq 0.05$; Adjusted analyses include controlling for pharmacy type, RUCC, and population by ZIP Code.
Rx, prescription; *aOR*, adjusted odds ratio; *CI,* confidence interval; *RUCC*, Rural-Urban Continuum Codes; *OD*, overdose.

pharmacies were more likely to carry naloxone, but OD rate and urbanicity did not influence naloxone availability.[22] In Indiana, Meyerson et al found that chain pharmacies, pharmacies with more than one full-time pharmacist, and those where pharmacists had received naloxone-related continuing education were associated with increased likelihood of stocking naloxone.[25]

A systematic review of the topic found that a heterogeneous group of 30 studies had wide-ranging findings, but overall one-third of pharmacies audited did not carry naloxone and almost half did not offer naloxone without a prescription.[26] While previous studies have explored the availability of naloxone under a standing order in different states, analysis of factors that may contribute to the likelihood that a pharmacy has naloxone available without a prescription remains limited. Our study is also unique for its high response rate as well as our use of a sample including all pharmacies that opted in to formalized training and registration under the standing order.

Improved access to naloxone through community pharmacies may come through multiple approaches. First, with less than a quarter of pharmacies registered, our findings highlight the need for more widespread participation in the Illinois Naloxone Standing Order. It appears that the public good and the financial incentives attached to increased dispensing of naloxone are insufficient to incentivize pharmacies to take the steps necessary to register under the standing order. Of note, Illinois Medicaid plans are required to cover at least one formulation of naloxone, with the intranasal formulation the most commonly covered formulation. Illinois Medicaid does not charge a copay for receipt of naloxone. Additional incentives may be necessary to mobilize greater pharmacy participation statewide.

Rural areas appeared to have particularly poor access to naloxone through community pharmacies. While 11.5% of Illinois residents live in rural areas, we found that only 22 (2.3%) of the pharmacies registered under the standing order were in rural areas.[27] While there was no significant difference in the primary outcome in rural vs urban pharmacies, the overall paucity of registered pharmacies in rural areas highlights a lack of access that may put rural people who use drugs at higher risk of death from overdose. This may further exacerbate the disproportionate impact of the opioid crisis on rural areas.[28,29]

Of the registered pharmacies we contacted, our findings highlight specific trends that may inform efforts to improve access to naloxone. We found that chain pharmacies were more likely than non-chain pharmacies to carry naloxone and have it in stock but were no more likely to have it in stock without a prescription required. This suggests that there are policies unique to chain pharmacies that facilitate registering under the standing order and stocking naloxone, but that perhaps training for customer-facing staff has been inadequate. This led ultimately to similar outcomes to non-chain pharmacies when it came to customers seeking to purchase naloxone without a prescription. These findings have some consistency with one Pennsylvania study, which found chain pharmacies to be more likely to carry naloxone and answer questions correctly about the standing order for naloxone.[22] Chain pharmacies may have more standardized training programs for certain staff members, maintain robust supply chains for naloxone, or have a stronger response to public pressure to contribute to reducing opioid-related deaths.

There was no statistically significant association between the number or rate of ODs in a ZIP Code and likelihood of naloxone availability. This finding suggests that there may be additional outreach or incentives necessary to encourage pharmacies in areas with the highest rates of OD to increase access to naloxone via the standing order.

Cost and available formulation may have a significant impact on how likely a customer is to obtain naloxone. In our sample, both cost and formulation were variable. The majority of pharmacies that had naloxone in stock carried the nasal naloxone spray (brand name Narcan) for an average cost of $135.99 for a two-pack. While Illinois Medicaid plans cover at least one formulation of naloxone without copay, private insurance and Medicare Part D plans have variable copay structures and formulation coverage. For uninsured individuals, those who don't want to use their insurance to fill this medication, or those for whom naloxone is not a covered medication, the out-of-pocket cost may be a significant deterrent to obtaining naloxone. Vials of naloxone, which can be used with a needle and syringe and injected intramuscularly, or with an atomizer for nasal administration, had a lower median price of $39.50; however, only 9% of pharmacies had this formulation in stock, and the availability and cost of other necessary supplies such as syringes, intramuscular needles, and/or nasal atomizers was unclear. We do believe that some of the high prices that were reported by pharmacy staff are inaccurate and for this reason we present the median price, which we believe accurately reflects what most consumers would pay out of pocket.

Our study highlights the need for additional strategies to maximize access to naloxone. Given that rural areas are less likely to have community-based naloxone distribution (often a service offered at harm reduction/syringe service programs), this need is particularly great in rural areas.[30–32] Future research is needed to understand whether naloxone availability in pharmacies is associated with increased utilization and, if so, how to increase availability of naloxone via standing order in retail pharmacies. Possible considerations could include the following: public education campaigns that would work to increase demand for naloxone in pharmacies, thereby encouraging pharmacies to register and stock naloxone; offering financial incentives or other public recognition for pharmacies that register for the standing order and stock naloxone formulations; and

improved public health outreach and educational programs (eg, academic detailing) to increase awareness among pharmacies, pharmacists, and pharmacy staff about the purpose of and evidence base of naloxone as it relates to reducing opioid-related mortality at the community level.

Research has found that pharmacists' discomfort dispensing naloxone to customers remains an important barrier and often results from inadequate training (Green, 2017; Thornton, 2017; Rudolph, 2018). As of November 20, 2017, only 19 states had mandated naloxone education for pharmacists (Roberts, 2019).[33] Illinois regulation requires participating pharmacists to complete an Illinois Department of Human Services- approved training module or to "understand the Naloxone Standardized Procedures" and watch two training videos (IDPH Naloxone FAQ), but it is unclear how much of this training is passed along to staff who directly interact with customers. One study comparing training material provided by states found that while most material covered the purpose and use of naloxone as well as the standing order legislation, few provided thorough education on how to communicate this information to customers (Carpenter, 2018). Overall, while there has been an increase in naloxone dispensed across all states with expanded access policies, retail pharmacy naloxone distribution is still underused and varies state by state (Xu, 2018).

LIMITATIONS

Our study has several limitations. We did not clarify the role of the staff member with whom we were speaking. It is possible that if we had asked to speak directly to the pharmacist, we would have obtained more accurate information; however, we felt it was most useful to mimic a more natural consumer interaction. It is possible, however, that responses would vary between staff members at an individual pharmacy. Information may also have been more accurate had we identified ourselves as academic research staff. Five of six callers had at least some medical background, but we believe that other studies could achieve the same goal in an analogous study using staff with no medical background.

We did not call pharmacies that were not listed on the IDPH website; so future research may include analysis of the percentage of total pharmacies in different regions that offer naloxone. We collected only information about out-of-pocket cost, which is likely only relevant to patients without insurance, those who don't want to use insurance when receiving naloxone, or those without naloxone included in their pharmacy benefit. Lastly, and perhaps most relevant to future research, we recognize that availability of naloxone in retail pharmacies may not directly correlate with increased utilization by people who use drugs (PWUD). Future studies should incorporate input from PWUD to delineate preferences in sources of naloxone.

CONCLUSION

We found that two years after implementation of the Illinois Naloxone Standing Order, only one-eighth of all pharmacies had naloxone in stock and available without a prescription. Within this group, chain pharmacies were more likely to carry naloxone and have it in stock but were no more likely to provide it without a prescription. Pharmacies in more densely populated ZIP Codes and those with a Rural-Urban Continuum Code reflecting rural areas that are adjacent to metro areas were less likely to have naloxone available without a prescription. Overdose rates in the surrounding community had no effect on naloxone availability. Our study illustrates a unique sample of all pharmacies statewide that have gone through formal training and registration under the standing order.

Increased access to naloxone in retail pharmacies in Illinois will require improved efforts related to awareness and implementation of the standing order, as well as further investigation into the reasons that a pharmacy that has gone through the process of applying to be able to use the standing order does not reliably stock naloxone and make it available without prescription. Specific attention should be given to areas where there is limited access to naloxone through community-based dispensing programs and where rates of overdose and potential for impact are highest.

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Improving Healthcare Professionals' Access to Addiction Medicine Education Through VHA Addiction Scholars Program

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Introduction: The seemingly inexorable rise of opioid-related overdose deaths despite the reduced number of COVID-19 pandemic deaths demands novel responses and partnerships in our public health system's response. Addiction medicine is practiced in a broad range of siloed clinical environments that need to be included in addiction medicine training beyond the traditional fellowship programs. Our objective in this project was to implement a knowledge-based, live virtual training program that would provide clinicians and other healthcare professionals with an overview of addiction, substance use disorders (SUD), and clinical diagnosis and management of opioid use disorder (OUD).

Methods: The Veterans Health Administration (VHA) Emergency Department Opioid Safety Initiative (ED OSI) offered a four-day course for healthcare professionals interested in gaining knowledge and practical skills to improve VHA-based SUD care. The course topics centered around the diagnosis and treatment of SUD, with a focus on OUD. Additionally, trainees received six months of support to develop addiction medicine treatment programs. Evaluations of the course were performed immediately after completion of the program and again at the six-month mark to assess its effectiveness.

Results: A total of 56 clinicians and other healthcare professionals participated in the Addiction Scholars Program (ASP). The participants represented nine Veteran Integrated Service Networks and 21 different VHA medical facilities. Nearly 70% of participants completed the initial post-survey. Thirty-eight respondents (97.4%) felt the ASP series contained practical examples and useful information that could be applied in their work. Thirty-eight respondents (97.4%) felt the workshop series provided new information or insights into the diagnosis and treatment of SUD. Eleven capstone projects based on the

information acquired during the ASP were funded (a total of $407,178). Twenty participants (35.7%) completed the six-month follow-up survey. Notably, 90% of respondents reported increased naloxone prescribing and 50% reported increased prescribing of buprenorphine to treat patients with OUD since completing the course.

Conclusion: The ASP provided healthcare professionals with insight into managing SUD and equipped them with practical clinical skills. The students translated the information from the course to develop medication for opioid use disorder (M-OUD) programs at their home institutions. [West J Emerg Med. 2024;25(4)465–469.]

INTRODUCTION

The national opioid epidemic is one of the leading preventable causes of morbidity and premature death in the United States. In 2017, the US Department of Health and Human Services (HHS) declared the opioid crisis a public health emergency.[1] The COVID-19 pandemic has exacerbated this crisis with an increased prevalence of opioid use disorder (OUD) and deaths from prescription and non-prescription opioids.[2] Veterans are at nearly twice the risk of fatal drug overdose when compared to non-veterans.[3] As part of the five priorities to combat the opioid crisis HHS highlighted the importance of improving access to prevention, treatment, and recovery support services.[1] However, there remain critical shortages of healthcare professionals who can provide these life-saving services.[4] Improving access to substance use disorder (SUD) care at any time, any place is an important part of the Veterans Health Administration's (VHA) strategy. As a result, there is a growing need for training healthcare professionals outside the traditional addiction medicine specialty on key components of addiction medicine and SUD.

The VHA is America's largest integrated healthcare system, providing care at 1,298 healthcare facilities including 171 medical centers and 1,113 VHA outpatient clinics. More than nine million enrolled veterans are served by the VHA each year.[5] Despite its size, the VHA system has a shortage of addiction specialists and SUD clinics. As a result, the responsibility of providing SUD care falls on a variety of specialties, including pharmacy and mental health, and primary care and emergency medicine. However, the education opportunities for these practitioners to obtain advanced training in addiction medicine is limited.

Currently, addiction medicine is not a required graduate medical education course for internal medicine, family medicine, or emergency medicine residencies. As a result, trainees receive variable exposure to SUD care during residency, leading to suboptimal preparation managing patients with addiction when practicing independently.[6,7] The traditional pathway for addiction medicine training is to complete a 12-month dedicated fellowship at one of the 90 sites accredited by the Accreditation Council for Graduate Medical Education.[8] This significant commitment limits the ability for frontline clinicians to obtain further training in addiction medicine. There is a need to create accessible didactic and practical clinical education in addiction medicine to increase frontline clinician comfort.

Lack of basic training in SUD is a significant barrier to physician engagement of medication for opioid use disorder (M-OUD) programs.[9,10] As a result, the Addiction Scholars Program (ASP) was developed to provide additional training for physician assistants, nurse practitioners, clinical pharmacists, academic detailing pharmacists, and physicians. The educational topics included a foundational understanding of the treatment of OUD, complex pain, and complex persistent opioid dependence. Our objective in this study was to measure the effectiveness, immediately and at six months, of a hybrid educational intervention paired with creation of multidisciplinary teams on knowledge retention and willingness to prescribe M-OUD.

METHODS

This was a post-implementation study of the ASP, a novel hybrid educational approach and facilitated, team-based quality improvement (QI) project. Surveys were performed at the conclusion of the course and at the six-month mark. The surveys focused on the course's effectiveness and the trainee's willingness to initiate an addiction medicine project at their site. We used descriptive statistics to interpret the results of the survey. The Emergency Department Opioid Safety Initiative (ED OSI) program was designated as a QI project through the Office of Pharmacy Benefits Management Academic Detailing Service from the institutional review board of the Edward Hines, Jr. VA Hospital and approved by the Rocky Mountain Regional VA Medical Center Research and Development service.

Addiction Scholars Program

The ASP is a part of the VHA ED OSI and was developed as an intensive course for clinicians interested in understanding VHA-based SUD care. Frontline clinicians

and other healthcare professionals who were current employees of the VHA were invited to apply to attend the ASP. Forty were accepted to attend the program. The course consisted of four virtual sessions that were each four hours long. Each session covered fundamental and advanced topics of addiction medicine for emergency and acute care settings.

The entire course was delivered virtually using the Microsoft Teams (Microsoft Corp, Redmond, WA) application. Topics included clinical management of OUD, opioid overdose management, buprenorphine induction, naloxone distribution, pain management in patients with OUD, and opioid-induced chronic pain syndrome. The program used a combination of lectures and case-based breakout sessions to reinforce key concepts. Lecturers were selected based on their experience and expertise in specific areas of addiction medicine. Interdisciplinary groups were strategically assembled for the case-based breakout sessions with members from the same VHA site and Veteran Integrated Service Networks (VISN). This allowed for a networking opportunity where group members could build connections that would lead to the development of M-OUD programs locally at their VHA site or at their VISN. The groups were paired with a member of the VHA ED OSI team who would facilitate discussion of the cases.

After successful completion of the course, trainees received six months of support to develop and implement addiction medicine treatment programs. Trainees were also encouraged to submit capstone projects, which were eligible for funding up to $50,000 (up to two years) to help implement addiction medicine projects at their local VHA site.

RESULTS

A total of 56 individuals participated in the ASP, including 32 clinicians, 10 clinical pharmacy practitioners, and 14 academic detailing pharmacists. The clinicians represented nine VISNs and 21 different VHA facilities. The class was composed of 15 physicians, seven nurses and nurse practitioners, 31 pharmacists, and three physician assistants. Participants ranged in age from 30–65 (mean 46.2 years) and had been in clinical practice for an average of 11 years (Table 1). Additionally, attendees represented numerous clinical service areas including emergency medicine, urgent care, primary care, pain management, mental health, and substance use treatment.

Of the 56 participants, 39 (almost 70%) responded to the initial post-survey. Thirty-eight respondents (97.4%) reported that the ASP series contained practical examples and useful information that could be applied in their work. Thirty-eight respondents (97.4%) felt that the workshop series provided new information or insights into the diagnosis and treatment of SUD. Thirty-five respondents (89.7%) were very or somewhat satisfied with the ASP series.

Twenty individuals who participated in the ASP responded to the six-month follow-up survey. The majority of respondents (85.0%) reported feeling "comfortable" or "very comfortable" initiating M-OUD since completing the ASP. Fourteen (70% of follow up respondents) pursued additional M-OUD training since completing the ASP. Of the 20 respondents, four worked in departments without an active M-OUD program; three of the four (75%) are currently working to develop an M-OUD program. Eighteen (90%) of the respondents reported increased naloxone prescribing since completing the ASP. Ten (50%) of the respondents increased prescribing of buprenorphine to treat patients with OUD since completing the course (Table 2).

At the conclusion of the ASP, 11 capstone projects were submitted and awarded a total of $407,178. Seven (63.6%) of the projects focused on the development of naloxone or buprenorphine programs. Other projects were focused on harm reduction with the development of a syringe service program, the use of fentanyl testing strips, development of a VISN-wide virtual learning program for SUD training, urine point-of-care testing for controlled medications, and music- and movement-based interventions to engage high-risk veterans in substance use treatment.

Table 1. Scholar characteristics.

	Scholars (%) ($N = 32$)
Profession	
Physician	15 (46.9)
Nurse practitioner	6 (18.8)
Nurse	1 (3.1)
Physician assistant	3 (9.4)
Pharmacist	7 (21.9)
Years out of training	
0–5 years	13 (40.6)
6–10 years	6 (18.8)
10+ years	10 (31.3)
Missing	3 (9.4)
Clinical Area	
Emergency department or urgent care	6 (18.8)
Mental health, substance use treatment, or psychiatry	14 (43.8)
Pain management	3 (9.4)
Primary care	5 (15.6)
Pharmacy	1 (3.1)
Missing	3 (9.4)

DISCUSSION

Our study demonstrated the ASP successfully provided additional addiction medicine training to clinicians and other healthcare professionals and that there is a desire for additional addiction medicine training within the VHA

Table 2. Results of initial and six-month follow-up survey.

	Initial follow-up (N = 39)
The ASP series contained practical examples and useful information that can be applied in their work.	38 (97.4%)
The workshop series provided new information or insights into the diagnosis and treatment of SUD.	38 (97.4%)
"Very" or "somewhat" satisfied with the ASP series.	35 (89.7%)
	6-month follow-up (n = 20)
"Comfortable" or "very comfortable" initiating M-OUD since completing the ASP.	17 (85%)
Pursued additional M-OUD training since completing the ASP.	14 (70%)
Work in departments without an active M-OUD program.	4 (20%)
Increased naloxone prescribing since completing the ASP.	18 (90%)
Increased prescribing of buprenorphine to treat patients with OUD since completing the ASP.	10 (50%)

ASP, Addiction Scholars Program; *SUD*, substance use disorder; *OUD*, opioid use disorder; *M-OUD*, medication for opioid use disorder.

system. The ASP was designed as an educational program with an emphasis on promoting facility-level team building to enhance cross-functional clinical care. These findings are encouraging as, after completing the ASP, healthcare professionals without formal addiction medicine training were able to advocate for OUD treatment in non-SUD specialty clinical settings at their local VHA site. Successful treatment of patients with OUD requires a multidisciplinary approach involving both the addiction medicine service and the outpatient primary care team. Empowering non-SUD specialty clinics with the knowledge and practical skills to treat OUD is essential in implementing the "no wrong door" approach to OUD treatment.[11] The support and networking opportunities provided by the ASP successfully led to the development of local addiction medicine programs at VHA sites as evidenced by the 11 capstone projects that were funded.

The success of the ASP was due in part to the blended learning structure of the course. Lectures were curated and delivered by experts in the field and ranged from basic addiction medicine topics to more advanced topics. This allowed for engagement of all learners regardless of their specialty or level of training. The course also leveraged a team-based learning approach through the breakout sessions, which reinforced key components of treating complex patients with OUD. Team-based learning has been shown to have positive outcomes for students in terms of student experience.[12]

The e-learning platform also allowed for engagement by a wider audience than would have otherwise been possible by an in-person course. The ASP gave additional addiction medicine training to those who would otherwise not have been eligible for a fellowship by the traditional pathway. This allowed for engagement of key stakeholders who could implement programs at local facilities in areas that are separate from dedicated SUD clinics. The ASP is a scalable program that can be further developed and replicated outside of the VHA system.

LIMITATIONS

Although the program did receive favorable ratings, it is important to note that attendees did self-select to attend; as a result, they may have been more biased in their ratings of an addiction medicine program. Future efforts will be made to recruit clinicians and other healthcare professionals who may be resistant or hesitant to the addition of substance use and opioid safety measures in their practice. Further studies are needed to assess actual interest in additional addiction medicine training throughout the VHA system. It should be noted, too, that this study provided only a six-month follow-up, at which point the participants' survey response rate was low. Additionally, the results of this study are survey based, and thus the limitations that apply to surveys also apply here.

The survey did not contain knowledge-based questions to assess retention of knowledge. Future iterations of the course will contain knowledge-based questions to assess for acquisition of knowledge. Future studies will also need to look at how the ASP influenced the development of addiction medicine programs in the VHA system. Studies will also need to examine how successful the management of OUD is in nontraditional settings that are outside the SUD clinics. Future studies can also be conducted to compare long-term outcomes for patients whose healthcare professionals participated in ASP compared to those who did not.

CONCLUSION

This feasibility study has shown that ASP equipped clinicians and other healthcare professionals with an intensive overview of addiction medicine. The students translated the information from the course to develop M-OUD programs at their home institutions.

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Initiation of Buprenorphine in the Emergency Department: A Survey of Emergency Clinicians

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Introduction: Initiation of buprenorphine for opioid use disorder (OUD) in the emergency department (ED) is supported by the American College of Emergency Physicians and is shown to be beneficial. This practice, however, is largely underutilized.

Methods: To assess emergency clinicians' attitudes and readiness to initiate buprenorphine in the ED we conducted a cross-sectional, electronic survey of clinicians (attendings, residents, and non-physician clinicians) in a single, academic ED of a tertiary-care hospital, which serves a rural population. Our survey aimed to assess emergency clinicians' attitudes toward and readiness to initiate buprenorphine in the ED and identify clinician-perceived facilitators and barriers. Our survey took place after the initiation of the IMPACT (Initiation of Medication, Peer Access, and Connection to Treatment) project.

Results: Our results demonstrated the level of agreement that buprenorphine prescribing is within the emergency clinician's scope of practice was inversely correlated to average years in practice ($R^2 = 0.93$). X-waivered clinicians indicated feeling more prepared to administer buprenorphine in the ED $R^2 = 0.93$. However, they were not more likely to report ordering buprenorphine or naloxone in the ED within the prior three months. Those who reported having a family member or close friend with substance use disorder (SUD) were not more likely to agree buprenorphine initiation is within the clinician's scope of practice ($P = 0.91$), nor were they more likely to obtain an X-waiver ($P = 0.58$) or report ordering buprenorphine or naloxone for patients in the ED within the prior three months ($P = 0.65$, $P = 0.77$). Clinicians identified availability of pharmacists, inpatient/outpatient referral resources, and support staff (peer recovery support specialists and care managers) as primary facilitators to buprenorphine initiation. Inability to ensure follow-up, lack of knowledge of available resources, and insufficient education/preparedness were primary barriers to ED buprenorphine initiation. Eighty-three percent of clinicians indicated they would be interested in additional education regarding OUD treatment.

Conclusion: Our data suggests that newer generations of emergency clinicians may have less hesitancy initiating buprenorphine in the ED. In time, this could mean increased access to treatment for patients with OUD. Understanding clinician-perceived facilitators and barriers to buprenorphine initiation allows for better resource allocation. Clinicians would likely further benefit from additional education regarding medications for opioid use disorder (MOUD), available resources, and follow-up statistics. [West J Emerg Med. 2024;25(4)470–476.]

INTRODUCTION

More than 564,000 individuals died of opioid overdose in the US from 1999–2020,[1] according to the US Centers for Disease Control and Prevention; more recent, provisional data suggests that annual overdose rates continued to rise in 2021.[2] As would be expected, with increased rates of overdose, emergency department (ED) visits for opioid overdose also increased in 2020.[3] Patients with opioid use disorder (OUD) are frequently seen in the ED with both overdose and other less emergent conditions. Patients seen in the ED after a non-fatal opioid overdose have >5% one-year mortality rat.[4] The ED is a low-barrier access point to the healthcare system, and ED visits represent a valuable opportunity to engage patients with OUD in potentially lifesaving treatment.

Buprenorphine, a US Food and Drug Administration (FDA)-approved medication for OUD (MOUD), has been shown to be effective in decreasing overall opioid use, reducing risk of opioid overdose, and reducing both opioid-associated and all-cause mortality.[5] Buprenorphine has been available to emergency clinicians for the treatment of opioid withdrawal since 2002, and research has shown the benefits of buprenorphine initiation in the ED.[6] Specifically, in comparison to referral to treatment or brief ED intervention, initiation of buprenorphine in the ED results in increased rates of engagement in addiction treatment at 30 days and decreased illicit opioid use.[7] The American College of Emergency Physicians (ACEP) recommends the initiation of buprenorphine in appropriate patients. Additionally, the ACEP consensus states: "Detecting and offering evidenced-based treatments for patients with opioid use disorder is aligned with the goals of emergency medicine to intervene on high-mortality disease processes."[8]

Unfortunately, MOUDs including buprenorphine are largely underutilized, and the majority of people with OUD do not received treatment with MOUDs.[9] Substance use disorders (SUD) are one of the most highly stigmatized medical conditions in the world among clinicians and the general public.[10,11] A study looking at emergency physicians' attitudes toward patients with SUD found that emergency physicians had a lower regard for patients with SUD than other medical conditions with behavioral components.[12] The MOUDs, including buprenorphine, are also stigmatized, which impacts treatment access and prescribing practices for these medications.[13] Previous findings identify the most significant barriers to prescribing buprenorphine in the ED include logistical or systemic factors as well as perceived patient factors (ie, social barriers and lack of interest in treatment).[14] Clinician lack of knowledge, as well as their attitudes and biases, can impact willingness to prescribe medications such as buprenorphine for patients with OUD, despite MOUD being a well studied and effective treatment.[6,15] Not only are patients on MOUD stigmatized but the prescribers who provide them with medications are also stigmatized.[16]

Population Health Research Capsule

What do we already know about this issue?
Initiation of buprenorphine in the Emergency Department (ED) for opioid use disorder (OUD) has been shown to be beneficial, but is largely underutilized.

What was the research question?
What are clinicians' attitudes toward initiating buprenorphine in the ED, and what are the barriers to prescribing?

What was the major finding of the study?
Clinician likelihood of initiating treatment in the ED was inversely correlated to years in practice. The primary barrier to initiating buprenorphine was inability to ensure follow-up.

How does this improve population health?
Eliminating barriers and improving clinician readiness to initiate buprenorphine in the ED could increase access to care for patients with OUD.

To promote engagement in and referral to treatment for OUD, our academic ED initiated the IMPACT project (Initiation of Medication, Peer Access, Connection to Treatment) in 2020. Key elements of the IMPACT project included electronic health record (EHR) prompts and order sets, peer recovery support specialists in the ED, and availability of inpatient and outpatient referral, all of which are barriers identified in previous studies.[15,17–18] Additionally, when the IMPACT project was introduced to the ED, clinicians were offered a financial incentive to obtain a US Drug Enforcement Administration X-waiver. The primary goal of our study was to assess emergency clinicians' attitudes toward and readiness to initiate buprenorphine in the ED, as well as identify perceived facilitators and barriers to initiating buprenorphine treatment in an academic ED, after implementation of the IMPACT project and its associated resources.

METHODS

This study was part of a State Opioid Response Implementation project called IMPACT. The primary objective of the project was to integrate peer recovery

support specialists (PRSS) in the ED, to increase buprenorphine prescribing for patients with OUD, and to increase engagement and referrals to treatment for all patients with SUD. We extracted data from the EHR regarding patient demographics, PRSS interaction with patients, and prescribing practices over a two-year period from March 2020–March 2022. A mixed-methods model was used to evaluate the data. This project was approved by the institutional review board.

We conducted a cross-sectional electronic-based survey regarding buprenorphine prescribing in the ED with all potential ED prescribers including attending physicians, resident physicians, physician assistants, and nurse practitioners. We developed the survey, adapting from previously published research.[15,17–18] Prior surveys had been conducted in large urban areas but had not been deployed in a more rural setting. Our survey was designed to identify prescribers' attitudes toward and readiness to initiate buprenorphine in the ED and identify perceived facilitators and barriers to initiating buprenorphine treatment in an academic ED of a large, tertiary-care hospital, which serves a rural population. Clinicians were made aware of the study through an initial email, two email reminders, a one-time announcement at our weekly didactic conference, and flyers posted throughout the ED. Participants were incentivized, as the first 100 participants received a $10 gift card, and all participants were entered for a chance to win a $100 gift card.

The survey completed by emergency clinicians included 10 questions focusing on years in practice, X-waiver status, prescribing practices in the ED in the prior three months, comfort with treatment of OUD and prescribing buprenorphine in the ED, and personal experience with SUD. Two additional Likert-scale questions assessed for barriers and facilitators to prescribing buprenorphine. (See Appendix A for full survey). The survey was published March 23, 2022, and closed May 15, 2022. Survey responses were recorded via Qualtrics (Qualtrics, Provo, UT), and the data was exported to a secure Excel file (Microsoft Corp, Redmond, WA) for analysis. We then organized and analyzed the data using SAS 9.4 (SAS Institute Inc, Cary, NC) with chi-squared or Fisher exact tests. We de-identified and extracted additional operational patient data on the IMPACT program on a rolling basis from the EHR.

RESULTS

A total of 95 surveys were distributed to all emergency clinicians (attending physicians, residents, physician assistants, and nurse practitioners) There were a total of 43 respondents and a response rate of 45% (16/50 attendings, 21/30 residents, 6/15 physician assistants and nurse practitioners). Three surveys were partially completed. We included two that had >50% of the questions answered and excluded one survey with only two questions completed as the latter respondent's intent to complete was interpreted as questionable. Of those who responded, their years in practice ranged from 1-50 with an average of 7.3 years. Of the 43 respondents, 31 indicated they were familiar with the IMPACT project and 12 said they were not. All the respondents who indicated they were not familiar with the IMPACT project were ED residents. (See Tabl.) Notably, 83% of all respondents indicated they would be interested in additional education related to medication and resources for OUD treatment.

A five-point Likert scale was used to assess respondents' level of agreement that prescribing buprenorphine was within their scope of practice. While 78.6% of respondents agreed that prescribing buprenorphine was within their scope, the level of agreement was found to be inversely correlated with average years in practice ($R^2 = 0.93162$) (Figure 1). Regarding X-waiver status, 16 individuals identified as having their X-waiver and 26 indicated they were not X-waivered. When asked why they were not waivered, four individuals indicated they were "not interested," three said cost was a barrier, seven said time was a barrier, and 12 responded "other." In the "other" category, two responded they were unsure how to obtain the waiver; two questioned whether it was needed; one said "in the process"; three said "just haven't done it"; one indicated they had completed the training but were not yet licensed; and one said "I know the data shows it works, but I

Table. Data summary of emergency clinicians who participated in a survey regarding ED-initiated buprenorphine.

	Count	Percentage
Participants (total)	42	
Attending physicians	16	38.1%
Non-physician clinicians	6	14.3%
Residents	20	47.6%
Years in practice		
Minimum	1	
Maximum	50	
Average	7.31	
Median	4	
Familiar with IMPACT		
Yes	31	73.8%
No	11	26.2%
X-waivered		
Yes	16	38.1%
No	26	61.9%
Family/friend with substance use disorder		
Yes	18	42.9%
No	24	57.1%

IMPACT, initiation of medication, peer access, and connection to treatment.

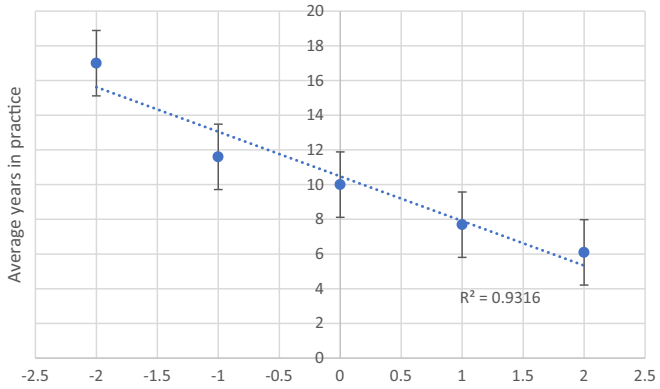

Figure 1. Agreement that buprenorphine is within the emergency clinician's scope of practice as assessed on a 5-point Likert scale in comparison to average years in practice.

still feel like a drug dealer." We found that those who had an X-waiver, in comparison to those who did not, were more likely to feel prepared to administer buprenorphine in the ED ($P = 0.02$).

To enable us to describe prescribing practices, prescribers were also asked whether they had ordered naloxone for patients in the ED in the prior three months; 29 said "yes" and 13 said "no." When asked whether they had ordered buprenorphine for patients in the ED in the prior three months, 18 said "yes" and 24 said "no." We also observed that those who had an X-waiver were not more likely to have reported ordering buprenorphine or naloxone for patients in the ED within the prior three months ($P = 0.17$), ($P = 0.51$).

Sixty-seven percent of clinicians agreed that they felt prepared to administer buprenorphine in the ED, 53.7% agreed that they felt prepared to prescribe buprenorphine as a bridge to outpatient treatment, and 47.6% agreed that they felt prepared to prescribe buprenorphine for home induction. Sixty-two percent of all respondents agreed that they had all the resources needed to initiate buprenorphine in the ED. Barriers and facilitators to initiating buprenorphine in the ED are identified in Figure 2 and Figure 3, respectively.

To assess possible personal barriers and facilitators of buprenorphine prescribing the following was asked: "Have you had, or do you currently have a family member or close friend with SUD?" Responses indicated 43% said "yes" and 57% said "no." Those who reported having a family member or close friend with SUD were not more likely to 1) agree that buprenorphine initiation is within the emergency clinician's scope of practice ($P = 0.91$); 2) obtain an X-waiver ($P = 0.58$); or 3) report ordering buprenorphine or naloxone for patients in the ED within the prior three months ($P = 0.65$), ($P = 0.77$).

IMPACT Project Qualitative Results

Over the two-year period, 1,205 patients were seen in the ED by PRSSs, 13% of whom were diagnosed with OUD or opioid withdrawal. A total of 377 were referred for buprenorphine treatment by the PRSSs within the ED; 168 of those patients received buprenorphine treatment, and 42 were given a take-home prescription. At the start of the study there were three X-waivered physicians; during the course of the project, 12 additional clinicians obtained their X-waiver, for a total of 15.

DISCUSSION

Our survey aimed to evaluate emergency clinicians' attitudes toward and preparedness to initiate buprenorphine in the ED as well as identify perceived facilitators and barriers to initiating buprenorphine treatment after the implementation of the IMPACT project and its associated resources. Our results showed that 78.6% of clinicians agreed that prescribing buprenorphine in the ED was within their scope of practice. As shown in Figure 1, the level of agreement that buprenorphine is within the emergency

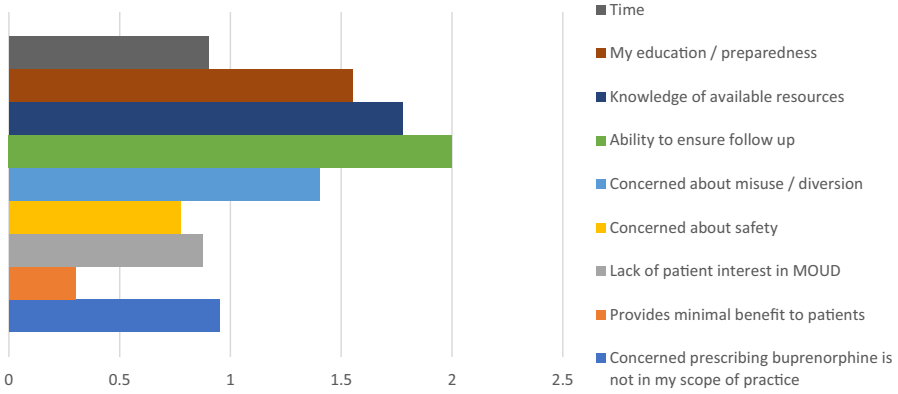

Figure 2. Clinician-perceived barriers to initiating buprenorphine in the emergency department. Identified barriers were graded with a 3-point Likert scale: somewhat a barrier, moderate barrier, significant barrier.
MOUD, medication for opioid use disorder.

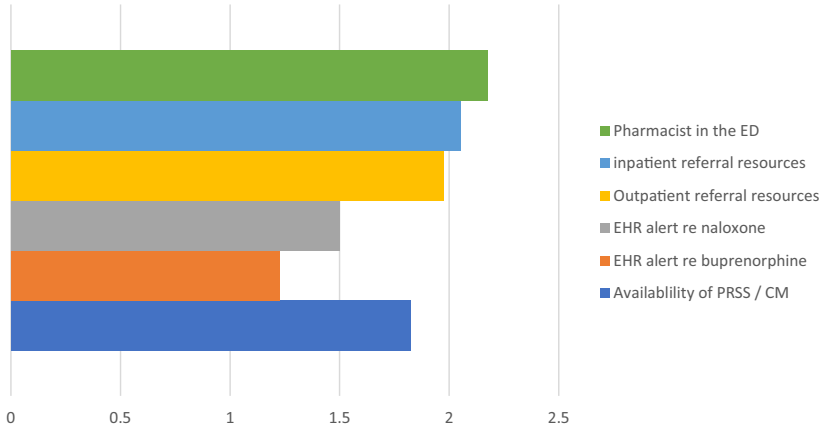

Figure 3. Clinician-perceived facilitators to initiating buprenorphine in the emergency department. Identified facilitators were graded with a 3-point Likert scale: somewhat a facilitator, moderate facilitator, significant facilitator.
ED, emergency department; *EHR*, electronic health record; *PRSS*, peer recovery support specialist; *CM*, case manager.

clinician's scope of practice was inversely correlated to years in practice. Another study found that clinicians with fewer years in practice were more likely to believe that OUD is like other chronic diseases and were more likely to approve of ED-initiated buprenorphine.[18] Other studies have identified emergency medicine residents as enthusiastic and eager to incorporate care for OUD into their practice.[17,19] We believe these results are encouraging and demonstrate that newer generations of clinicians may have less hesitancy toward initiating MOUD treatment in the ED setting. This change will, in time, likely increase access to care for those with OUD.

Sixty-seven percent of all clinicians agreed that they felt prepared to administer buprenorphine in the ED. We suspect clinicians' level of preparedness could be improved with continuing education lectures and feedback. Notably, the majority of respondents reported they would be interested in additional education related to medication and resources for OUD treatment.

We found that those with an X-waiver, in comparison to those who did not have an X-waiver, were more likely to feel prepared to administer buprenorphine in the ED. Other studies have found that X-waivered clinicians reported higher levels of readiness or preparedness to initiate buprenorphine in the ED in comparison to those who were not X-waivered.[14,17] Previously, an eight-hour training course was required to obtain an X-waiver; this training requirement, and the hassle of obtaining a waiver, was previously identified as a barrier to initiating buprenorphine in the ED.[14,17–18,20] However, finding that X-waivered clinicians felt more prepared to administer buprenorphine in the ED may reflect the value that was associated with the previously required education course. Notably, we also found that those who had an X-waiver were not more likely to have reported ordering buprenorphine or naloxone for patients in the ED within the prior three months. This finding potentially supports the idea that simply increasing the number of X-waivered clinicians does not significantly improve access to care if X-waivered clinicians are not actively prescribing MOUDs.[21,22] Notably, our data was collected prior to the recent elimination of the national X-waiver requirement.

When we asked whether having had a friend or family member with SUD would affect clinicians' attitudes toward buprenorphine in the ED, we found that 42.8% of clinicians reported having had a family member or close friend with SUD. This personal relationship, however, did not make clinicians statistically more likely to 1) agree that prescribing buprenorphine was within the emergency clinician's scope of practice; 2) obtain an X-waiver; or 3) report ordering buprenorphine or naloxone for patients in the ED within the prior three months. To our knowledge, a prescriber's personal relationships to individuals with SUD has not been evaluated in prior studies.

Sixty-two percent of clinicians indicated they have the resources they need to initiate buprenorphine in the ED. With the IMPACT project, as described above, clinicians have resources such as peer recovery support specialists in the ED, EHR prompts, and close outpatient follow-up available. Additionally, our academic ED is staffed with pharmacists and case managers/social workers 24/7. Given the number of resources available, we would have expected that more clinicians would have felt they have the resources necessary to initiate buprenorphine in the ED. We suspect it is possible that many clinicians felt they did not have the resources necessary because they were simply unaware of the available resources. Notably, less than 75% of respondents were familiar with the IMPACT project. All of those who were unfamiliar with the IMPACT project were residents; this highlights an opportunity for additional education.

A number of studies have been conducted looking at facilitators and barriers to buprenorphine initiation in the

ED.[14,17–18] Previously identified barriers to initiating buprenorphine in the ED include the following: lack of training/experience; concerns regarding misuse/diversion/harm; patient interest; time/competing priorities in the ED; concerns regarding follow-up; concerns regarding increased ED volume; and feeling as if prescribing buprenorphine was not within their scope of practice.[14,17–18]

Notably, with the implementation of the IMPACT project and its associated resources, several systemic/logistical barriers have been eliminated as PRSSs are available in the ED, outpatient follow-up can be ensured, and the EHR is equipped with prompts and order sets regarding both buprenorphine and outpatient referrals.

Our clinicians identified inability to ensure follow-up, limited knowledge of available resources, and lack of education/preparedness as the top three barriers to initiating buprenorphine in the ED. Although the COAT (comprehensive opioid addiction treatment) clinic has a standing appointment for ED referrals, and PRSSs work to facilitate these appointments, and even accompany patients to these appointments, concern regarding follow-up was still the primary barrier identified by clinicians. A recent study validated these concerns as it found that less than 30% of patients who fill buprenorphine prescriptions from the ED fill subsequent buprenorphine prescriptions.[23] Currently we do not have data regarding ED follow-up rates or rates of subsequent buprenorphine refills; however, this is an area of interest for future investigation to better evaluate the effectiveness of our IMPACT program.

Previously identified facilitators to buprenorphine initiation in the ED include ability to ensure follow-up; support staff – PRSSs/social work/care managers; department protocols; EHR order sets; pharmacist consultation; and feedback on patient experiences.[14,17–18] Our clinicians identified availability of pharmacists and of both inpatient and outpatient resources, and the presence of PRSSs and care managers as primary facilitators to buprenorphine initiation in the ED. The fact that clinicians identified pharmacist availability as a significant facilitator likely highlights underlying clinician discomfort with the pharmacology of buprenorphine and again highlights an opportunity for ongoing education and experience. Notably, time was not a primary barrier identified by our clinicians, and this may be due to the presence of additional support staff in the ED.

LIMITATIONS

Our study has several limitations. Overall we had a small sample size, and our respondents all work at the same academic center. Additionally, nearly half of respondents were residents with fewer than three years in clinical practice. Our data was collected prior to the elimination of the X-waiver requirement. It is possible that this new legislation has since influenced prescribers' attitudes toward buprenorphine as well as prescribing practices. Results related to facilitators and barriers may not be generalizable to community-based, non-academic EDs that do not have similar resources. Additionally, our results may not be generalizable to academic EDs in urban areas.

CONCLUSION

The results of our survey identified the following: 1) agreement that buprenorphine is within the emergency clinician's scope of practice was inversely correlated to years in practice; 2) >80% of clinicians were interested in additional education regarding MOUDs and resources for OUD treatment; 3) those with an X-waiver were more likely to report feeling more prepared to administer buprenorphine in the ED in comparison to those who were not X-waivered; and 4) clinicians who reported having had a family member or close friend with SUD were not more likely to agree that buprenorphine initiation is within the emergency clinician's scope of practice, nor were they more likely to obtain an X-waiver or report ordering buprenorphine or naloxone for patients in the ED within the prior three months. We also identified clinician-perceived barriers and facilitators to initiating buprenorphine in the ED. Our clinicians identified inability to ensure follow-up as a primary barrier to initiating buprenorphine in the ED.

More research is needed on retention in treatment following ED referral to identify what factors are associated with successful transitions of care from ED-initiated MOUD to community-based treatment. Education/preparedness was also identified as a significant barrier. We plan to address this with additional didactics and program updates. Time was less of a barrier, likely secondary to the availability of pharmacists, support staff, and inpatient and outpatient resources, which were identified as facilitators. A better understanding of facilitators and barriers allows for better resource allocation.

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A Novel Use of the "3-Day Rule": Post-discharge Methadone Dosing in the Emergency Department

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Introduction: Methadone is a medically necessary and lifesaving medication for many patients with opioid use disorder. To adequately address these patients' needs, methadone should be offered in the hospital, but barriers exist that limit its continuation upon discharge. The code of federal regulations allows for methadone dosing as an inpatient as well as outpatient dispensing for up to three days to facilitate linkage to treatment. As a quality initiative, we created a new workflow for discharging patients on methadone to return to the emergency department (ED) for uninterrupted dosing.

Methods: Our addiction medicine team changed hospital methadone policy to better allow hospitalization as a window of opportunity to start methadone. This necessitated the creation of a warm-handoff process to link patients to methadone clinics if that linkage could not happen immediately on discharge. Thus, our team created the "ED Bridge" process, which uses the "3-day rule" to dispense methadone from the ED post hospital discharge. We then followed every patient we directed through this workflow as an observational cohort for outcomes and trends.

Results: Of the patients for whom ED bridge dosing was planned, 40.4% completed all bridge dosing and an additional 17.3% received at least one but not all bridge doses. Established methadone patients made up 38.1% of successful linkages, and 61.9% were patients who were newly started on methadone in the hospital.

Conclusion: Improving methadone as a treatment option remains an ongoing issue for policymakers and advocates. Our ED bridge workflow allows us to expand access and continuation of methadone now using existing laws and regulations, and to better use hospitals as a point of entry into methadone treatment. [West J Emerg Med. 2024;25(4)477–482.]

INTRODUCTION

There are many regulatory barriers to initiating medications for opioid use disorder (MOUD) in traditional healthcare settings. Since treatment with methadone, an opioid agonist, or with buprenorphine, a partial opioid agonist, remains the standard of care for patients with opioid use disorder (OUD), there has been much focus recently on easing or circumnavigating barriers to facilitate linkage to treatment. While the passage of the 2023 Consolidated Appropriations Act removed the X-waiver requirement for buprenorphine prescribing,[1] methadone dispensing remains restricted to opioid treatment programs (OTP). Given these

restrictions on prescribing and other legal considerations, many hospitals are often hesitant to start and titrate methadone for inpatients with OUD.

Every year drug-related deaths continue to increase, and in 2021 over 80,000 people died of an opioid overdose.[2] Underuse of MOUD is common among patients seen in the hospital despite evidence supporting emergency department (ED) and inpatient initiation as beneficial opportunities to start treatment.[3,4] To address this deficit, our tertiary medical center created the Substance Use Intervention Team (SUIT) in 2018.[5] The SUIT is comprised of emergency physicians who are dual- or triple-boarded in medical toxicology and/or addiction medicine, psychiatric nurse practitioners, social workers, a recovery support specialist, and a pharmacist; SUIT is available during business hours, Monday through Friday. The team is a comprehensive addiction medicine consult service, working toward increasing the recognition, treatment, and linkage to outpatient care for all substance use disorders. The SUIT offers all forms of MOUD, including buprenorphine and methadone. For patients who requested or preferred methadone, the dose titration was guided by the 2019 version of the California [CA] Bridge in-hospital methadone start protocol,[6] tailored to each patient, with the most aggressive possible titration being 40 milligrams (mg) on day 1, 50 mg on day 2, and 60 mg on day 3, at which point, the dose was not increased until every five days.

Population Health Research Capsule

What do we already know about this issue?
Federal regulations allow EDs to dispense methadone for opioid use disorder, and hospitals can use the 3-day rule to assist with linkages to methadone maintenance programs.

What was the research question?
We looked at the feasibility of using the ED as a post-acute care landing site to bridge patients' methadone treatment in discharging hospitalized patients.

What was the major finding of the study?
Forty percent of patients (21/54) completed all bridge dosing, of whom 62% were newly initiated on methadone in the hospital.

How does this improve population health?
This workflow is a novel use of the 3-day rule to expand access to methadone via the ED.

Starting more patients on methadone necessitated the crafting of new policies and procedures at our center that would allow a warm handoff to methadone OTPs. The Code of Federal Regulations Title 21 restricts the dispensing of methadone to OTPs and specifies that methadone may be administered for three days in a healthcare setting for the purpose of alleviating withdrawal while arrangements are made to refer to treatment.[6] It does not limit treatment to three days; however, if the patient is in the hospital for reasons other than withdrawal, MOUD can be used "to maintain or detoxify a person as an incidental adjunct to medical or surgical treatment of conditions other than addiction."[7] Therefore, methadone, if started while an inpatient, can be continued for the entirety of the stay. Prior to SUIT's creation, our tertiary medical hospital had an internal policy that if methadone was started for a patient not previously enrolled in an OTP, the patient had to be weaned prior to discharge because of the prescribing limitation. Because weaning without further maintenance treatment only addresses the physical dependence in the short term while neglecting the chronic disease of OUD, it increases risk of relapse, fatal overdose, and all-cause mortality.[8–11] This policy, although compliant with the law, was not evidence-based best practice.

The SUIT created a new policy and workflow that allowed the start of an inpatient titration of methadone for patients not previously enrolled in an OTP, arranged linkage to OTPs while still inpatient, and avoided weaning prior to discharge; if patients could not immediately be treated at an OTP upon discharge (due to gaps in treatment, including weekend or holiday closures), the ED is used as a post-discharge setting for continued dosing under the three-day rule to complete a warm handoff. This workflow was reviewed by our hospital's pharmacy, compliance, and legal departments, all of which agreed that it complied with existing laws and helped us enact the change in hospital policy. Once this process was built, our team realized that it was also helpful for those patients in established OTPs who were discharged on weekends or holidays and couldn't return to their OTP for dosing until the next business day.

Having the ED as a post-acute care landing site for methadone continuation helped avoid disruption of established MOUD as well as newly initiated MOUD. Because the new-start methadone titration was more aggressive than a typical outpatient initiation of methadone, when patients returned to the ED, the dose administered was their discharge dose and was not titrated in the ED to keep them at steady-state and to avoid a need for observation in the ED after dosing. During the timeframe this workflow was built and used, the OTPs in our city independently underwent changes. One OTP in particular agreed to honor hospital titrations on day 1 in their clinic if the patient brought discharge paperwork with them. The program became a

preferred option for this workflow, although many patients either already used or requested other OTPs.

This article serves as a proof of concept and an observational cohort of all patients that SUIT directed to return to the ED for methadone dosing.

METHODS

The setting of this study was our tertiary urban medical center. Patients identified as being in need of an "ED bridge" were included in this study if they were seen by the SUIT consult service; if they were identified as either already in a methadone OTP or newly started on methadone during the hospitalization and in need of enrollment in an OTP; and if the primary team determined that they would be discharged on a day where the patient would not immediately be able to get outpatient methadone dosing but with a plan in place for linking to an OTP within 72 hours of discharge. This identification usually happened on a Thursday or Friday in anticipation of a weekend discharge or for new methadone starts when an OTP appointment could not be made for the day after discharge. Social workers on the SUIT team made clear follow-up plans by contacting cooperating OTPs ahead of time. Patients were excluded from the study if they ended up not discharging as planned and the ED bridge was no longer required, or if patients declined to return. These patients were manually tracked by chart review to determine whether they returned to the ED for dosing over the period from July 2019–July 2022.

The "ED bridge" process consisted of 1) instructing the patient to return to the ED every day starting the morning following the day of discharge for methadone administration until the day of planned OTP intake or return (maximum three days); 2) writing a care plan note in the chart notifying the ED of the dosing plan, days of dosing, and policy; 3) entering an expected arrival notification on the ED track board; and 4) triaging the patient on arrival to a low-acuity part of the ED for methadone dosing and immediate discharge as long as they did not appear to be intoxicated or have another complaint.

A templated note for the "ED bridge" care plan (Appendix 1) was approved by the hospital's Pharmacy and Therapeutics Committee to provide consistency for the process. It included a dot phrase for a note template that the emergency clinician could also use when the patient returned. The electronic health record (EHR) used in our hospital is Epic (Epic Systems Corporation, Verona WI). Our hospital's methadone policy was amended to include the ED bridge pathway and approved by our hospital's compliance and legal offices. The pharmacy department disseminated hospital-wide notification about the policy updates and provided education about the new process to prescribers, pharmacists, nurses, and clinical staff. This study received institutional review board approval.

The primary outcome measurements were the patient return rate to the ED for dosing and the number of doses completed. An ED bridge was considered successful if the patient came for dosing on all planned days; partially successful if they came for dosing on some of the planned days but missed days of dosing; and unsuccessful if they did not come for any of the planned days of dosing. Outcomes and demographic data are expressed by descriptive statistics.

RESULTS

There were 53 planned ED bridges set up for 47 unique patients. One ED bridge was excluded after the patient stayed through the weekend and didn't require it. Several patients used the ED bridge workflow more than once due to repeated hospitalizations: three patients used it twice, and one patient used it three times. Demographic characteristics of the 52 planned bridges are summarized in the Table. All the patients with OUD who used this workflow were using heroin.

Of the 52 planned ED bridges, 21 patients completed all necessary bridge doses (40.4%). Nine patients (17.3%) returned to the ED for at least one day but didn't present for all planned days. The remaining plans were not successful because 22 patients (42%) either did not return to the ED or left the ED before receiving one dose. In total, 94 visits for methadone dosing in the ED were planned via the ED bridge workflow, and 40 visits actually occurred. The average ED length of stay (LOS) from triage to discharge was 120 minutes, with a range of 36-682 minutes. Six of the 40 visits required full evaluations for additional complaints. Excluding these six visits, the average ED LOS was 89 minutes. Of the 52 planned ED bridges, the average number of days required to complete linkage to treatment was 1.8 days. For patients who successfully completed all necessary bridge doses, the average number of days for linkage was 1.3 days.

Patients were linked to one of 10 methadone clinics, all of which accepted patients with Medicaid. Eight patients who were already established in a methadone clinic accounted for 38.1% of successful linkages.

DISCUSSION

For the purposes of this study, a patient was defined as a "new" methadone patient if they were not enrolled in a clinic prior to their admission to the hospital and as an "established" patient if they were. The terms "new" and "established" were not descriptors of stability in treatment because occasionally even established patients needed to be newly restarted on methadone due to missing doses at their established OTP, and the outcomes of whether they complied with the ED bridge plan were essentially similar between the two groups. Because our project lacked follow-up with patients at a later timepoint, we were unable to discern the reason for patients not returning to the ED.

Table. Characteristics of participants in the emergency department bridge program for post-discharge methadone dosing.

Characteristics (at time of ED bridge)	Total (n = 52)	Successful bridge (n = 21)	Partially successful (n = 9)	Unsuccessful (n = 22)
Age				
Average (years)	44.6	47.9	45.1	40.5
Range (years)	29 – 69	29 – 69	31 – 61	29 – 64
Housing status				
Unhoused	25%	28.6%	11.1%	27.3%
Race				
White	48%	28.6%	44.4%	68.2%
Black	42.3%	52.4%	55.6%	27.3%
Hispanic/LatinX	7.7%	19%	0%	0%
Other	1.9%	0%	0%	0%
Gender				
Female	46.2%	38.1%	44.4%	54.5%
Male	58.3%	61.9%	55.6%	45.5%
Route of opioid use				
Stable recovery/ no active drug use	3.8%	4.8%	11.1%	0%
Intranasal only	48.1%	57.1%	44.4%	40.9%
Intravenous	48.1%	38.1%	44.4%	59.1%
Insurance				
Government	98.1%	100%	100%	95.5%
Uninsured	1.9%	0%	0%	4.5%
Methadone program status				
New	76.9%	61.9%	100%	81.8%
Established	23.1%	38.1%	0%	18.2%
Average # of bridge days planned (days)	1.8	1.3	2.8	1.9
Average # of bridge days completed (days)	0.8	1.3	1.3	0

ED, emergency department.

"Success" was defined as the patient returning for all planned days. There didn't appear to be any demographic factor that correlated with the success of the bridge, although this study was not powered to look for any statistical trends. The clearest explanation from the data we were able to collect is that if a bridge plan was shorter, it was more likely to be successful. On average, patients returned for approximately one day. Plans longer than one day were less likely to be successful. Nearly half of the 10 unsuccessful bridge plans occurred within a relatively short four-month time span (September–December 2021). Emergency department wait times and the COVID-19 pandemic may have contributed to this high rate of unsuccessful bridge doses during that time.

Prior to instituting the ED bridge process in our center, we would routinely hold patients committed to treatment in the hospital to ensure linkage to a methadone clinic with no missed doses to decrease the patients' risk of relapse, overdose, and death upon discharge. The ED bridge process allowed greater flexibility: patients who were committed to treatment but were ready for discharge otherwise could leave and come back for dosing; patients who were getting placed in post-acute care settings but needed to transport for methadone could now transport back to the ED for dosing, thereby allowing weekend discharges; and even patients who were leaving against medical advice were offered the opportunity to dose in the ED to reinforce the message that MOUD is a priority. While it is difficult to determine whether every ED bridge plan decreased LOS, the fact that 40 visits to our ED for methadone dosing did occur via the ED bridge process suggests that we did decrease inpatient hospital days and that this mitigated the increased use of ED resources for these visits.

Instituting the ED bridge workflow was an adjustment for the ED staff. Since there was no pop-up in the EHR, the

triage nurses at times needed to be reminded to look for an expected arrival note and to be reminded that these patients could be triaged to the low acuity part of the ED. Most clinicians wrote standard ED notes and did not use the preformed templated note for a methadone visit. It took some time for all staff members to get used to the new workflow, which likely explained the average LOS being approximately 1.5 hours when a full evaluation was not required. The LOS also accounted for time spent in the waiting room and clinicians ordering methadone and providing discharge instructions. It was not 1.5 hours of observation after the dose was given. Based on our team's experiences with teaching the workflow, it appeared that the ED staff was receptive to the overall idea, in part because our institution had gotten used to the culture of the emergency physician-led SUIT team. During the COVID-19 pandemic, there was also turnover in the ED nurse workforce that necessitated retrainings on the workflow, which could have also contributed to the wide variation in LOS.

This study took place in a large urban environment from 2019–2022, a period that not only encompassed the COVID-19 pandemic but also the continued worsening of the opioid epidemic. During that time, there were significant and evolving changes to how OTPs functioned due to COVID-19 emergency conditions and to the desire to reduce barriers to treatment. The OTPs changed their intake process, sometimes several times throughout that period, at first to be more restrictive[12] and then later to allow flexibility. Prior to this period, a typical OTP had specific days designated for intake appointments. Intakes could take approximately one hour, and a patient may not have actually started dosing on that day. Patients were often instructed to return a few days later to then meet with the clinician to start their methadone titration.

The typical initial dosing schedule is daily dosing Monday through Saturday with a take-home dose dispensed on Saturday for use on Sunday when the OTP was closed. Initially our SUIT program was able to help patients complete phone intakes while hospitalized; however, this protocol later evolved to match the changes in OTPs, which developed expanded days for walk-in intakes. Several OTPs also changed their workflows regarding day of intake and day of first dose, and sometimes we had to use our ED bridge protocol to keep dosing patients during the gap between the day of their intake and the day of their first dose. During this period, OTPs also permitted more take-home methadone doses, sometimes switching to Monday-Wednesday-Friday dosing schedules with every other day take-home doses, weekly dosing schedules with six days of take-home doses, or even monthly dosing with 27 days of take-home doses. This allowed patients to not have to go to the OTP as often, facilitating social distancing, but it also led to greater access to diverted methadone. The goal of our "ED bridge" workflow was to decrease dose disruption by providing a way for patients to obtain methadone safely while complying with dispensing restrictions. It is possible patients obtained methadone through other means and, thus, did not return for the ED bridge.

One OTP in our urban area decreased the barriers to entry significantly over this time period: they expanded intakes to Monday through Friday; allowed dosing even before full completion of intake; did not require photo ID as long as the patient had identifying paperwork (including hospital discharge papers); and accepted all forms of government insurance. This OTP ended up becoming the default option that we could rely on when setting up our ED bridge plans, even though we still did use the workflow for linking to other OTPs as well. In areas of the country with more limited and restrictive access to methadone OTPs, our three-day ED bridge model may not be as feasible.

LIMITATIONS

This study took place in an urban area with federal and state support for OTPs. We did not look at patient follow-through for OTP intakes or retention in long-term treatment. Another limitation is that feedback from ED staff on this new workflow was not collected to fully assess attitudes and barriers.

CONCLUSION

Expanding access to methadone remains an issue for policymakers and advocates. Ideas such as mobile clinics, new guidelines suggesting limited dispensing, and proposals to allow standard commercial pharmacies to dispense methadone are all ongoing considerations.[13] Our ED bridge workflow, however, allows us to expand access and continuation of methadone using existing laws and regulations, and to better use hospitals as a point of entry into methadone treatment.

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Variability in Practice of Buprenorphine Treatment by Emergency Department Operational Characteristics

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Introduction: We sought to describe emergency department (ED) buprenorphine treatment variability among EDs with varying operational characteristics.

Methods: We performed a retrospective cohort study of adult patients with opioid use disorder discharged from 12 hospital-based EDs within a large healthcare system as a secondary data analysis of a quality improvement study. Primary outcome of interest was buprenorphine treatment rate. We described treatment rates between EDs, categorized by tertile of operational characteristics including annual census, hospital and intensive care unit (ICU) admission rates, ED length of stay (LOS), and boarding time. Secondary outcomes were ED LOS and 30-day return rates.

Results: There were 7,469 unique ED encounters for patients with opioid use disorder between January 2020–May 2021, of whom 759 (10.2%) were treated with buprenorphine. Buprenorphine treatment rates were higher in larger EDs and those with higher hospital and ICU admission rates. Emergency department LOS and 30-day ED return rate did not have consistent associations with buprenorphine treatment.

Conclusion: Rates of treatment with ED buprenorphine vary according to the operational characteristics of department. We did not observe a consistent negative relationship between buprenorphine treatment and operational metrics, as many feared. Additional funding and targeted resource allocation should be prioritized by departmental leaders to improve access to this evidence-based and life-saving intervention. [West J Emerg Med. 2024;25(4)483–489.]

INTRODUCTION

The opioid crisis is a worsening public health emergency, with over 80,000 opioid-involved overdose deaths in the US in 2021, and it is unlikely to abate in the absence of effectively implemented harm reduction and treatment strategies.[1] Buprenorphine is an effective, evidence-based treatment resulting in increased abstinence from illicit opioid use and decreased opioid-related mortality.[2,3] Emergency department (ED) buprenorphine treatment is an evidence-based practice and has been associated with increased follow-up and reduced illicit drug use and medical costs.[4,5] Although buprenorphine prescribing from EDs has increased in recent years, prescribing still lags far behind the apparent need, with disparities by payer status, race, and ethnicity.[6,7]

Improved implementation relies on identification and removal of barriers, providing resources for patients and clinicians, and dispelling stigma and misperceptions.[8] Emergency department operational considerations,

including perceptions of insufficient time and increased ED return visits, are commonly cited as perceived barriers to implementation.[9] However, the real-world interplay between ED buprenorphine initiation and ED operations is not well described. Understanding the impact of ED buprenorphine treatment on ED clinical operational outcomes can inform decisions on resource allocation for ED buprenorphine program development. Conversely, barriers to implementation likely vary depending on the baseline operational performance of the department. Identification of operational characteristics of EDs with lower buprenorphine treatment rates would allow for targeted interventions.

We sought to describe the knowledge gap regarding ED buprenorphine treatment variability and operational barriers to implementation by 1) quantifying treatment rates between hospital EDs with different baseline operational characteristics, and 2) measuring the impact of ED buprenorphine treatment on operational metrics.

Population Health Research Capsule

What do we already know about this issue?
Understanding the impact of emergency department (ED) buprenorphine on operations can inform resource allocation decisions for ED buprenorphine program development.

What was the research question?
How does ED buprenorphine impact operations? How do ED operational characteristics impact treatment rates?

What was the major finding of the study?
A small number of patients with opiod use disorder were prescribed buprenorphine (2.5% in small hospitals, 11.6% in large hospitals). ED length of stay and 30-day return did not differ based on buprenorphine treatment.

How does this improve population health?
Departmental leadership can prioritize ED buprenorphine program development without fear of negative operational impact to increase access to life saving treatment.

METHODS

We performed a retrospective cohort study of adult (age ≥18) ED patients with opioid use disorder (OUD) discharged from any of the academic (one) or community (11) hospital-based EDs within a large healthcare system between January 2020–May 2021. The study was approved by our institutional review board for secondary data analysis of a completed quality improvement project.

To identify ED patients with OUD who may benefit from buprenorphine treatment, we applied an electronic health record (EHR) computable phenotype previously developed and validated by Chartash et al.[10] Data were extracted by querying an ED analytics data mart populated by a nightly extract from the Epic Clarity (Epic Systems Corporation, Verona, WI) database. Patients were identified by searching from phenotype-specific diagnosis codes and ED chief complaints. Pertinent codes included International Classification of Diseases, 10th Rev, Clinical Modification (ICD-10) diagnostic codes relating to opioid use (T40.0*, T40.1*, T40.2*, T40.3*, T40.4*, T40.6*, and F11*) coded by either the treating clinician or subsequently by a medical coder. We additionally included patients not identified by ICD-10 diagnostic code ED chief complaints relating to opioid use. Chief complaint data is entered into the EHR at time of ED encounter from a prepopulated list, limiting our selection of search terms. Within the limits of our database, inclusion of encounters containing "opioid" or "naloxone" most closely reflected original phenotype terminology. Per phenotype, patients with the terms "benzodiazepine" or "alcohol" in their ED discharge diagnosis were excluded to limit false positive inclusion.

Encounter-level data extracted included the following: patient demographics; chief complaint; disposition; ED length of stay (LOS); doses of medications administered and prescribed; and follow-up information, including 30-day ED return rate and number of days until ED return within the same health system. All data was deidentified for analysis by the research team.

The primary outcome of interest was ED buprenorphine treatment, defined as percentage of patients administered buprenorphine during and/or prescribed buprenorphine as part of the ED visit among all patients with OUD identified by the EHR phenotype. After consulting with key administrative leaders and system stakeholders, we partitioned EDs based on operational characteristics including annual ED census; hospital and intensive care unit (ICU) admission rates; median ED LOS (time from ED arrival to ED departure); and median boarding time (time from admission order placed to ED departure). Hospitals were divided into tertiles for each characteristic. As no power or sensitivity analyses were performed, and our goal was descriptive and hypothesis-generating, we did not perform hypothesis-testing comparative analyses. Statistical analyses were performed using RStudio version 4.0.5 (RStudio PBC, Boston, MA) and IBM SPSS 26 (SPSS, Inc, Chicago, IL).

RESULTS

The 2021 annual census for the 12 EDs ranged from 8,934 to 103,381 patients. Among 541,962 total unique ED

Table 1. Characteristics of cohort of patients with opioid use disorder.

		ED buprenorphine treatment	
		Yes	No
Total encounters	541,962	759	6,710
Gender			
Male	243,961 (46.9)	436 (57.4)	3,528 (52.6)
Female	286,504 (52.9)	323 (42.6)	3,182 (47.4)
Not reporting	1,497 (0.3)	0	0
Race			
Black	55,975 (10.3)	91 (12)	610 (9.1)
White	374,736 (69.1)	537 (70.8)	5,094 (75.9)
Another race	111,251 (20.5)	131 (17.3)	1,006 (15)
Insurance status			
Self-pay	62,124 (11.5)	3 (0.4)	22 (0.3)
Medicare/Medicaid	307,513 (56.7)	589 (77.6)	4,955 (73.8)
Other insurer	163,489 (30.2)	162 (21.3)	1,648 (24.6)
VA	8,836 (1.6)	5 (0.7)	85 (1.3)
Average buprenorphine dose (mg)			
Administered	N/a	76.28	N/a
Prescribed	N/a	103.42	N/a
Encounters with naloxone prescription	N/a	268 (45.5)	1,041 (21)
*Percentages noted in parentheses			

ED, emergency department; *VA*, Veterans Administration; *mg*, milligrams.

encounters across sites from January 1, 2020–May 31, 2021, 7,469 (1.4%) visits were phenotype positive and constituted our study population, representing 5,637 unique patients, with a mean of 622 visits per ED site (range 51–2,547). Phenotype-positive patients were predominantly White (75.4%) and male (53.1%) (Table 1). A minority (759, 10.2%) were treated with buprenorphine during the ED encounter, 695 of whom (91.6%) received buprenorphine administered in the ED, 301 (40%) received a buprenorphine prescription, and 237 (31.2%) received both.

Buprenorphine was administered in the ED more frequently than it was prescribed at discharge, irrespective of operational characteristics. Larger hospitals and those with higher hospital and ICU admission rates had higher buprenorphine treatment rates (Table 2). EDs experiencing longer boarding times also trended toward higher rates of treatment.

Median ED LOS was similar among patients treated with buprenorphine versus not treated, although confidence intervals were wide (Table 3). Lower admission rate, smaller ED size, and smaller volume were associated with longer ED LOS for patients treated with buprenorphine. Proportion of patients returning to the ED within 30 days and time to ED return did not differ consistently based on treatment with buprenorphine.

DISCUSSION

Within this single health system, we observed that ED buprenorphine treatment rates varied according to the baseline operational characteristics of the ED, which may be a proxy for the progressiveness or philosophical approach of a given ED's local champions and leadership team. We observed lower rates of buprenorphine treatment in EDs with smaller annual census and lower acuity (as measured by overall and ICU admission rates), which are presumably practice settings where there may be less perception of insufficient time. However, smaller EDs are less likely to have multiple prescribing clinicians working simultaneously. Prior studies have suggested that practice variation portends lower quality care and inequities in access to effective treatment for OUD.[11,12] Our data supports the need for interventions designed to promote buprenorphine treatment in smaller, lower acuity EDs to narrow this variation.

Buprenorphine treatment did not appear to have a consistent association with ED LOS, in contrast to commonly cited barriers.[9] Thirty-day return rates and time to ED return were similar between patients with OUD, regardless of their treatment with buprenorphine, a far cry from cited fears of EDs becoming "overrun" by patients seeking buprenorphine refills.[13]

Table 2. Buprenorphine administration and prescription, categorized by emergency department operational characteristics.

	Average value per quantile (SD)	OUD visits (n = 7,469)	Buprenorphine administered (n = , %)	Buprenorphine prescribed (n = , %)	Administered and prescribed (n = , %)	Any buprenorphine (n = , %)	No buprenorphine (n = , %)
Annual ED census volume	Patients						
Small (n = 4)	11,424 (±2,413)	245	6 (2.4%)	1 (0.4%)	1 (0.4%)	6 (2.5%)	239 (97.6%)
Middle (n = 4)	29,351.5 (±5,715)	1,245	61 (4.9%)	2 (0.2%)	2 (0.2%)	61 (4.9%)	1,184 (95.1%)
Large (n = 4)	69,739 (±30,656)	5,979	628 (10.5%)	298 (5%)	234 (3.9%)	692 (11.6%)	5,287 (88.4%)
ED number of beds	Beds						
Small (n = 4)	10.25 (±2.5)	245	6 (2.4%)	1 (0.4%)	1 (0.4%)	6 (2.5%)	239 (97.6%)
Middle (n = 4)	21 (±4.34)	1,245	61 (4.9%)	2 (0.2%)	2 (0.2%)	61 (4.9%)	1,184 (95.1%)
Large (n = 4)	49.5 (±17.23)	5,979	629 (10.5%)	298 (5%)	234 (3.9%)	692 (11.6%)	5,287 (88.4%)
Hospital admission rate	Rate						
Low (n = 4)	7.90% (±4.7%)	527	26 (4.9%)	1 (0.2%)	1 (0.2%)	26 (4.9%)	501 (95.1%)
Middle (n = 4)	16.98% (±1.8)	1,745	115 (6.6%)	6 (0.3%)	4 (0.2%)	117 (6.7%)	1,628 (93.3%)
High (n = 4)	27.41% (±3.2%)	5,197	554 (10.7%)	294 (5.7%)	232 (4.5%)	616 (11.9%)	4,581 (88.2%)
ICU admission rate	Rate						
Low (n = 4)	0.2% (±0.4%)	245	6 (2.5%)	1 (0.4%)	1 (0.4%)	6 (2.5%)	239 (97.6%)
Middle (n = 4)	1.8% (±0.3%)	2,027	135 (6.7%)	6 (0.3%)	4 (0.2%)	137 (6.8%)	1,890 (93.2%)
High (n = 4)	3.1% (±0.6%)	5,197	554 (10.7%)	294 (5.7%)	232 (4.5%)	616 (11.9%)	4,581 (88.2%)
ED length of stay	Minutes						
Short (n = 4)	106.3 (±8.6)	245	6 (2.5%)	1 (0.4%)	1 (0.4%)	6 (2.5%)	239 (97.6%)
Middle (n = 4)	149.8 (±4.7)	4,216	587 (13.9%)	287 (6.8%)	225 (5.3%)	649 (15.4%)	3,567 (84.6%)
Long (n = 4)	160.5 (±2.1)	3,008	102 (3.4%)	13 (0.4%)	11 (0.4%)	104 (3.5%)	2,904 (96.5%)
Median ED boarding time	Minutes						
Short (n = 4)	59.5 (±10.2)	245	6 (2.5%)	1 (0.4%)	1 (0.4%)	6 (2.5%)	239 (97.6%)
Middle (n = 4)	78.4 (±4.6)	1,437	91 (6.3%)	2 (0.1%)	2 (0.1%)	91 (6.3%)	1,346 (93.7%)
Long (n = 4)	110.5 (±24)	5,787	598 (10.3%)	298 (5.2%)	234 (4%)	662 (11.4%)	5,125 (88.6%)

ED, emergency department; *ICU*, intensive care unit; *OUD*, opioid use disorder.

Support from key departmental stakeholders is a repeatedly identified facilitator for implementing ED buprenorphine programs, and our observations corroborate this finding.[13] If LOS and ED return rate are relatively unaffected by ED buprenorphine treatment, this has important implications that might allow departmental leaders to promote greater resourcing and mitigate some of their apprehensions to facilitate buprenorphine treatment without fear of negative operational impacts.

LIMITATIONS

Our study intent was descriptive and should be considered hypothesis-generating. The use of secondary data limited our ability to power the study, and 95% confidence intervals were

Table 3. Emergency department operational outcomes by ED operational characteristics.

	ED OUD length of stay (minutes)			30-Day ED OUD return visits			Days before ED OUD return			
	Buprenorphine	95% CI	No buprenorphine	95% CI	Buprenorphine	No buprenorphine	Buprenorphine	95% CI	No buprenorphine	95% CI
Annual ED census volume										
Small (n = 4)	264	(148.2, 379.8)	181.6	(159.4, 203.8)	1 (0.1%)	81 (1.2%)	7	N/a	8.5	(6.8, 10.3)
Middle (n = 4)	250.4	(211.8, 289)	263.7	(251.1, 276.3)	14 (1.8%)	318 (4.7%)	8.7	(4.7, 12.8)	11.2	(10.2, 12.2)
Large (n = 4)	238	(216.9, 259.1)	275.6	(268.4, 282.7)	203 (26.8%)	1525 (22.7%)	11.5	(10.2, 12.67)	11	(10.6, 11.5)
ED number of beds										
Small (n = 4)	264	(148.2, 379.8)	181.6	(159.4, 203.8)	1 (0.1%)	81 (1.2%)	7	N/a	8.5	(6.8, 10.3)
Middle (n = 4)	250.4	(211.8, 289)	263.7	(251.1, 276.3)	14 (1.8%)	318 (4.7%)	8.7	(4.7, 12.8)	11.2	(10.2, 12.2)
Large (n = 4)	238	(216.9, 259.1)	275.6	(268.4, 282.7)	203 (26.8%)	1525 (22.7%)	11.5	(10.2, 12.7)	11	(10.6, 11.5)
Hospital admission rate										
Low (n = 4)	258	(212.4, 303.7)	245.2	(225.1, 265.3)	6 (0.8%)	156 (2.3%)	7.8	(4.7, 11)	10.4	(9.1, 11.8)
Middle (n = 4)	266	(224.9, 306.1)	287	(276.1, 297.9)	33 (4.4%)	461 (6.9%)	9.3	(6.3, 12.2)	10.2	(9.4, 10.9)
High (n = 4)	233.4	(210.7, 256.1)	266.8	(259.1, 274.6)	179 (23.6%)	1307 (19.5%)	11.7	(10.4, 13)	11.3	(10.8, 11.7)
ICU admission rate										
Low (n = 4)	264	(148.2, 379.8)	181.6	(159.4, 203.8)	1 (0.1%)	81 (1.2%)	7	N/a	8.5	(6.8, 10.3)
Middle (n = 4)	264.1	(228.8, 299.5)	289.2	(278.9, 299.6)	38 (5%)	536 (8%)	9.1	(6.5, 11.7)	10.5	(9.8, 11.2)
High (n = 4)	233.4	(210.7, 256.1)	266.8	(259.1, 274.6)	179 (23.6%)	1307 (19.5%)	11.7	(10.4, 13)	11.3	(10.8, 11.7)
ED length of stay										
Short (n = 4)	264	(148.2, 379.8)	181.6	(159.4, 203.8)	1 (0.1%)	81 (1.2%)	7	N/a	8.5	(6.8, 10.3)
Middle (n = 4)	225.8	(205.2, 246.3)	279.7	(271.6, 287.9)	187 (24.6%)	1059 (15.8%)	11.3	(10.1, 12.6)	11.1	(10.6, 11.6)
Long (n = 4)	321.7	(261.8, 381.6)	265.5	(255.8, 275.3)	30 (4%)	784 (11.7%)	11	(7.9, 14.1)	11	(10.4, 11.6)
Median ED boarding time										
Short (n = 4)	264	(148.2, 379.8)	181.6	(159.4, 203.8)	1 (0.1%)	81 (1.2%)	7	N/a	8.5	(6.8, 10.3)
Middle (n = 4)	285.9	(242.6, 329.2)	300.6	(285.8, 315.4)	27 (3.6%)	370 (5.5%)	9	(6, 12)	11.4	(10.5, 12.3)
Long (n = 4)	232.6	(211, 254.1)	266.2	(259.3, 273.1)	190 (25%)	1473 (22%)	11.6	(10.3, 12.9)	11	(10.5, 11.4)

ED, emergency department; *ICU*, intensive care unit; *OUD*, opioid use disorder.

often wide. Treatment rates may be falsely lowered by the presence of patients already on treatment and, therefore, not offered ED-based buprenorphine, although this would be unlikely to impact comparison between sites. Our dataset is also limited by size and confinement to a single health system as well as lack of patient diversity, which may limit generalizability. Importantly, unmeasured operational and cultural factors may prompt any given ED's leadership team to support buprenorphine treatment, and many of those same factors likely influence the general operational characteristics of the ED.

While this health system operates on a common EHR, clinicians are all employed by the health system, and incentives at all sites are tied to relative value units, there is a strong element of local control over the operations of each local ED, with little admixing of staff or operational processes between them. Nevertheless, clinicians may have moved between sites or worked at multiple sites. There may be unmeasured temporal trends during the study period, and a minority of more progressive EDs (including only one academic ED) may have contributed disproportionately to our findings. Finally, our partitioning of EDs by organizational metrics was based on internal comparisons specific to our healthcare system. Attempts to use national benchmarking data from the Academy of Administrators in Academic Emergency Medicine or Emergency Department Benchmarking Alliance were unsuccessful, as national mean and median metrics created severely uneven group sizes. While our approach may limit generalizability to other healthcare systems, it still may have implications for future hypothesis-testing research.

CONCLUSION

The evidence supporting the societal benefit of ED initiation of buprenorphine for patients with opioid use disorder is clear, but ED operational leadership and stakeholder buy-in is key to increasing implementation. Based on our study results, we hypothesize that ED buprenorphine treatment rates varied based on operational characteristics of EDs, with lower treatment rates at smaller, lower acuity facilities. We did not observe consistent differences in length of stay or return visits. Future research will allow departmental leadership to continue prioritizing the evidence-based practice of ED buprenorphine treatment to decrease variability while improving quality of care and access to life-saving treatment for patients with OUD. This is particularly important given the recent removal of the X-waiver requirement.

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Harm Reduction in the Field: First Responders' Perceptions of Opioid Overdose Interventions

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Introduction: Recent policy changes in Washington State presented a unique opportunity to pair evidence-based interventions with first responder services to combat increasing opioid overdoses. However, little is known about how these interventions should be implemented. In partnership with the Research with Expert Advisors on Drug Use team, a group of academically trained and community-trained researchers with lived and living experience of substance use, we examined facilitators and barriers to adopting leave-behind naloxone, field-based buprenorphine initiation, and HIV and hepatitis C virus (HCV) testing for first responder programs.

Methods: Our team completed semi-structured, qualitative interviews with 32 first responders, mobile integrated health staff, and emergency medical services (EMS) leaders in King County, Washington, from February–May 2022. Semi-structured interviews were recorded, transcribed, and coded using an integrated deductive and inductive thematic analysis approach grounded in community-engaged research principles. We collected data until saturation was achieved. Data collection and analysis were informed by the Consolidated Framework for Implementation Research. Two investigators coded independently until 100% consensus was reached.

Results: Our thematic analysis revealed several perceived facilitators (ie, tension for change, relative advantage, and compatibility) and barriers (ie, limited adaptability, lack of evidence strength and quality, and prohibitive cost) to the adoption of these evidence-based clinical interventions for first responder systems. There was widespread support for the distribution of leave-behind naloxone, although funding was identified as a barrier. Many believed field-based initiation of buprenorphine treatment could provide a more effective response to overdose management, but there were significant concerns that this intervention could run counter to the rapid care model. Lastly, participants worried that HIV and HCV testing was inappropriate for first responders to conduct but recommended that this service be provided by mobile integrated health staff.

Conclusion: These results have informed local EMS strategic planning, which will inform roll out of process improvements in King County, Washington. Future work should evaluate the impact of these interventions on the health of overdose survivors. [West J Emerg Med. 2024;25(4)490–499.]

INTRODUCTION

The public health crisis of opioid use disorder (OUD) and opioid overdose continues unabated, with rates continuing to rise.[1–3] Survivors of non-fatal overdose have a significantly greater risk of repeat overdose and overdose-related mortality within the following year, emphasizing the importance of first responder interventions.[4–7] These trends are mirrored locally in King County, Washington, where the annual 9-1-1 call volume of probable overdoses and other opioid use-related incidents increased by more than 20% from 2018–2021.[8] A critical window for intervention exists, as approximately 40% of individuals who died of an overdose in 2018 had at least one emergency medical services (EMS) encounter during the preceding year.[9]

Recent legislative changes in Washington State presented a unique opportunity to pair evidence-based interventions with first responder services to address the rise in opioid overdoses. Specifically, in February 2021, the Washington State Supreme Court struck down the statute that made possession of controlled substances a class C felony. The state government responded by passing a temporary law that expanded the role of first responders (eg, firefighters, paramedics, and police officers) to connect adults found with small amounts of controlled substances to case management instead of the criminal legal system.[10] In 2023 the legislature rolled back some of these changes with a permanent bill that increased criminal penalties for drug possession and public use and made pre-trial diversion to treatment programs contingent on the prosecutor's consent.[11]

While first responders have historically provided important referrals to community resources,[12] such programs have not historically offered harm-reduction resources or treatment initiation. Specifically, there are three medical services that are known to reduce overdose death and increase access to care for people who use drugs: leave-behind naloxone[13,14]; field-based initiation of buprenorphine treatment[14–19]; and HIV and hepatitis C virus (HCV) testing.[20] These interventions have documented efficacy in emergency departments[13,15] and community clinics[14,20] while demonstrating promising results during brief encounters with street medicine teams and paramedics.[16–19] In particular, the distribution of naloxone kits is cost effective[21,22] and significantly reduces opioid-related fatalities.[23–25] Buprenorphine treatment for OUD may decrease all-cause and opioid-related mortality by up to 50%,[26–29] and HIV and HCV testing improves access to care for people who use drugs.[30] However, there is a paucity of literature on the implementation of these three evidence-based programs in first responder systems.

Grounded in community engaged research (CEnR) principles,[31] our team partnered with the Research with Expert Advisors on Drug Use (READU), a group of academically trained and community-trained researchers with lived and living experience of substance use, to address this gap. The primary objective was to examine the facilitators and barriers to the adoption of leave-behind naloxone, field-based initiation of buprenorphine treatment, and HIV and HCV testing for first responder programs. The secondary objective was to inform local EMS overdose response policy and programming.

Population Health Research Capsule

What do we already know about this issue?
First responders have not historically offered harm reduction services that are known to reduce overdose death and increase access to care for people who use drugs.

What was the research question?
What are the facilitators and barriers for first responders to provide harm reduction services in the field?

What was the major finding of the study?
Perceived facilitators were tension for change, relative advantage, and compatibility, while barriers were limited adaptability, lack of evidence,and prohibitive cost.

How does this improve population health?
Participants experienced a tension for change and were activated to implement leave-behind naloxone, field-based buprenorphine, and HIV and hepatitis C virus testing.

METHODS

Study Design and Setting

From March–June 2022, we conducted 32 semi-structured interviews with first responders, mobile medical clinicians, and EMS leaders working in King County, Washington. The study was approved by the University of Washington Institutional Review Board.

Theoretical Framework

This study was informed by the Consolidated Framework for Implementation Research (CFIR).[32] By providing a consistently applied set of analytical categories, consisting of "constructs" situated within "domains," the CFIR[32] simplifies processes, highlights barriers, and identifies potential areas of improvement (Figure). As described below, this framework provided the scaffolding for the interview guides, deductive coding, and thematic analysis, which highlighted various constructs as perceived facilitators

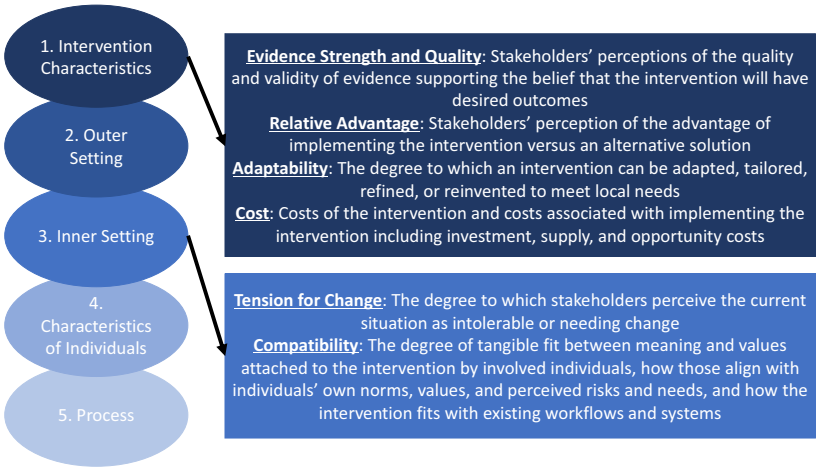

Figure. Adapted Consolidated Framework for Implementation Research (CFIR) with numbered domains and selected constructs.

(ie, tension for change, relative advantage, compatibility) and barriers (ie, adaptability, evidence strength and quality, and cost).

Reflexivity and Partnership

Our study team was composed of harm reductionists, including both academically trained researchers with advanced degrees in public health, psychology, and medicine, and community-trained researchers with lived and living experience of drug use and EMS system involvement. Together, we embraced CEnR principles,[31] practiced reflexivity,[33] and centered the perspectives of people who use drugs in the study's design, execution, and analyses. Prior to starting data collection, we engaged in bidirectional training during which community-trained READU members educated the academically trained researchers on effective outreach strategies and experiences with past studies, while academically trained researchers shared knowledge about qualitative study design and analysis.

Participant Recruitment

Participants were recruited through convenience and snowball sampling. We emailed recruitment materials to leaders and administrators at a variety of first responder agencies in King County to disseminate information to potential participants, including paramedics, firefighters, police officers, mobile integrated health staff (ie, co-responding social workers and firefighters engaged in community paramedicine), and mobile medical clinicians (ie, social workers, nurses, physician assistants, and nurse practitioners performing street outreach). Interested individuals contacted the study team through our study phone or email, and they were screened for eligibility. Inclusion criteria included experience working as a first responder, a mobile medical clinician, or in a management/leadership position in a first responder organization in King County; being over 18 years of age; and speaking English.

Data Collection

Demographic information collected from participants included age, gender, race and/or ethnicity, employment, and highest level of educational attainment. Separate but related interview guides informed by the CFIR[32] framework were developed for first responders, mobile medical clinicians, and EMS leaders. Topics covered in the interviews included participants' perceived role within the opioid epidemic; perceptions of services provided to people who use drugs; and the perceived feasibility, acceptance, and appropriateness of leave-behind naloxone, field-initiated buprenorphine, and HIV and HCV testing. The interview guides were iteratively refined, and the final guides are included as an appendix. An academically trained researcher with prior experience in qualitative methods was paired with a community trained READU member to conduct each interview.

Thematic Analysis

We used an integrated deductive and inductive thematic approach[34,35] to analysis. Once the initial interviews were completed, we familiarized ourselves with the data, reviewed the transcripts for accuracy, and noted initial impressions together. We grouped emergent observations into inductive codes and situated them in our preliminary codebook with the pre-existing deductive CFIR codes.[32] We applied the codebook to a single interview transcript, engaged in line-by-line coding as a group, and reconciled any disagreements in code applications to finalize the codebook. Individual team members then primarily applied the revised codebook to each transcript, and another conducted secondary coding, addressing any differences.

Subsequent semi-structured interviews were conducted until thematic saturation was reached. Interviews were recorded, transcribed, deidentified, uploaded to the qualitative data management software Dedoose (SocioCultural Research Consultants, LLC, Manhattan Beach, CA), and coded deductively using existing CFIR codes[32] and inductively using codes created from reviewing a

sample of transcripts.[36] We summarized coded data to identify barriers and facilitators to adopting leave behind naloxone, field-based buprenorphine initiation, and HIV and HCV testing for first responder programs, and we extracted prototypical examples of each.

RESULTS

Participant Demographics

We interviewed 32 first responders, mobile medical clinicians, and EMS leaders who worked in seven different cities located in King County, Washington (Table 1). Participants included Basic Life Support professionals (ie, firefighter/emergency medical technicians), Advanced Life Support professionals (ie, paramedics), police officers, nurses, and advanced registered nurse practitioners, social workers, and EMS leaders. Of the first responders interviewed, 19 (59%) had been in their current role for more than 10 years. Participants were 31.3% female and 12.5% racially/ethnically diverse, and most were above the age of 36 with at least some college education.

Table 1. Interviewees' demographic information.

Age	n (%)
20–25	2 (6.3%)
26–35	5 (15.6%)
36–45	11 (34.4%)
46–55	6 (18.8%)
56–65	8 (25%)
Gender	n (%)
Male	20 (62.5%)
Female	10 (31.3%)
Trans, non-binary, or gender non-conforming	2 (6.3%)
Race and/or ethnicity	n (%)
White	28 (87.5%)
Asian or Pacific Islander	2 (6.3%)
Hispanic	1 (3.1%)
Mixed race	1 (3.1%)
Employment	n (%)
Basic Life Support professionals (ie, firefighter/emergency medical technicians)	8 (25%)
Advanced Life Support professionals (ie, paramedics)	6 (18.8%)
Police officers	5 (15.6%)
Nurses and advanced registered nurse practitioners	3 (9.4%)
Social workers	5 (15.6%)
Emergency medical services leaders	5 (15.6%)
Number of years in current role	n (%)
<1	2 (6.3%)
1–4	8 (25%)
5–9	3 (9.4%)
10–19	8 (25%)
>20	11 (34.4%)
Highest level of educational attainment	n (%)
Associate's degree	8 (25%)
Bachelor's degree	8 (25%)
Master's degree	10 (31.3%)
Doctoral degree	2 (6.3%)
Unspecified	4 (12.5%)

Qualitative Results

Through the lens of the CFIR framework,[32] our thematic analysis revealed several perceived facilitators (ie, tension for change, relative advantage, and compatibility) and barriers (ie, limited adaptability, lack of evidence strength and quality, and prohibitive cost) to the adoption of three evidence-based clinical interventions for first responder systems: 1) leave behind naloxone; 2) field-based initiation of buprenorphine treatment; and 3) HIV and HCV testing.

Leave-behind Naloxone

There was widespread support for the distribution of leave-behind naloxone with many acknowledging a tension for change and finding the intervention relatively advantageous and compatible within existing systems (Table 2). Many interviewees recognized that naloxone is a safe, easy-to-use, indispensable medication that should be accessible to patients, their loved ones, and other community responders. Implementation of leave- behind naloxone was also largely thought to be feasible with several interviewees explaining that distribution could be effortlessly integrated into current workflows.

A smaller group of individuals expressed concern about potential barriers, particularly limited adaptability, lack of evidence strength and quality, and prohibitive cost. Some police officers thought that naloxone distribution may encourage unsafe behaviors (eg, using larger amounts or more potent substances) and felt that it was incongruous with their departments' current approach to controlling drug use through legal penalties and incarceration. Other service professionals worried that increased access to naloxone would lead to community members, rather than first responders, managing more overdose responses and consequently decreasing the likelihood of connecting people to treatment and other resources. Lastly, several interviewees in leadership or management roles were skeptical about the relative benefit of naloxone, explaining that they believed there ought to be more evidence on the efficacy of leave-behind naloxone programs. They also worried about the resources and training required for implementation.

Table 2. Interviewees' perceived facilitators and barriers to implementing a leave-behind naloxone program.

Facilitators	
Tension for change	"And I think, yes, certainly the fire department should play a role in having access to that and being able to hand it out and providing education on how to use it and when to use it."—Paramedic (ID #25)
Relative advantage	"I think that naloxones are [a] lifesaving intervention, and it's relatively easy for people to administer to their friends or bystanders can administer to people they don't know. So, I do think naloxone is very important and it should be out there and there should be access to it. And us leaving it behind with people, I think is a good idea."—Paramedic (ID #7)
Compatibility	"I think that's probably the easiest one … We could absolutely get the Narcan … First responders definitely can provide [those] as an intervention."—Mobile integrated health social worker (ID #20)
Barriers	
Limited adaptability	"I feel like it'd be a psychological thing for officers, especially officers who've been around for 10 plus years, where we used to arrest drug dealers and put them in jail. And now we're ignoring the crimes they're committing and we're giving them naloxone so that they can further just continue to use drugs. So, I can see someone who is maybe not looking at the full picture or just has their personal beliefs." —Police officer (ID #1)
Lack of evidence strength and quality	"I worry that we're just put[ting] more people in withdrawal and sort of miss[ing] the opportunities to do something about it."—Interviewee in leadership or management role (ID #28)
Prohibitive cost	"But I also have some skepticism that sort of just throwing out naloxone kits is gonna make a big difference. I'm not opposed to it, but it does require more effort and time and energy, and there's a cost to it. And quite frankly, we have [a] limited budget, and so, who's going to pay for those things? I don't know. So I'm measured in my support for that program, but if there's evidence that it saves lives, then we will work towards that."—Interviewee in leadership or management role (ID #27)

Field-based Initiation of Buprenorphine Treatment

Despite having less familiarity with the medication compared to naloxone, most interviewees recognized a tension for change and approved of the implementation of field-based initiation of buprenorphine treatment, considering it evidence-based, appropriate, and relatively advantageous for their settings (Table 3). Many felt unprepared to address withdrawal, particularly when a patient's overdose may have been fully reversed with bystander naloxone, but buprenorphine was seen as a "destigmatizing" tool that relieves symptoms, demonstrates compassion, and builds trust between patients and first responders. Additionally, participants described how the recent uptick in overdose responses, occasionally with the same individuals, led to burnout and a desire to address the upstream causes of substance use. Several highlighted how field-based initiation of buprenorphine treatment could bridge vulnerable individuals to ongoing treatment, potentially preventing future overdoses, decreasing overall call volumes, and saving lives.

Those opposed were largely concerned with this intervention's limited **adaptability** to the rapid service delivery model of emergency services, emphasizing that the time needed for the intervention may overburden an already overwhelmed system. However, others suggested that the deployment of specialized teams (eg, mobile integrated health or mobile medical clinic teams) dedicated to treating this patient population may be a way to offset these demands. Finally, some police officers worried about the **evidence strength and quality** of buprenorphine, speculating that it could be diverted for non-prescribed use and could encourage ongoing risky behaviors by curbing withdrawal symptoms.

HIV and Hepatitis C Virus Testing

Interviewees observed the tension for change in their organizations and generally supported increasing access to HIV and HCV testing (Table 4). Some felt that first responder encounters could serve as relatively advantageous opportunities to engage individuals who may not feel comfortable seeking care in more traditional settings. Providing HIV and HCV testing in a trauma-informed manner was seen to increase education around prevention and improve linkage to care.

Many, however, were concerned about the adaptability, appropriateness, and feasibility of HIV and HCV testing during an EMS response. Some worried that it would be inconsistent with the rapid service delivery model of emergency services since point-of-care testing takes at least 20 minutes to complete.[37,38] Others voiced that testing may feel compulsory and coercive if completed immediately after an unnerving overdose event. Like field-based buprenorphine starts, some interviewees alternatively proposed having first responders hand off these patients to a specialized team that would have more time to conduct the tests, provide the appropriate counseling, and arrange follow-up as needed for confirmatory diagnosis and treatment.

Table 3. Interviewees' perceived facilitators and barriers to field-based initiation of buprenorphine treatment.

Facilitators	
Tension for change	"I think the opioid issue that we have in our kind of city right now, it's big and it takes a big toll on people. And I think that if there is evidence that shows that Suboxone or buprenorphine can help, and ... especially if we're following in the footsteps of another agency or agencies that have used it and have some data on what works and what doesn't, then I would be all for it."—Mobile medical nurse (ID #15) "Suboxone is good stuff. If we're truly trying to help people transition out of addiction, it's a great tool to help manage withdrawals. As far as in the field, I think if we could provide them access to it, absolutely, I would be 100% behind that."—Firefighter (ID #4) "I think EMS is often the first interaction of a pretty traumatic chain of events leading to the ED. And so, I think if that engagement were positive, there'd be less hesitation to call 911, number one, for overdose. And then number two, every chance we can give someone to decrease or stop their opioid use is well worth it. It feels a little more like we're making a difference than giving the naloxone, the Narcan, 'cause here it's like, 'This is going to help you wean your body off this stuff.'"—Mobile medical social worker (ID #11)
Relative advantage	"I would say, absolutely any way that we can expand our reach to our community and get them more support, and for addictions and for recovery, I would think would be optimal. And I think that the fire service is a great way to allow that to happen ... I'm in full support. I think that would be advantageous in our community."—Paramedic (ID #25) "And it seems far more of a viable option to me than the leave at home [naloxone]. So the [leave behind naloxone] was just gonna solve the problem in the minute. But it does not take away the next problem, which is I need more, whereas buprenorphine does address that ... But the better option [is] to how to get that medicine to people."—Interviewee in leadership or management role (ID #28)
Barriers	
Limited adaptability	"That would be potentially good ... [But] we're [a] busy unit ... how much out of service time would that add to the unit to do that?"—Paramedic (ID #22)
Lack of evidence strength and quality	"We've made life easier for all these [people who use drugs] out in Seattle, and it hasn't made things better. It's actually made things worse. I mean, we're looking at like 270 deaths so far just in this first quarter. That is four times more than three or four years ago. So, I don't know if giving suboxone is actually helpful."—Police officer (ID #1)

EMS, emergency medical services; *ED*, emergency department.

Table 4. Interviewees' perceived facilitators and barriers to HIV and hepatits C virus testing.

Facilitators	
Tension for change	"This is one of those things that is in our realm of ... responsibility. Our primary goal is to help people with what's happening right now, but if we can also help them out with like, 'Well, what is the next step for you?'"—Mobile integrated health social worker (ID #17)
Relative advantage	"Hundred percent like the idea of being able to have an agency that has a contract that this is what they do. You go out, and you provide somebody an HIV test. We have people that are specially trained to deal with all the ramifications of somebody who finds out they have HIV, 'cause that's gonna be a horrible feeling."—Firefighter (ID #4)
Barriers	
Limited adaptability	"That wouldn't be something useful for first responders because our priority is not necessarily testing and trying to diagnose whether individuals have [a] specific disease."—Firefighter (ID #2) "I just think that'd be horrible to do to somebody ... Like HIV or hepatitis C, like those are huge things. So, you just don't want to just drop a bomb on somebody on top of them being ... During a drug overdose, for example."—Paramedic (ID #25)

DISCUSSION

Working on the frontlines of the opioid epidemic, first responders, mobile medical clinicians, and EMS leaders are confronted with skyrocketing overdose responses. Many want to improve the care of patients who use drugs, beyond acute overdose reversal, but feel uncertain about how to proceed. People who use drugs have also expressed a need for improved care with many refusing EMS transport following

overdose due to law enforcement's presence at overdose scenes,[39] unmanaged withdrawal symptoms, and anticipated stigmatizing treatment by EMS and emergency clinicians.[40] Our thematic analysis informed by the CFIR framework[32] identified several perceived facilitators (ie, tension for change, relative advantage, and compatibility) and barriers (ie, limited adaptability, lack of evidence strength and quality, and prohibitive cost) to the adoption of three evidence-based clinical interventions for first responder systems: 1) leave-behind naloxone; 2) field-based initiation of buprenorphine treatment; and 3) HIV and HCV testing. However, there are few examples of implementing these evidence-based interventions in first responder systems with one narrative review finding only 27 programs out of nearly 22,000 EMS agencies nationally described in the literature, with many providing naloxone distribution and community referrals while few facilitated linkage to medications for OUD.[41]

Many recognized the tension for change in their community and the relative advantage of distributing naloxone kits and treating OUD with buprenorphine in the field. Leave-behind naloxone is a cost-effective,[21,22] widely accepted[42–44] tool that reduces opioid overdose-related mortality[45,46] and does not increase risky drug use behavior.[47] Existing EMS programs distributing naloxone kits demonstrated feasibility[48] and increased connection to other resources.[49] Most interviewees believed leave-behind naloxone was compatible with and could be easily integrated into their workflows, yet several highlighted the importance of securing sustainable funding to address costs and receiving additional training to address the perceived lack of evidence strength and quality before implementation. Participants were similarly enthusiastic about the prospect of treating opioid withdrawal and OUD with buprenorphine. In addition to an initial case series describing treating withdrawal from naloxone administration with buprenorphine,[18] a pilot study examining prehospital buprenorphine treatment for OUD showed 50% retention in treatment at seven days and 36% in 30 days.[19]

Notably, participants working in law enforcement were more skeptical of harm reduction than those employed in healthcare and social services. Some expressed frustration with recent legislation that curtailed criminal penalties for drug possession and public use. Other law enforcement officers expressed sentiments similar to those of healthcare and social services workers but questioned what their role in addressing the opioid epidemic could be under the new laws. Importantly, police officers still regularly respond to medical emergencies involving drug use, including overdoses, highlighting the urgent need for targeted education on how to use these evidence-based interventions effectively in the field.

Lastly, the most discussed barrier to all three interventions, particularly field-based initiation of buprenorphine and HIV and HCV testing, was a feeling from frontline professionals that implementation had limited adaptability to the rapid service delivery model of emergency services. However, others recommended either deploying a specialized team to the scene or transporting the patient to a diversion facility that could provide wraparound services. Local mobile medical clinic teams have successfully integrated harm reduction services into their care of those experiencing homelessness,[50] and the creation of mobile integrated health response units have expanded case management and referrals through multidisciplinary collaborations in fire departments.[51] With longer dispatch time and the ability to do longitudinal follow-up, these teams may be well suited to provide post-overdose care.

The Philadelphia Fire Department has an alternative response unit ("AR-2") equipped with Advanced Life Support capabilities, which is located in an area heavily impacted by opioid overdoses. It responds to those resuscitated with naloxone but who refuse transportation to the hospital, and early data demonstrates that 84% of patients accepted services, including treatment facility placement, resources, and/or naloxone kits.[52] Diversion facilities offering low-barrier access to treatment and other services could also operate as an alternative to a prolonged EMS response or emergency department visits; in fact, a former hospital facility in Columbus, Ohio, now equipped with 60 beds dedicated to addiction stabilization serves as the primary post-overdose receiving center for individuals seeking treatment and deemed medically stable by EMS.[53]

LIMITATIONS

Our objective in this study was to examine the facilitators and barriers to the adoption of leave-behind naloxone, field-based initiation of buprenorphine treatment, and HIV and HCV testing for first responder programs. However, the results may only be applicable to the geographic location of the interviewees, which included first responders, mobile medical clinicians, and EMS leaders working in King County, Washington. Racial and ethnic minorities were notably poorly represented in our study. Because there is no publicly available data on the demographic information of EMS professionals locally, we were unable to assess whether our sample was representative. Our convenience and snowball sampling may have also introduced bias. Most participants described being in their current role for more than 10 years, which is likely much higher than the general first responder population. Finally, we did not track the decline-to-be interviewed rate.

CONCLUSION

Without the tools to address the uptick in opioid overdoses, first responders, mobile medical clinicians, and

EMS leaders in King County experienced a tension for change and are now activated to implement leave- behind naloxone, field-based initiation of buprenorphine treatment, and HIV and HCV testing through new EMS protocols, post-overdose response teams, and diversion facilities. In this study we took a team-based approach and centered the perspectives of people with lived and living experience of drug use to ensure that this research led to action. Members of READU highlighted our work's relevance to the community and framed these findings to inform policy, particularly with the recent changes in Washington State legislation. Future works should evaluate the impact of these interventions on the health of overdose survivors.

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Bystanders Saving Lives with Naloxone: A Scoping Review on Methods to Estimate Overdose Reversals

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Introduction: People who use drugs in community settings are at risk of a fatal overdose, which can be mitigated by naloxone administered via bystanders. In this study we sought to investigate methods of estimating and tracking opioid overdose reversals by community members with take-home naloxone (THN) to coalesce possible ways of characterizing THN reach with a metric that is useful for guiding both distribution of naloxone and advocacy of its benefits.

Methods: We conducted a scoping review of published literature on PubMed on August 15, 2022, using PRISMA-ScR protocol, for articles discussing methods to estimate THN reversals in the community. The following search terms were used: *naloxone AND ("take home" OR kit OR "community distribution" OR "naloxone distribution")*. We used backwards citation searching to potentially find additional studies. Overdose education and naloxone distribution program-based studies that analyzed only single programs were excluded.

Results: The database search captured 614 studies, of which 14 studies were relevant. Backwards citation searching of 765 references did not reveal additional relevant studies. Of the 14 relevant studies, 11 were mathematical models. Ten used Markov models, and one used a system dynamics model. Of the remaining three articles, one was a meta-analysis, and two used spatial analysis. Studies ranged in year of publication from 2013–2022 with mathematical modeling increasing in use over time. Only spatial analysis was used with a focus on characterizing local naloxone use at the level of a specific city.

Conclusion: Of existing methods to estimate bystander administration of THN, mathematical models are most common, particularly Markov models. System dynamics modeling, meta-analysis, and spatial analysis have also been used. All methods are heavily dependent upon overdose education and naloxone distribution program data published in the literature or available as ongoing surveillance data. Overall, there is a paucity of literature describing methods of estimation and even fewer with methods applied to a local focus that would allow for more targeted distribution of naloxone. [West J Emerg Med. 2024;25(4)500–506.]

INTRODUCTION

People who use drugs in community settings have the risk of a fatal overdose, which can be mitigated by naloxone administered via bystanders during overdose incidents. Currently, there is some public health infrastructure in place to track naloxone distribution. In California, the Department of Health Care Services (DHCS) acts as a hub for dissemination of naloxone to community-based organizations.[1] These organizations are, in turn, charged with maintaining distribution and use data. However, the DHCS is not the only distributor of naloxone, nor do programs that distribute naloxone have any way to require individuals to report use. Further, naloxone in Narcan nasal spray form has recently been approved (in March 2023) by

the US Food and Drug Administration for over-the-counter (OTC) distribution. Due to this multitude of factors, it is not known how frequently community-distributed naloxone is administered to treat overdose.

While naloxone distribution is an effective, evidence-based intervention, and OTC formulations are approved, there is still pushback against highly visible and available naloxone distribution points from policymakers and community members due to the stigma associated with drug use and, by extension, the legal landscape.[2,3] In this study we sought to investigate methods of estimating and tracking opioid overdose reversals by community members with take-home naloxone (THN) to coalesce possible ways of characterizing THN reach with a metric that is useful for guiding both distribution of naloxone and advocacy of its benefits.

Population Health Research Capsule

What do we already know about this issue?
Administration of naloxone mitigates the risk of a fatal overdose in community settings; however, surveillance of community naloxone and its administration is weak.

What was the research question?
What methods exist for tracking or estimating opioid overdose reversals by community members with naloxone?

What was the major finding of the study?
The scoping review yielded 14 studies: 11 mathematical models, one meta-analysis, and two spatial analyses.

How does this improve population health?
Few methods have been published to estimate community naloxone administration; methods must be adapted for local use before informing policy or advocacy.

METHODS

With PRISMA-ScR protocol using the PubMed database,[4] we conducted a scoping review on methods to estimate opioid overdose reversals by community members using THN, before any potential intervention by first responders or clinicians. The database search was followed by backwards citation searching to identify relevant articles omitted in the database search. PubMed, a database provided by the National Center for Biotechnology Information at the US National Library of Medicine, was used for the scoping review due to its coverage of 35 million citations contained within the literature compilations of MEDLINE, PubMed Central, and Bookshelf.[5]

Search Strategy

We performed a search on August 15, 2022, using PubMed to find articles that discussed surveillance or estimation of THN administration. The search was restricted to articles published in the English language, but it was not restricted by year of publication. The terms used for the search strategy were selected to ensure that relevant studies found in pilot searches were all included. Since there has been an evolving lexicon surrounding "take-home" naloxone, alternative terms had to be included in the search, even though this diluted the proportion of relevant studies in the final search. We used the following search terms: *naloxone AND ("take home" OR kit OR "community distribution" OR "naloxone distribution")*.

Articles from the PubMed search that discussed THN and were possibly related to surveillance or estimation were sorted into methodology buckets for possible further review based on title and abstract, or review of full articles where uncertainty existed. These methodology buckets included the following: 1) mathematical models; 2) meta-analysis; 3) spatial analysis; 4) other possibly relevant articles; 5) opioid overdose education and naloxone distribution (OEND) program-based studies; and 6) other articles deemed not relevant.

The articles sorted into the first four buckets—mathematical models; meta-analysis; spatial analysis; and other possibly relevant articles—were read in full for confirmation of final inclusion. We excluded from further review bucket 5 (OEND program-based studies) because these studies have straightforward methodology and are already a well-known method of tracking THN administration, which is evidenced by the number of OEND program-based studies (59 studies captured with our database search strategy). These OEND program-based studies are discussed further in the *Discussion* section. After selection of PubMed articles for final inclusion, we performed backwards citation searching on these articles using titles, with abstracts as needed. The full text of possibly relevant articles was reviewed for final inclusion.

Data Extraction and Synthesis

We extracted the following data using a standardized table: method (bucket); model type; data sources; location (country, location – community); and funding sources. Method corresponded to the bucket categories discussed above. Model type was relevant for studies in bucket 1 (mathematical models), and the recorded model type was based on how authors self-described their studies. These self-

descriptions for mathematical models included Markov modeling and system dynamics modeling. Data was synthesized through concept mapping.

RESULTS

The database search resulted in the capture of 614 studies. Of these, 108 studies were marked as possibly relevant based on titles or abstracts discussing THN programs, surveillance, or estimation. Using full articles as needed, 39 studies were categorized into buckets of interest (1–4). Following categorization, full article review resulted in 14 articles for final inclusion. Backwards citation searching of the 765 references contained within the 14 articles resulted in three articles for full review. All three were excluded from final analysis leaving 14 articles for final inclusion. These 14 articles were from buckets 1–3. Figure 1 presents a flowchart of the captures and the review of literature.

Study Characteristics

The included studies varied in their objectives. Developing a way to identify how much naloxone was administered by bystanders was often a contributor to the overall goals of the studies instead of the primary objective. This section presents a synthesis of study objectives and the methods employed to surveil or estimate community naloxone use. The Table presents an overview of the studies by method.

Mathematical Models

Of the 14 studies, 11 employed mathematical models. Of these, 10 used Markov models and were published between 2012–2022. Markov models define several non-overlapping statuses (ie, chronic opioid use, cessation of opioid use, overdosing, dead) and represent each individual within a simulated population as a member of one of the statuses.[6] Individuals transition from one state to another, not necessarily linearly, based on probability parameters that represent change in individual statuses over time. This means that model output of any prior or subsequent population distribution within the system can be derived from any given population distribution. The one remaining mathematical modeling study used a system dynamics model and was published in 2022. System dynamics modeling represents different variables (ie, population, treatment availability, overdose deaths) within a system and the relationships between them, factoring in temporal delay as appropriate.[7] This means that the model output of any subsequent population distribution within the system may be based on both the given population distribution and the changes preceding the given population distribution.

Studies employing mathematical models varied in their primary objectives. Five of the studies employing Markov models were designed to evaluate the cost effectiveness of naloxone distribution. Four of these cost-effectiveness studies use variations of the same Markov model, which was originally developed in 2013 by Coffin and Sullivan, who authored two of the four articles.[8–11] The one remaining cost-effectiveness study, by Uyei et al, was unique in that it also investigated naloxone distribution in conjunction with other interventions, including pre-exposure prophylaxis for HIV prevention.[12]

Of the remaining five Markov model studies, all modeled the effects of naloxone distribution on opioid overdose death rates. Coffin et al (2022) modeled the US population using the Markov model developed previously by Coffin and Sullivan in 2013.[13] Irvine et al (2018) and Irvine et al (2019) modeled the population of British Columbia using a model developed by Irvine et al in 2018.[14,15] Irvine et al (2022) modeled the US population, and Linas et al (2021) modeled

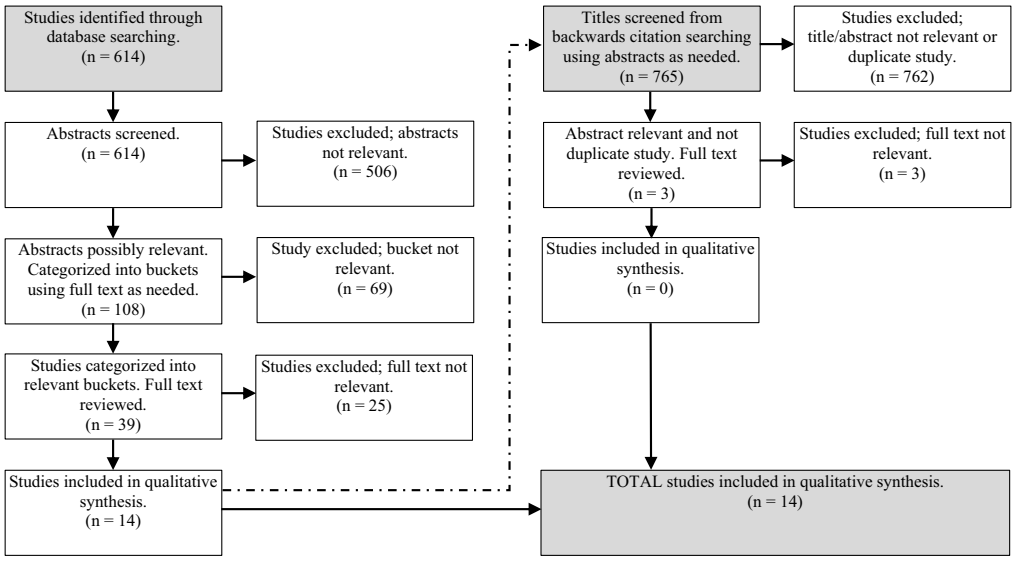

Figure 1. PRISMA flowchart.

Table. Study characteristics by method.

Method (bucket)	Model type	First author	Year	Data sources	Location country	Location community	Funding sources
Mathematical models	Markov model	Acharya M	2020	Literature, Surveillance data, Assumption	US	US	Not reported
		Coffin PO	2022	Literature, Assumption	US	US	National Institutes of Health
		Coffin PO	2013	Literature, Expert input, Assumption	US	US	National Institute of Allergy and Infectious Diseases (National Institutes of Health)
		Coffin PO	2013	Literature, Assumption	Russia	Russia	Open Society Foundation
		Irvine MA	2018	Surveillance data, Literature, Expert input, Assumption	Canada	British Columbia	Canadian Institutes of Health Research, Natural Science and Engineering Research Council of Canada
		Irvine MA	2019	Surveillance data, Literature, Expert input, Assumption	Canada	British Columbia	British Columbia Government, Canadian Institutes of Health Research, Natural Science and Engineering Research Council of Canada, Michael Smith Foundation for Health Research, National Institutes of Health
		Irvine MA	2022	Literature, Modified-Delphi panel	US	US	National Institute on Drug Abuse (National Institutes of Health)
		Langham S	2018	Literature, Assumption	UK	UK	Mundipharma International Ltd.
		Linas BP	2021	Surveillance data, Literature, Assumption	US	Rural, urban Massachusetts	National Institute on Drug Abuse (National Institutes of Health)
		Uyei J	2017	Surveillance data, Literature, Assumption	US	Connecticut	Connecticut Department of Public Health, National Institute of Mental Health (National Institutes of Health)
	System dynamics model	Stringfellow EJ	2022	Surveillance data, Literature, Expert input, Assumption	US	US	US Food and Drug Administration
Meta-analysis		McAuley A	2015	OEND program studies	Canada, UK, US	n/a	National Health Service Scotland
Spatial analysis		Rowe C	2016	Surveillance data	US	San Francisco	National Institute on Drug Abuse (National Institutes of Health)
		Yi G	2022	Surveillance data	US	Baltimore	Not reported

urban and rural Massachusetts populations also using the 2018 Irvine et al model.[16,17]

The one study using a system dynamics model was conducted by Stringfellow et al in 2022 and investigated the effects of different interventions, including naloxone distribution, on opioid overdose death rates.[18]

Mathematical models employed various data sources to inform the parameters used. These sources included parameters from published literature and surveillance data (ie, public health department records, coroner reports, insurance claims). When sources of data were not available, authors used their own assumptions or expert input,

including a modified-Delphi panel in the 2022 Irvine et al study.[16] The studies do not apply the mathematical models to any specific cities or smaller communities, although the 2021 Linas et al study models a generalized rural city and a generalized urban city in Massachusetts.[17] Adopting the mathematical models employed in these studies to estimate bystander naloxone administration in a particular community of interest would require the input of local parameters, which could be an intensive effort if surveillance infrastructure is not established.

Meta-analysis

One study by McAuley et al, published in 2015, consisted of a meta-analysis of nine OEND program studies, synthesizing their outcomes and accounting for participants lost to follow-up to report the proportion of naloxone kits that are likely to be used in the first three months after distribution.[19] The studies that comprised the meta-analysis were from Canada, the United Kingdom, and the US. Adopting a meta-analysis methodology to estimate bystander naloxone administration in a particular community of interest would involve synthesizing data from OEND programs in the community.

Spatial Analysis

Two studies, by Rowe et al (2016) and Yi et al (2022), used geographic system information (GSI) mapping technology to conduct spatial analysis of naloxone overdose incidents. The studies determined the relationship between proximity of the census tract in which naloxone was administered and the nearest naloxone distribution site.[20,21] Rowe et al conducted an analysis of San Francisco, California, and Yi et al conducted an analysis of Baltimore, Maryland. Surveillance data was used to establish this relationship. The GSI mapping and spatial analysis methodology used in these studies could be adopted in other jurisdictions to estimate bystander naloxone administration in a particular neighborhood of interest based in part on distance from naloxone distribution points.

DISCUSSION

Limited Methods to Estimate Take-home Naloxone Use

The limited number of studies captured in this scoping review evidences the lack of surveillance and estimation methods for the administration of THN, outside of OEND program records based on self-reports. Of the methods used, mathematical modeling and meta-analysis provided direct estimations of the proportion of distributed naloxone administered; however, both methods were applied only over large geographic areas (entire countries, states or provinces, amalgamating different cities around the globe) or theoretical cities representing a large geographic area ("urban city of Massachusetts").

Mathematical modeling was the most popular form of estimating administration of naloxone by community members. Further, the popularity of modeling increased relative to the other methods. While making up 79% of study methodologies found overall, it comprises 89% of studies in the five years from 2018–2022, as shown in Figure 2. Reasons for the popularity of mathematical models may be convenience, including the use of expert input and assumptions for unknown parameters, and the ability to tailor models to different geographic areas by adjusting parameters. Nine of the 11 modeling studies used one of two model bases, Coffin and Sullivan (2013) and Irvine et al (2018).[9,14]

The relative disuse of meta-analysis may be explained by the lower practical value of naloxone administration data averaged over multiple locations, as opposed to applying local data to inform program growth and gauge impact. Meta-analysis of naloxone use in other communities may be informative in jurisdictions lacking their own surveillance data, but care must be exercised in selecting which communities and programs to use as references. The spread of OEND programs, however, may provide an opportunity for more applicable comparisons. Further, large proportions of follow-up loss are evidenced in some OEND programs, adding uncertainty to meta-analysis results; three of the nine OEND programs that McAuley et al (2015) used in their analysis had three-month follow-up rates of less than 70% (eg, 34%, 30%, 23%).[19]

Spatial analysis yielded a relationship between naloxone administration and distance from naloxone distribution point. Both studies included in this scoping review (Rowe et al 2016, and Yi et al 2022) were reliant upon self-reported data from OEND programs. This data, which is needed to construct a GSI map, may be useful for identifying geographic areas for intervention but may be less useful for extrapolation to unreported THN use. Further, only the study by Yi et al (2022) characterized the relationship between probability of bystander naloxone administration at

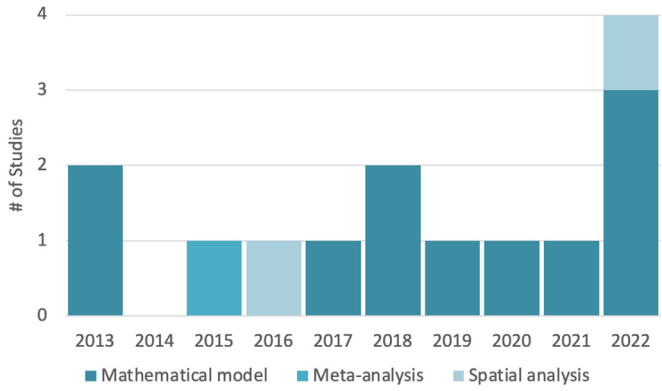

Figure 2. Methods used over time.

an overdose and distance from distribution point.[21] Rowe et al (2016) instead reported total number of administration events as a function of distance, further limiting external validity of the results.[20]

Opioid Education and Naloxone Distribution Programs

While we excluded individual OEND program-based studies from this scoping review, they are important for discussion and comprised 59 of the captured articles in the systematic search. Data from these programs, whether or not published in peer-reviewed journals, is the foundation for the parameters in mathematical models, the component studies of meta-analysis, and the location data for spatial analysis. The accuracy of all methods to estimate naloxone administration by bystanders wraps back around to the quality of self-reported data from OEND programs. When estimations of THN use are put forward to inform policy, the methods behind the estimate must be justifiably better than local OEND data, if available. Amalgamated data provided by government institutions and national coalitions may also be available but will lack local specificity.[22,23]

LIMITATIONS

There are limitations to this scoping review and its applicability. In our study we did not attempt to include methods published in the gray literature in our initial search strategy. This limitation was addressed in part through informal preliminary searches, correspondence with public health personnel at the California Department of Public Health and the CA Bridge program, and citation searching. Further, it was not expected that methods for estimation of bystander naloxone use would exist without being published in peer-reviewed journals.

A related limitation of this study is that the initial search for relevant articles was limited to the PubMed database. This decision was based on the PubMed search terms comprehensively capturing all studies identified by previous informal preliminary searches and correspondence with public health personnel. Additionally, the search strategy attempted to capture any potentially missed literature through backwards citation searching, and the absence of any new relevant articles supported the parameters of the initial search.

Another limitation to this scoping review is that it did not attempt to ascertain the comparative value of methods used in estimating bystander naloxone use. It is possible that preferred methods for determining bystander naloxone use will be dependent upon intended use of the analysis and preference for risk. Methods highly influenced by OEND program data will inherently provide underestimation, while others may cause overestimation. Finally, the environment surrounding harm reduction is constantly changing. The recent approval of OTC naloxone is a new policy that the studies captured in our review do not address.

CONCLUSION

The present scoping review describes the available methods for estimating bystander administration of naloxone. Mathematical models, particularly Markov models, are most common. System dynamics modeling, meta-analysis, and spatial analysis have also been used. All methods are heavily dependent upon OEND program data published in the literature or available as ongoing surveillance data. Overall, there is a paucity of literature describing methods of estimation, and of these few have been applied with a local focus. This is of concern as harm reduction is still regarded with stigma. Further, even as naloxone distribution becomes more normalized, both politically and socially, effective distribution will remain important in a landscape of funding and resource scarcity with complementary interventions and competing policy priorities.

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Impact of Bystander Cardiopulmonary Resuscitation on Out-of-Hospital Cardiac Arrest Outcome in Vietnam

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Introduction: Patients experiencing an out-of-hospital cardiac arrest (OHCA) frequently do not receive bystander cardiopulmonary resuscitation (CPR), especially in low- and middle-income countries (LMIC). In this study we sought to determine the prevalence of OHCA patients in Vietnam who received bystander CPR and its effects on survival outcomes.

Methods: We performed a multicenter, retrospective observational study of patients (≥18 years) presenting with OHCA at three major hospitals in an LMIC from February 2014–December 2018. We collected data on the hospital and patient characteristics, the cardiac arrest events, the emergency medical services (EMS) system, the therapy methods, and the outcomes and compared these data, before and after pairwise 1:1 propensity score matching, between patients who received bystander CPR and those who did not. Upon admission, we assessed factors associated with good neurological survival at hospital discharge in univariable and multivariable logistic models.

Results: Of 521 patients, 388 (74.5%) were men, and the mean age was 56.7 years (SD 17.3). Although most cardiac arrests (68.7%, 358/521) occurred at home and 78.8% (410/520) were witnessed, a low proportion (22.1%, 115/521) of these patients received bystander CPR. Only half of the patients were brought by EMS (8.1%, 42/521) or private ambulance (42.8%, 223/521), 50.8% (133/262) of whom had resuscitation attempts. Before matching, there was a significant difference in good neurological survival between patients who received bystander CPR (12.2%, 14/115) and patients who did not (4.7%, 19/406; $P < .001$). After matching, good neurological survival was absent in all OHCA patients who did not receive CPR from a bystander. The multivariable analysis showed that bystander CPR (adjusted odds ratio: 3.624; 95% confidence interval 1.629–8.063) was an independent predictor of good neurological survival.

Conclusion: In our study, only 22.1% of total OHCA patients received bystander CPR, which contributed significantly to a low rate of good neurological survival in Vietnam. To improve the chances of survival with good neurological functions of OHCA patients, more people should be trained to perform bystander CPR and teach others as well. A standard program for emergency first-aid training is necessary for this purpose. [West J Emerg Med. 2024;25(4)507–520.]

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a prominent cause of death and disability worldwide,[1–4] accounting for up to 10% of overall mortality in low- and middle-income countries (LMIC).[5–7] It is defined as the loss of functional cardiac mechanical activity in association with an absence of systemic circulation, occurring outside a hospital setting.[8,9] The exact burden of OHCA on public health globally is unknown since many cases are not attended by emergency medical services (EMS), and there are often wide variations among different regions, countries, and continents in both their reporting systems and survival outcomes.[5,10–13]

In Asia-Pacific countries, EMS systems are often underdeveloped and vary considerably. Survival outcomes for OHCA in Pan-Asia differ considerably, and these variations may be related to differences in patients and the EMS system.[12] These differences suggest that survival outcomes for OHCA can be improved by interventions to enhance EMS systems,[14] such as increasing bystander cardiopulmonary resuscitation (CPR) through community-based CPR training programs,[15] increasing availability of public access defibrillators,[16] and improving post-resuscitation care.[17] The OHCA patients in LMICs are considerably less likely to receive bystander CPR than those in high-income countries (HIC).[12] Furthermore, in areas with underdeveloped EMS infrastructures, extremely ill or injured patients are frequently transported to hospitals by non-EMS vehicles.[18–21]

Vietnam is an LMIC with a population of 96.462 million people, ranking 15th in the world and third in Southeast Asia, and it still struggles with a lack of development in prehospital services.[18,19,22,23] The Vietnamese government implemented a countrywide strategy for the EMS system in 2008; nonetheless, only a few localities, such as urban areas, have a working EMS system. In addition, the availability of ambulances, qualified and authorized medical personnel, and life-saving equipment is restricted. Medical control and frequent monitoring of quality indicators are also uncommon.[22] Prehospital treatment is typically left to bystanders, and the injured or sick individual is usually taken immediately to the next vehicle large enough to handle him or her; bystander CPR is also frequently not performed.[18–20] As a result, these issues prevent the integration of prehospital and hospital treatment protocols and clinical data collection for surveillance, quality improvement, and research-related activities, and patients with life-threatening diseases or injuries are frequently not offered Basic Life Support (BLS) and Advanced Life Support (ALS) services until they arrive at the hospital.[18–20,24]

Understanding the present state of bystander CPR and how it affects the outcomes of OHCA patients locally is critical for increasing survival in Vietnam and other countries where clinical practice is hampered by inadequate medical resources. In this study we aimed to investigate the survival rates from OHCA and to compare the survival rates of non-matched and matched OHCA cohorts who received bystander CPR and who did not receive bystander CPR.

Population Health Research Capsule

What do we already know about this issue?
Global survival rates for out-of-hospital cardiac arrest (OHCA) vary considerably due to differences in patients and EMS systems.

What was the research question?
How does the current state of bystander cardiopulmonary resuscitation (CPR) impact outcomes of OHCA in Vietnam?

What was the major finding of the study?
A low rate of bystander CPR (22.1%) contributed to low survival. However, bystander CPR was associated with good neurological survival (adjusted OR 3.624; 95% CI 1.629–8.063).

How does this improve population health?
Training more people to perform CPR and encouraging them to teach others can improve the chances of OHCA patients surviving with good neurological outcomes.

METHODS

Study Design and Setting

This multicenter, retrospective observational study is part of the Pan-Asian Resuscitation Outcomes Study (PAROS) Clinical Research Network, which collects data on OHCA patients admitted to hospital emergency departments (ED) in countries across Asia.[18,19,25,26] In this study, we retrieved data from Vietnam in the PAROS database. The hospitals in Vietnam participating in the PAROS study are three public-sector, tertiary hospitals in the three largest cities of the country: Hanoi (northern Vietnam) which serves an estimated 10 million people; Hue (central Vietnam) which serves 1.154 million people; and Ho Chi Minh City (southern Vietnam) which serves 13 million people. The hospitals receive patients from all parts of each city. The reasons for selecting these institutions were as follows: 1) they are academic hospitals, responsible for educating hospital staff, treating patients who need procedures such as cardiac catheterization that cannot be performed in local hospital

settings, and receiving most of the cases attended by the EMS; and 2) these three hospitals serve a diverse population of varying socioeconomic status and ethnicity. This hospital-based sample represents the general urban population in Vietnam.

Several ambulance services are available in Vietnam, but only one emergency service has an emergency number (telephone number 115), trained and accredited medical staff, life-saving equipment, medical oversight, and quality indicators that are regularly monitored.[22,27] Several other private organizations also provide emergency services with the ability to deliver CPR, life-saving drugs, and defibrillation, or at least have a health professional trained to deal with emergencies.[28] However, the ambulance dispatched by these organizations is not coordinated by an EMS dispatch center.[29] For this study, we categorized the type of prehospital transportation into two groups: EMS, which refers to ambulances dispatched by an EMS dispatch center; and non-EMS, which refers to private ambulances, private transport, or public transport. We defined a private ambulance as an ambulance that was not dispatched by an EMS dispatch center. Private transport includes transport in vehicles by family members, relatives, neighbors, or passersby. Public transport includes taxis, buses, or other types of public transport.

Participants

This study included all patients >18 years presenting with OHCA to the emergency departments (ED) of the three hospitals. We excluded OHCA patients who had suffered traumatic injury. We defined a case of OHCA as a person who was unresponsive, not breathing, and without a pulse outside the hospital setting.[30–32] The diagnosis of OHCA or the return of spontaneous circulation (ROSC) was confirmed by EMS personnel on the scene/enroute, or by a physician in the ED. We excluded patients for whom resuscitation was not attempted by EMS or private ambulance personnel at the scene/enroute and who were immediately pronounced dead (because of rigor mortis, lividity, or "do not resuscitate" orders) at the ED. However, we included patients on whom resuscitation was attempted but who were later pronounced dead before they reached the hospital.

Data Collection

We used a standardized classification and case record form to collect data on common variables. The data dictionary of the PAROS study is available as an online supplement to previously published papers.[12,18] The data was extracted from emergency dispatch records, ambulance patient case notes, and ED and in-hospital records and entered into the PAROS study database using an electronic data capture system. Patient identifiers were not entered in the database to protect patient confidentiality. We then extracted data from Vietnam and merged the data sets for the three hospitals. Each hospital contributed five years of data from February 2014–December 2018.

Variables

We included variables based on Utstein recommendations,[33,34] such as information on the following: 1) bystander CPR; 2) availability of public access defibrillators; 3) response times; 4) provision of ALS (eg, intravenous drugs, advanced airway management including endotracheal intubation or alternative airway devices); 5) cause of the arrest (a cardiac arrest was presumed unless it was known or likely that the arrest had a non-cardiac cause (eg, asthma, terminal illness, cerebrovascular accident, drug overdose, suicide, drowning, or trauma); and 6) provision of specialized post-resuscitation care (hypothermia or extracorporeal membrane oxygenation [ECMO]). We also collected data on the location of the OHCA (eg, home, public area). We collected data on system variables; the list of variables is available as an online supplement to previously published papers.[12,18]

Outcomes

The primary outcome of the present study was good neurological survival on hospital discharge or at day 30 post-arrest. We used the Cerebral Performance Category (CPC) score to evaluate the neurological function of the OHCA patients.[35,36] The CPC score was calculated based on data collected from clinical records, and telephone and face-to-face interviews. In this study we defined good neurological function as a CPC score of 1 or 2,[12] which indicates survival with mild or moderate disability. We also examined secondary outcomes that included the following: the proportions of patients in whom spontaneous circulation returned at the scene/enroute; patients who survived to hospital admission; and patients who were discharged from the hospital.

Statistical Analyses

Description and Comparison of Cohorts

We report data as numbers and percentages (%) for categorical variables and medians and interquartile ranges (IQR 25–75%) or means and SDs for continuous variables. We compared OHCA patients who received bystander CPR with those who did not receive bystander CPR for each variable. We used the chi-squared test or Fisher exact test for categorical variables and the independent samples *t*-test, Mann-Whitney U test, or one-way analysis of variance for continuous variables in comparisons of these variables.

Matching Method

We carried out pairwise 1:1 propensity score matching (Supplementary Figure), using the nearest neighbor matching method to reduce the effect of bias by unbalanced covariates and potential confounding.[37,38] The propensity

score was estimated using multiple logistic regression analysis that included the independent variables of age (either <60 years or ≥60 years), gender (either male or female), past medical history (none, heart diseases only, other diseases, such as diabetes, cancer, hypertension, renal disease, respiratory disease, hyperlipidemia, stroke, HIV, and others, or both heart diseases and other diseases), and etiology of OHCA (either presumed cardiac or non-cardiac, such as respiratory, drowning, electrocution, and others) with bystander CPR and without bystander CPR.

Assessing Factors Associated with Survivability

Upon admission, we assessed factors associated with good neurological survival on hospital discharge using logistic regression analysis. To reduce the number of predictors, multicollinearity and overfitting, we used different ways to select variables. First, we started variable selection with a univariable logistic regression analysis of each variable that included independent variables related to participating hospitals, patient-related factors, cardiac arrest event-related factors, EMS system- and therapy-related factors. We included variables for consideration in the multivariable logistic regression analysis if the *P*-value was <0.05 in the univariable logistic regression analysis, as well as factors that were clinically important (including age, past medical history, presence of a witness, etiology of OHCA, type of prehospital transportation and bystander CPR). Second, we used a stepwise backward elimination method to select variables for multivariable logistic regression analysis. Similarly, we used these methods of variable selection and analysis to assess factors associated with survival to hospital admission and survival to hospital discharge. We present odds ratios (OR) and 95% confidence intervals (CI).

We used SPSS Statistics 25.0 (SPSS, Inc, Chicago, IL) for data analysis. For all statistical analyses, significance levels were two-tailed, and we considered $P < 0.05$ as statistically significant.

RESULTS

During the study period, 779 OHCA patients had their data submitted to the PAROS database. We removed from the study 31 individuals <18 years old and 109 with traumatic injuries. We additionally removed 30 patients (4.69%; 30/639) due to a prolonged prehospital stay (ie, more than one day), which might have indicated input mistakes or enrollment of patients transferred from the referring hospitals. Moreover, we excluded 88 patients (13.77%; 88/639) from our analysis due to the absence of most variables. In total we included 521 eligible patients in our analyses (Figure).

The Primary and Secondary Outcomes

Of the 521 OHCA patients, 98 (18.8%) had a ROSC at the scene/enroute, and for 113 (21.7%) patients, spontaneous circulation returned in the ED (Table 1). Overall, 18.4% (96/521) of patients survived on hospital admission, and 9.4% (49/521) survived to hospital discharge; 6.3% (33/521) survived with good neurological function (a CPC score

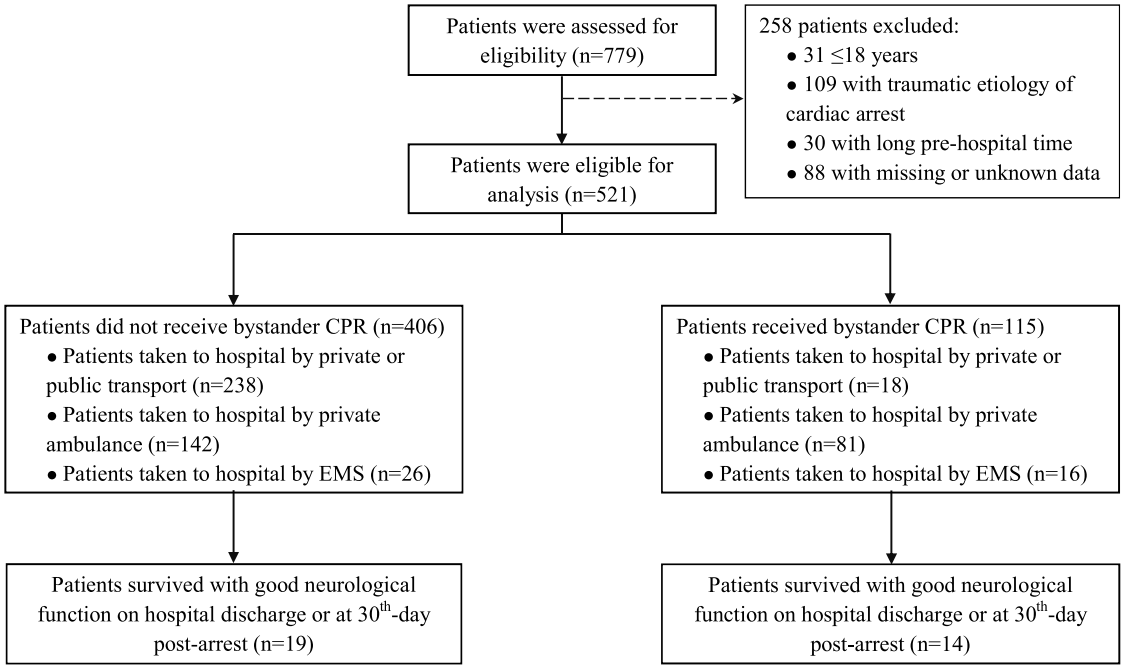

Figure. Flowchart of type of bystander cardiopulmonary resuscitation, transportation to the hospital, and outcome of patients with out-of-hospital cardiac arrest included in the study, Vietnam, February 2014–December 2018.
CPR, cardiopulmonary resuscitation; *EMS*, emergency medical services.

Table 1. Outcomes of non-matched and matched cohorts of patients with out-of-hospital cardiac arrest according to the type of bystander cardiopulmonary resuscitation, Vietnam, February 2014–December 2018.

	Before matching				After matching			
Variables	All cases (n = 521)	No bystander CPR (n = 406)	Bystander CPR (n = 115)	*P*-value[a]	All cases (n = 212)	No bystander CPR (n = 106)	Bystander CPR (n = 106)	*P*-value[b]
ROSC, no. (%)								
ROSC at scene/ enroute	98 (18.8)	57 (14.0)	41 (35.7)	<0.001	39 (18.4)	0 (0.0)	39 (36.8)	<0.001
ROSC at ED	113 (21.7)	81 (20.00	32 (27.8)	0.07	49 (23.1)	18 (17.0)	31 (29.2)	0.03
Outcome of patient at ED, no. (%)				0.06				<0.001
Died in ED	425 (81.6)	338 (83.3)	87 (75.7)		185 (87.3)	106 (100.0)	79 (74.5)	
Admitted	96 (18.4)	68 (16.7)	28 (24.3)		27 (12.7)	0 (0.0)	27 (12.7)	
Patient status, no. (%)				0.14				<0.001
Died in the hospital	41 (7.9)	31 (7.6)	10 (8.7)		10 (4.7)	0 (0.0)	10 (9.4)	
Remains in hospital at day 30 post arrest	6 (1.2)	5 (1.2)	1 (0.9)		0 (0.0)	0 (0.0)	0 (0.0)	
Discharged alive	49 (9.4)	32 (7.90	17 (14.8)		17 (8.0)	0 (0.0)	17 (16.0)	
Post arrest CPC 1 or 2, n (%)	33 (6.3)	19 (4.7)	14 (12.2)	<.001	14 (6.6)	0 (0.0)	14 (13.2)	<0.001

[a]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the non-matched cohort.
[b]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the matched cohort.
CPC, cerebral performance category; *CPR*, cardiopulmonary resuscitation; *ED*, emergency department; *ROSC*, return of spontaneous circulation.

of 1 or 2) on hospital discharge or at 30th-day post-arrest (Table 1).

Clinical Characteristics and Pre-Hospital and In-Hospital Management

Among the total number of OHCA patients, 74.5% (388/521) were men and the mean age was 56.7 years (SD 17.3). Less than a fifth of the patients (18.1%; 85/470) had a past medical history of heart disease (Table 2). Most OHCAs occurred at home (68.7%; 358/521) and during the day (56.6%; 181/320) (Table 3). The witnessed OHCAs accounted for 78.8% (410/520) of patients (Table 3), most of which were bystander-witnessed cardiac arrests, including layperson (4.2%; 22/520), family members (13.8%; 72/520), and healthcare professionals (49.8%; 259/520). A cardiac condition was the presumed cause of cardiac arrest in 44.9% (234/521) of patients (Table 3). Of the 521 OHCA patients, 49.1% (256/521) were taken to hospital by private or public transport, 42.8% (223/521) were taken by private ambulance, and only 8.1% (42/521) were taken by EMS (Table 4 and Supplementary Table 1).

Only 31.9% (43/135) of OHCA patients received prehospital defibrillation (Table 5). Only 22.1% (115/521) of the patients received bystander CPR, and 5.3% (14/262) received a bystander automated external defibrillator (AED) (Table 5). Epinephrine was given to 23.4% (122/521) of patients with cardiac arrest at the scene/enroute, and 20.7% (108/521) received prehospital advanced airway management (Table 5). Hypothermia therapy was given to 15.0% (78/521) of OHCA patients, but only 1.3% (7/519) were given ECMO therapy (Table 5). The characteristics, management, and complications of the study cohort are shown in Tables 2, 3, 4, and 5.

Impact of Bystander CPR on the Outcomes

In non-matched and matched cohorts, Tables 1, 2, 3, 4, and 5 compare the general characteristics, prehospital and in-hospital treatment, and outcomes of OHCA patients who did not receive bystander CPR to those who did.

In Non-Matched Cohort

There was a significant difference in resuscitation attempted by EMS or private ambulance between patients who received bystander CPR (61.7%; 58/94) and patients who did not receive bystander CPR (44.6%; 75/168; $P = 0.01$) (Table 4). The proportion of patients in whom spontaneous circulation returned at the scene/enroute was significantly higher in patients who received bystander CPR (35.7%; 41/115) compared to patients who did not receive bystander CPR (14.0%; 57/406; $P < 0.001$) (Table 1).

Table 2. Patient-related characteristics of non-matched and matched cohorts of patients with out-of-hospital cardiac arrest according to the type of bystander cardiopulmonary resuscitation, Vietnam, February 2014–December 2018.

	Before matching				After matching			
Variables	All cases (n = 521)	No bystander CPR (n = 406)	Bystander CPR (n = 115)	*P*-value[a]	All cases (n = 212)	No bystander CPR (n = 106)	Bystander CPR (n = 106)	*P*-value[b]
Hospital participated								
Hospital				0.03				0.14
Bach Mai, no. (%)	396 (76.0)	306 (75.4)	90 (78.3)		176 (83.0)	91 (85.8)	85 (80.2)	
Hue, no. (%)	24 (4.6)	24 (5.9)	0 (0.0)		2 (0.9)	2 (1.9)	0 (0.0)	
Cho Ray, no. (%)	101 (19.4)	76 (18.7)	25 (21.7)		34 (16.0)	13 (12.3)	21 (19.8)	
Patient-related								
Age (year), mean (SD)	56.7 (17.3)	57.6 (17.2)	53.7 (17.6)	0.04	56,6 (17.5)	60.0 (16.6)	53.1 (17.8)	<.001
Gender (male), no. (%)	388 (74.5)	305 (75.10	83 (72.2)	0.52	154 (72.6)	78 (73.6)	76 (71.7)	0.76
Past medical history, no. (%), n1 = 470[c]								
Heart disease	85 (18.1)	60 (16.5)	25 (23.6)	0.10	38 (17.9)	13 (12.3)	25 (23.6)	0.03
Diabetes	64 (13.6)	46 (12.6)	18 (17.00	0.30	30 (14.2)	12 (11.3)	18 (17.0)	0.24
Cancer	38 (8.1)	34 (9.3)	4 (3.8)	0.06	11 (5.2)	7 (6.6)	4 (3.8)	0.35
Hypertension	111(23.6)	85 (23.4)	26 (24.5)	0.80	47 (22.2)	21 (19.8)	26 (24.5)	0.41
Renal disease	38 (8.1)	27 (7.4)	11 (10.4)	0.33	15 (7.1)	4 (3.8)	11 (10.4)	0.06
Respiratory disease	75 (16.0)	53 (14.6)	22 (20.8)	0.13	37 (17.5)	15 (14.2)	22 (20.8)	0.21
Hyperlipidemia	4 (0.9)	4 (1.1)	0 (0.0)	0.58	0 (0.0)	0 (0.0)	0 (0.0)	NA
Stroke	16 (3.4)	15 (4.1)	1 (0.9)	0.14	6 (2.8)	5 (4.7)	1 (0.9)	0.21
HIV	1 (0.2)	1 (0.3)	0 (0.0)	> 0.99	0 (0.0)	0 (0.0)	0 (0.0)	NA

[a]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the non-matched cohort.
[b]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the matched cohort.
[c]n1 was defined as the total number of patients recorded if a variable was given or not in the non-matched cohort.
CPR, cardiopulmonary resuscitation; *NA*, not available.

However, there was no significant difference in survival to hospital admission between patients who received bystander CPR (24.3%; 28/115) and patients who did not (16.7%; 68/406; $P = 0.06$) and survival to hospital discharge between patients who received bystander CPR (14.8%; 17/115) and patients who did not (7.9%; 32/406; $P = 0.14$) (Table 1). In contrast, the rate of good neurological survival on hospital discharge or at day 30 post-arrest in patients who received bystander CPR (12.2%, 14/115) was significantly higher than that in patients who did not receive bystander CPR (4.7%, 19/406; $P < .001$) (Table 1).

In Matched Cohort

We used propensity score matching to obtain 106 pairs of patients with similar characteristics (Tables 1, 2, 3, 4, and 5). Among OHCA patients who did not receive bystander CPR, none received resuscitation attempted by EMS or private ambulance (Table 4) or had ROSC at the scene/enroute (Table 1). As a result, none of the OHCA patients survived on hospital admission or obviously survived to hospital discharge (Table 1).

Association of Bystander CPR with Survivability

In contrast to the association between bystander CPR and survival to hospital admission (Supplementary Table 2), Supplementary Tables 3 and 4 show bystander CPR was identified in the univariable logistic regression to be significantly associated with increased chance of survival to hospital discharge (OR 2.027; 95% CI 1.081–3.802) and good neurological survival on hospital discharge or at day 30 post-arrest (OR 2.823; 95% CI 1.368–5.825). However, the multivariable logistic regression showed that bystander CPR was independently associated with only an increased chance of good neurological survival on hospital discharge or at day

Table 3. Event-related characteristics of non-matched and matched cohorts of patients with out-of-hospital cardiac arrest according to the type of bystander cardiopulmonary resuscitation, Vietnam, February 2014–December 2018.

	Before matching				After matching			
Variables	All cases (n = 521)	No bystander CPR (n = 406)	Bystander CPR (n = 115)	*P*-value[a]	All cases (n = 212)	No bystander CPR (n = 106)	Bystander CPR (n = 106)	*P*-value[b]
Location type, n (%)				<0.001				<0.001
In EMS/private ambulance	63 (12.1)	46 (11.3)	17 (14.8)		40 (18.9)	24 (22.6)	16 (15.1)	
Healthcare facility	50 (9.6)	14 (3.4)	36 (31.3)		40 (18.9)	8 (7.5)	32 (30.2)	
Home residence	358 (68.7)	304 (74.9)	54 (47.0)		109 (51.4)	59 (55.7)	50 (47.2)	
Public area	50 (9.6	42 (10.3	8 (7.0		23 (10.8)	15 (14.2)	8 (7.5)	
Time of the day, no. (%), n1 = 320[d], n2 = 105[d]	181 (56.6)	125 (53.0)	56 (66.7)	0.03	64 (61.0)	13 (44.8)	51 (67.1)	0.04
Witnessed arrest, n1 = 520[d]	410 (78.8)	297 (73.30	113 (98.3)	<0.001	128 (60.4)	24 (22.6)	104 (98.1)	<0.001
Arrest witnessed by, no. (%), n1 = 520[d]				<0.001				<0.001
Not witnessed	110 (21.2)	108 (26.7)	2 (1.7)		84 (39.6)	82 (77.4)	2 (1.9)	
Bystander (lay person)	22 (4.2)	16 (4.0)	6 (5.2)		11 (5.2)	6 (5.7)	5 (4.7)	
Bystander (family)	72 (13.8)	19 (4.7)	53 (46.1)		65 (30.7)	16 (15.1)	49 (46.2)	
Bystander (healthcare worker)	259 (49.8)	229 (56.5)	30 (26.1)		31 (14.6)	2 (1.9)	29 (27.4)	
EMS/private ambulance	57 (11.0)	33 (8.1)	24 (20.9)		21 (9.9)	0 (0.0)	21 (19.8)	
Presumed cardiac etiology of OHCA	234 (44.9)	184 (45.3)	50 (43.5)	0.73	82 (38.7)	36 (34.0)	46 (43.4)	0.16
Shockable first arrest rhythms[c], n1 = 135[d], n2 = 56[d]	93 (68.9)	51 (67.1)	42 (71.2)	0.61	39 (69.6)	NA	39 (69.6)	NA

[a]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the non-matched cohort.
[b]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the matched cohort.
[c]Shockable first arrest rhythms included ventricular tachycardia, ventricular fibrillation, or unknown shockable rhythms.
[d]n1 and n2 were defined as the total number of patients recorded if a variable was given or not in the non-matched and matched cohorts.
CPR, cardiopulmonary resuscitation; *EMS*, emergency medical services; *NA*, not available; *OHCA,* out-of-hospital cardiac arrest.

30 post-arrest (adjusted OR 3.624; 95% CI 1.629–8.063) (Table 6). Other factors were associated with survivability, as shown in Table 6 and Supplementary Tables 2, 3, and 4.

DISCUSSION

Of 521 OHCA patients included in our analysis, just over one-fifth (22.1%) received bystander CPR. As a result, less than one-fifth (18.4%) of these patients survived to hospital admission, only one-tenth (9.4%) were discharged from the hospital, and just over one-twentieth (6.3%) were discharged from the hospital with good neurological function (Table 1). Our study found that the survival rate of medical OHCA patients on admission aligns with the rate (20.4%; 8,341/40,878) reported by the French national registry.[39] This could be due to the Franco-German EMS model, where physicians often accompany patients in ambulances.[40] However, our results surpass a previous study in Hanoi, Vietnam, which reported lower rates of bystander CPR (8.4%; 20/239), survival at discharge (3.8%; 9/239), and good neurological survival (0.4%; 1/239).[20]

The differences could be due to the distinct inclusion criteria between the studies. For instance, our study included OHCA patients who received resuscitation attempts by EMS/private ambulance personnel at the scene/enroute and excluded those with traumatic injuries. Despite having a lower rate of bystander CPR, our study has a higher rate of survival to discharge than the rate reported in a retrospective cohort study in Thailand (3.4%; 42/1240),[41] and even has a higher rate of survival to discharge than the rates reported in studies in Japan (5.2%; 2,677/51,377), Korea (8.5%; 681/

Table 4. System-related characteristics of non-matched and matched cohorts of patients with out-of-hospital cardiac arrest according to the type of bystander cardiopulmonary resuscitation, Vietnam, February 2014–December 2018.

	Before matching				After matching			
Variables	All cases (n = 521)	No bystander CPR (n = 406)	Bystander CPR (n = 115)	*P*-value[a]	All cases (n = 212)	No bystander CPR (n = 106)	Bystander CPR (n = 106)	*P*-value[b]
Prehospital transport, no. (%)				<0.001				<0.001
EMS	42 (8.1)	26 (6.4)	16 (13.9)		16 (7.5)	1 (0.9)	15 (14.2)	
Private ambulance	223 (42.8)	142 (35.0)	81 (70.4)		111 (52.4)	37 (34.9)	74 (69.8)	
Private or public transport	256 (49.1)	238 (58.6)	18 (15.7)		85 (40.1)	68 (64.2)	17 (16.0)	
Resuscitation attempted by EMS/private ambulance, no. (%), n1 = 262[c], n2 = 125[c]	133 (50.8)	75 (44.6)	58 (61.7)	0.01	55 (44.0)	0 (0.0)	55 (63.2)	<0.001
Time to initiation of CPR (min), mean (SD), n1 = 87[c]	7.3 (8.7)	9.1 (5.6)	5.1 (11.1)	<0.001	5,5 (11.5)	NA	5,5 (11.5)	NA
Time to defibrillation at scene (min), mean (SD), n2 = 36[c]	9.0 (6.2)	9.7 (5.1)	7.7 (7.9)	0.13	8.5 (8.4)	NA	8.5 (8.4)	NA

[a]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the non-matched cohort.
[b]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the matched cohort.
[c]n1 and n2 were defined as the total number of patients recorded if a variable was given or not in the non-matched and matched cohorts.
CPR, cardiopulmonary resuscitation; *EMS*, emergency medical services; *NA*, not available.

7,990), and Singapore (2.5%; 76/3,023).[12] Our rate for good neurological survival to hospital discharge is also higher than the rates reported in these countries: Thailand (1.6%; 9/573); Japan (2.8%; 1,436/51,377); Korea (3.0%; 236/7,990); and Singapore (1.7%; 50/3,023).[12]

We recognize that our cohort is likely to be a highly selected population, as many OHCA patients in Vietnam are not brought to the hospital and die outside the hospital setting.[42–44] These findings could be due to a selection bias in our study, as we only had data on patients brought to the three highest level public sector hospitals in Vietnam. Furthermore, we included OHCA patients brought to the hospital by EMS/private ambulances. Among these patients, there were no cases for whom resuscitation was not attempted by EMS/private ambulance personnel at the scene/enroute and then were immediately pronounced dead at the ED. These might inflate the survival rate. Therefore, these cases may not reflect all OHCAs in the country.

A pivotal component in successful resuscitation from OHCA is the chain of survival.[45,46] Rapid public-access defibrillation (PAD) with AEDs and bystander CPR improve survival rates.[6,47–50] However, our study found that a small number of OHCAs receiving bystander CPR still considerably influenced the lower overall survival rates (Table 1). Most patients not receiving bystander CPR were taken to the hospital by private or public transport (Table 4), usually without first-aid.[24,42,43,51] In such situations, bystander first-aid is vital for OHCA outcomes.[52] However, bystander CPR is rarely performed in Vietnam,[24] which could be due to the lack of knowledge, absence of dispatcher-assisted CPR (T-CPR) programs, fear of harm or infection, and legal concerns[53] that may prevent bystanders from using such techniques (eg, CPR, PAD) and using them effectively.[54] Most CPR-willingness studies have been conducted in HICs,[53,55] with few in LMICs.

A study in Lebanon discovered a negative correlation between the lack of previous training and confidence in performing CPR and the willingness to do CPR in OHCA patients.[54] It is clear that timely CPR and defibrillation, regardless of who does them, are crucial for improving survival rates from OHCAs.[56] While enhancing EMS response times is challenging and potentially costly, simplified training programs can engage the public effectively. For instance, a focus on compression-only CPR has increased bystander CPR rates and survival rates.[57] The aim should not be to dilute the quality of CPR training but to extend outreach to more individuals in the community to build a pyramid of first responders.[14] To improve bystander first-aid in Vietnam, more laypeople should be trained through a recognized emergency first-aid program.[58] Plans for the future should include dedicated training and quality improvement activities for T-CPR at dispatch centers.

Table 5. Therapy-related characteristics of non-matched and matched cohorts of patients with out-of-hospital cardiac arrest according to the type of bystander cardiopulmonary resuscitation, Vietnam, February 2014–December 2018.

	Before matching				After matching			
Variables	All cases (n = 521)	No bystander CPR (n = 406)	Bystander CPR (n = 115)	*P*-value[a]	All cases (n =212)	No bystander CPR (n = 106)	Bystander CPR (n = 106)	*P*-value[b]
Pharmacotherapy, no. (%)								
Epinephrine (at scene)	122 (23.4)	67 (16.5)	55 (47.8)	<0.001	52 (24.5)	0 (0.0)	52 (49.1)	<0.001
Epinephrine (at ED)	480 (92.1)	374 (92.1)	106 (92.2)	>0.99	196 (92.5)	99 (93.4)	97 (91.5)	0.60
Prehospital intervention, no. (%)								
Prehospital defibrillation, n1 = 135[c], n2 = 56[c]	43 (31.9)	29 (38.2)	14 (23.7)	0.07	12 (21.4)	NA	12 (21.4)	NA
Bystander AED applied, n1 = 262[c], n2 = 125[c]	14 (5.3)	7 (4.2)	7 (7.4)	0.26	7 (5.6)	0 (0.0)	7 (8.0)	0.10
ED defibrillation performed, no. (%)	68 (13.1)	48 (11.8)	20 (17.4)	0.12	24 (11.3)	6 (5.7)	18 (17.0)	0.01
Prehospital advanced airway, no. (%)	108 (20.7)	62 (15.3)	46 (40.0)	<0.001	43 (20.3)	0 (0.0)	43 (40.6)	<0.001
Advanced airway used at ED, no. (%)	297 (57.0)	241 (59.4)	56 (48.7)	0.04	111 (52.4)	59 (55.7)	52 (49.1)	0.34
Admission coronary angiography, no. (%)								
Emergency PCI performed	23 (4.4)	18 (4.4)	5 (4.3)	0.97	5 (2.4)	0 (0.0)	5 (4.7)	0.06
Emergency CABG performed	2 (0.4)	2 (0.5)	0 (0.0)	>0.99	NA	NA	NA	NA
Post-resuscitation care, no. (%)								
ECMO therapy initiated, n1 = 519[c]	7 (1.30)	5 (1.2)	2 (1.7)	0.65	2 (0.9)	1 (0.9)	1 (0.9)	>0.99
Hypothermia therapy initiated	78 (15.0)	53 (13.1)	25 (21.7)	0.02	26 (12.3)	2 (1.9)	24 (22.6)	<0.001

[a]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the non-matched cohort.
[b]The comparison between patients who did not receive bystander CPR and who received bystander CPR in the matched cohort.
[c]n1 and n2 were defined as the total number of patients recorded if a variable was given or not in the non-matched and matched cohorts.
AED, automated external defibrillation; *CABG*, coronary artery bypass grafting; *CPR*, cardiopulmonary resuscitation; *ECMO*, extracorporeal membrane oxygenation therapy; *ED*, emergency department; *NA*, not available; *PCI*, percutaneous coronary intervention.

In our study, EMS attended to and transported a small number of OHCA patients to the hospital (Table 4). This finding might be attributed to a lack of resources, knowledge, and infrastructure for emergency medical treatment, such as EMS dispatch centers.[22,27] Despite economic and political changes that have resulted in strong economic growth in Vietnam,[59] ambulances, qualified and accredited medical personnel, and life-saving equipment are in short supply. Medical supervision and frequent monitoring of quality indicators are also rare.[22,27] At the same time, recruiting new EMS workers or healthcare practitioners is fraught with difficulties.[27] For example, following graduation, all doctors and nurses must complete an 18-month clinical training program in inpatient settings to obtain their complete clinical license.[28] However, EMS is not recognized as a clinical training facility, which makes obtaining postgraduate certification difficult. As a result, ambulance medical staff are understaffed, overworked, and underequipped; and EMS centers are overburdened.[27] Moreover, call center staff do not have the ability to identify a possible person in cardiac arrest and provide CPR instructions to callers.[22] Public bystanders are also reluctant to call EMS, and this may

Table 6. Factors related to survival outcomes in a non-matched cohort of patients with out-of-hospital cardiac arrest in Vietnam, February 2014–December 2018: multivariable logistic regression analyses.

Factors	Survival to admission[a]		Survival to discharge[b]		Good neurological function[c]	
	AOR (95% CI)	*P*-value	AOR (95% CI)	*P*-value	AOR (95% CI)	*P*-value
Patient-related						
Age ≥ 60 years	0.545 (0.311–0.955)	0.03	0.329 (0.155–0.698)	<0.001	0.273 (0.106–0.702)	0.01
Past medical history						
Heart diseases	NA	NA	0.073 (0.015–0.356)	<0.001	0.027 (0.003–0.265)	<0.001
Cancer	0.167 (0.038–0.740)	0.02	NA	NA	NA	NA
Renal disease	0.059 (0.008–0.453)	0.01	NA	NA	NA	NA
Respiratory disease	2.490 (1.320–4.697)	0.01	4.310 (1.869–9.941)	<0.001	8.386 (2.834–24.812)	<0.001
Event-related						
Location type						
In EMS/private ambulance	Reference	<0.001	NA	NA	NA	NA
Healthcare facility	3.175 (0.679–14.848)	0.14	NA	NA	NA	NA
Home residence	7.827 (2.294–26.708)	<0.001	NA	NA	NA	NA
Public area	10.330 (2.384–44.757)	<0.001	NA	NA	NA	NA
Witnessed arrest	3.657 (1.471–9.091)	0.01	3.625 (1.057–12.431)	0.04	NA	NA
Presumed cardiac etiology	NA	NA	3.337 (1.570–7.094)	<0.001	7.236 (2.611–20.053)	<0.001
System-related						
Prehospital transportation						
Private or public transport	0.204 (0.106–0.392)	<0.001	NA	NA	NA	NA
Therapy-related						
Bystander CPR	NA	NA	1.962 (0.980–3.929)	0.06	3.624 (1.629–8.063)	<0.001
Constant	0.024	<0.001	0.023	<0.001	0.022	<0.001

[a]Indicate the patient received hospital admission.
[b]Indicate whether the patient was discharged alive or remained in the hospital on the day 30 post-arrest.
[c]Indicate the patient's neurological outcome at the time of discharge or the 30th day after the cardiac arrest.
AOR, adjusted odds ratio; *CI*, confidence interval; *CPR*, cardiopulmonary resuscitation; *EMS*, Emergency Medical Services; *NA*, not available; *OHCA*, out-of-hospital cardiac arrest.

explain why in our study we found that a very low proportion of OHCA patients received bystander CPR or were taken to the hospital by EMS.

In 2011, the Ministry of Health began issuing licenses for private ambulances to provide first-aid or patient transportation.[28] These services are equipped to perform CPR, administer life-saving drugs, use defibrillators, and generally have a medical professional on board trained to handle emergencies. However, our study found that only about two-fifths of OHCA patients were transported by these services. A significant number of these patients did not receive CPR from bystanders (Table 4). Moreover, for OHCA patients who did not receive CPR from bystanders, resuscitation attempts were often not performed by EMS/private ambulance personnel (Table 4). These findings could be due to limited medical interventions provided by some private organizations and healthcare workers' difficulty in recognizing cardiac arrests.[29] Bystanders might also be unwilling to call private ambulance services; the injured or sick person or OHCA patient is often carried quickly by the nearest private vehicle large enough to accommodate them and brought to the hospital by friends and relatives.[24,29,42]

In this study, univariable logistic regression identified two factors as significantly lowering the likelihood of good neurological survival at hospital discharge: patients who were transported to the hospital by private or public transportation, and patients who did not receive bystander CPR (Supplementary Table 4). Comparatively, those who received bystander CPR were found in multivariable logistic regression to be independently related to a high probability of surviving until hospital discharge with good neurological function (Table 6). These findings highlight the most important factor that strongly predicted good neurological survival at hospital discharge was bystander CPR, which overwhelmed other factors included in

our multivariable logistic regression (Table 6). These findings also mean that bystander CPR plays the first crucial role in the chain of survival, regardless of the type of prehospital transport.[14,45,46,57,60]

LIMITATIONS

There are several limitations to this study. Firstly, our study was limited by its retrospective design. As a result, our data was missing many variables. For instance, we only had information on whether resuscitation attempts were made by EMS/private ambulance personnel for 262 patients. Moreover, most time-stamped data was absent for various events (eg, response times), and we excluded 88 patients from our analysis due to the absence of most variables. These limitations have resulted in an implicit selection bias, hindered our ability to calculate a higher propensity score, and limited any potential definitive conclusions. Secondly, it is not feasible to ascertain whether bystander CPR adhered to the American Heart Association or Red Cross protocol. Consequently, bystander CPR may vary significantly and not align with standard recommendations.

Thirdly, our study was conducted in three of the highest level public sector hospitals in Vietnam and focused on a highly selected population of cases. However, the study did not include patients brought to the hospital by EMS/private ambulances who were pronounced dead in the field. As a result, the number of persons suffering from OHCA is expected to be much larger than what was reported in this hospital-based study. Additionally, we found that many OHCA patients arrived at the hospital by private transportation rather than EMS/private ambulances. Some of these individuals may have been seen by primary care doctors, may have died at home, or may not have been transported to the hospital at all. Moreover, the number of OHCA patients varied significantly across hospitals. This difference is because the Hue Central General and the Cho Ray Hospitals had only a small number of patients enrolled in 2017 and 2018. Thus, these factors have also resulted in an implicit selection bias or incomplete enrolment and inclusion of patients in the OHCA database. Differences in figures found between Vietnam and other countries might be accounted for by these factors. Finally, the sample size was relatively small, which might have led to overfitting in the multivariable prediction models. Therefore, we did not include more variables at the medical institutions in these models.

CONCLUSION

Our study showed that the low proportion of OHCA patients who received bystander CPR contributed significantly to a low rate of good neurological survival in Vietnam. Upon admission, bystander CPR was an independent predictor of good neurological survival at hospital discharge. To improve the chances of good neurological survival of OHCA patients, more people should be trained to perform bystander CPR and teach others as well. A standard program for emergency first-aid training is necessary for this purpose.

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End-tidal Carbon Dioxide Trajectory-based Prognostication of Out-of-hospital Cardiac Arrest

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Background: During cardiopulmonary resuscitation (CPR), end-tidal carbon dioxide ($EtCO_2$) is primarily determined by pulmonary blood flow, thereby reflecting the blood flow generated by CPR. We aimed to develop an $EtCO_2$ trajectory-based prediction model for prognostication at specific time points during CPR in patients with out-of-hospital cardiac arrest (OHCA).

Methods: We screened patients receiving CPR between 2015–2021 from a prospectively collected database of a tertiary-care medical center. The primary outcome was survival to hospital discharge. We used group-based trajectory modeling to identify the $EtCO_2$ trajectories. Multivariable logistic regression analysis was used for model development and internally validated using bootstrapping. We assessed performance of the model using the area under the receiver operating characteristic curve (AUC).

Results: The primary analysis included 542 patients with a median age of 68.0 years. Three distinct $EtCO_2$ trajectories were identified in patients resuscitated for 20 minutes (min): low (average $EtCO_2$ 10.0 millimeters of mercury [mm Hg]; intermediate (average $EtCO_2$ 26.5 mm Hg); and high (average $EtCO_2$: 51.5 mm Hg). Twenty-min $EtCO_2$ trajectory was fitted as an ordinal variable (low, intermediate, and high) and positively associated with survival (odds ratio 2.25, 95% confidence interval [CI] 1.07–4.74). When the 20-min $EtCO_2$ trajectory was combined with other variables, including arrest location and arrest rhythms, the AUC of the 20-min prediction model for survival was 0.89 (95% CI 0.86–0.92). All predictors in the 20-min model remained statistically significant after bootstrapping.

Conclusion: Time-specific $EtCO_2$ trajectory was a significant predictor of OHCA outcomes, which could be combined with other baseline variables for intra-arrest prognostication. For this purpose, the 20-min survival model achieved excellent discriminative performance in predicting survival to hospital discharge. [West J Emerg Med. 2024;25(4)521–532.]

Keywords: *Cardiopulmonary resuscitation; end-tidal carbon dioxide; group-based trajectory modeling; out-of-hospital cardiac arrest; survival; trajectory.*

INTRODUCTION

The annual incidence of out-of-hospital cardiac arrest (OHCA) is estimated to be 28–44 cases per 100,000 population worldwide.[1] The estimated proportion of survival to discharge in OHCA was 7.6% in Europe, 6.8% in North America, 3.0% in Asia, and 9.7% in Australia.[1] High-quality cardiopulmonary resuscitation (CPR) is critical in improving OHCA outcomes.[2,3] Capnography is recommended to monitor CPR quality in real time and adjust chest compression quality accordingly.[2,3] During CPR, end-tidal carbon dioxide ($EtCO_2$) is primarily determined by pulmonary blood flow, thereby reflecting the blood flow generated by CPR.[4,5]

The 2020 International Liaison Committee on Resuscitation (ILCOR) consensus[6,7] recommended that $EtCO_2$ ≥20 millimeters of mercury (mm Hg) measured after 20 minutes (min) of CPR may predict survival to discharge. Nonetheless, this weak recommendation was supported by only moderate-quality evidence. A 2018 ILCOR systematic review noticed that the measurement time points of $EtCO_2$ were very heterogeneous across different studies.[8] Accordingly, ILCOR[6,7] suggested that instead of single $EtCO_2$ values, the $EtCO_2$ trend should be further explored in future studies for its prognostic performance.

The previous study noted that $EtCO_2$ trajectory during CPR was associated with OHCA outcomes.[9] However, the predictive ability of $EtCO_2$ trajectory at a specific timing was not explored in the previous study.[9] Whether $EtCO_2$ can be combined with other metrics for intra-arrest prognostication was considered a critical knowledge gap by the 2020 American Heart Association (AHA) guidelines.[2] In our recent study,[10] we incorporated the minimum $EtCO_2$ value into the return of spontaneous circulation after cardiac arrest (RACA) score and improved the performance of RACA score in predicting ROSC, suggesting that $EtCO_2$ could potentially help intra-arrest prognostication.

In the current study, we further developed models that could predict survival at hospital discharge. Instead of a single $EtCO_2$ value,[10] we attempted to combine $EtCO_2$ trajectory and other predictors in deriving prediction models. Moreover, these models were developed using time-specific windows to prognosticate patient outcomes during resuscitation, including 10- and 20 min[6,7] after initiation of CPR.

Population Health Research Capsule

What do we already know about this issue?
The end-tidal carbon dioxide ($EtCO_2$) level during cardiopulmonary resuscitation (CPR) is associated with outcomes following out-of-hospital cardiac arrest (OHCA).

What was the research question?
Could $EtCO_2$ trajectories during CPR be combined with baseline variables to predict outcomes of OHCA?

What was the major finding of the study?
The area under the curve of the $EtCO_2$-based model for survival was 0.89 (95% confidence interval 0.86–0.92).

How does this improve population health?
An $EtCO_2$ trajectory-based prediction model may help emergency medical services to predict OHCA outcomes and facilitate allocation of medical resources.

MATERIALS AND METHODS

This observational study was a secondary analysis of a prospectively collected OHCA database registered in the emergency department (ED) of National Taiwan University Hospital (NTUH). The institutional review board approved this study (reference number: 201906082RINB) and waived the requirement for informed consent. The study was performed according to the recommendations from Worster et al[11] regarding health record review studies in emergency medicine research with all elements followed. The results are reported according to the transparent reporting of a multivariable prediction model for individual prognosis or diagnosis (TRIPOD) statement.[12]

Study Setting

The NTUH is a tertiary-care medical center with 2,600 beds, including 220 beds in intensive care units. Approximately 100,000 patients visit NTUH ED annually. Patients with OHCA are transported directly to the resuscitation bay of the critical care area in the ED for CPR, which is delivered according to resuscitation guidelines.[2,3] Also, since 2013 ED staff have been trained with the A-C-L-S (airway-circulation-leadership-support) teamwork model[9,13,14] to streamline the resuscitation process via both strengthened technical and non-technical skills.[15,16] Any intervention, such as tracheal intubation performed during CPR, are timestamped by nurses with a specially designed mobile application. The $EtCO_2$ is recorded every two min right before pulse check. The $EtCO_2$ is monitored with devices attached to the advanced airways, including supraglottic airways and endotracheal tubes. For patients with OHCA who never achieve return of spontaneous circulation (ROSC), CPR is usually performed for at least 30 min in the ED, except for those with a documented do-not-resuscitate (DNR) order.

Study Population

Patients with OHCA sent to the NTUH ED between January 1, 2015–December 31, 2021 were screened. The inclusion criteria for the study were as follows: 1) non-traumatic arrest; 2) absence of ROSC before ED arrival; (3) absence of documented DNR order before CPR; 4) age ≥18 years; and 5) insertion of advanced airways during CPR. Based on the CPR duration, the included patients would be further selected for primary and secondary analyses. If the included patients received CPR ≥20 min and had $EtCO_2$ measurements ≥3 times within 20 min of CPR, they would be selected into the 20-min group for the primary analysis. Similarly, if the included patients received CPR ≥10 min and had $EtCO_2$ measurements ≥3 times within 10 min of CPR, they would be selected into the 10-min group for secondary analysis.

Data Collection, Variable Definitions, and Outcome Measures

In the NTUH database, OHCA events were recorded based on the Utstein template.[17] Data requested for analysis included age, gender, variables derived from the Utstein template, advanced airway insertion timing, $EtCO_2$ values with measurement timing, and outcomes. For ED resuscitation, the time point of the initial chest compression delivered in the ED was set as time zero for reference. Time to advanced airway use was defined as the interval between time zero and time for completing advanced airway insertion. If advanced airway devices were inserted before ED arrival, the time to advanced airway was recorded as zero. Duration of CPR in the ED referred to the time interval between time zero and the end of resuscitation, either due to ROSC or death. Time-specific $EtCO_2$ referred to the $EtCO_2$ level measured after the specific time elapsing following time zero.

The primary outcome was survival status at the time of hospital discharge. The secondary outcome was ROSC, defined as a palpable pulse for 20 seconds.[18] Data abstraction for the current analysis was performed by trained researchers who were blinded to the study hypothesis.

Statistical Analysis

In the primary analysis, we used the 20-min group to build models for predicting survival (20-min survival model) and ROSC (20-min ROSC model). In the secondary analysis, similar procedures were applied to develop the 10-min survival model and 10-min ROSC model. We first performed group-based trajectory modeling (GBTM) to identify trajectory groups based on the $EtCO_2$ level. The GBTM is an explanatory modeling technique to identify hidden groups of individuals with similar trajectories for a particular variable of interest.[19] The GBTM performs better when longitudinal data is measured at least three times.

For descriptive statistics, categorical variables are presented as proportions, and continuous variables are presented as medians with interquartile ranges. We examined categorical variables using the chi-squared test, whereas continuous variables were compared using the Kruskal-Wallis test or Mann-Whitney test, as appropriate. We used

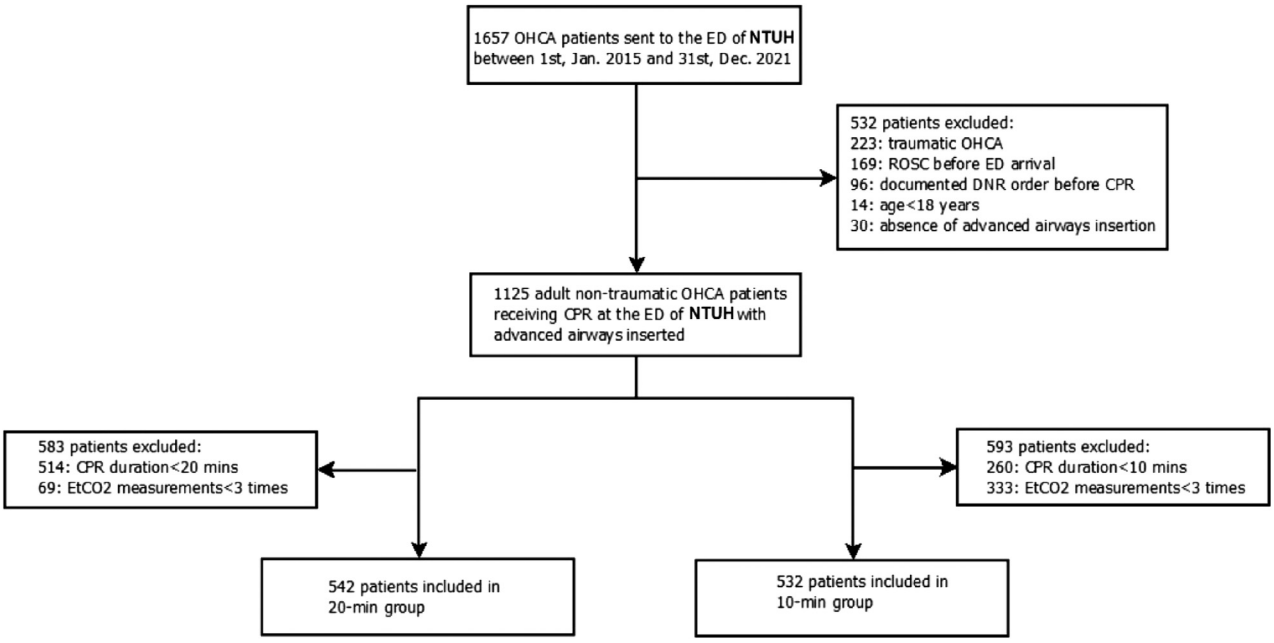

Figure 1. Patient inclusion flowchart.
CPR, cardiopulmonary resuscitation; *DNR*, do-not-resuscitate; *ED*, emergency department; *NTUH*, National Taiwan University Hospital; *OHCA*, out-of-hospital cardiac arrest; *ROSC*, return of spontaneous circulation.

multivariable logistic regression analyses to develop the prediction models. All available variables, including basic demographics, peri-CPR events, and $EtCO_2$ trajectory were accounted for in the regression model via a stepwise, variable selection procedure. The $EtCO_2$ trajectory would be tested as ordinal or categorical variables in the model-building process. We used generalized additive models (GAM)[20] to identify the appropriate cutoff point(s) for dichotomization. The discriminative performance and calibration of the prediction model were assessed by area under the receiver operating characteristic curve (AUC) and the Hosmer-Lemeshow goodness-of-fit test, respectively. We internally validated the prediction model using the bootstrapping procedure with 1,000 repetitions to examine the robustness of the effect estimate of each variable in the prediction model.

We performed GBTM and bootstrapping using the traj package and bootstrap procedure of Stata software (StataCorp LLC, College Station, TX), respectively. We used the R 4.1.1 software (R Foundation for Statistical Computing, Vienna, Austria) for other analyses. A two-tailed *P*-value <0.05 was considered statistically significant.

RESULTS

The patient selection procedure resulted in 542 and 532 patients in the 20-min and 10-min groups, respectively (Figure 1). The two groups were not mutually exclusive. Because not all patients in the 20-min group had $EtCO_2$ measurements ≥3 times within 10 mins, the 20-min group patients may not have been necessarily included in the 10-min group. Also, because some of the patients in the 10-min group would achieve ROSC within 20 min of CPR, the 10-min group patients would not necessarily have been included in the 20-min group. Therefore, there was an overlap of 385 patients between the 20-min and 10-min groups who met the selection criteria for both groups.

In the primary analysis, we identified and named three $EtCO_2$ trajectories as low, intermediate, and high trajectories according to their respective average $EtCO_2$ levels (Figure 2). The characteristics of the 20-min group and comparisons between these $EtCO_2$ trajectories are presented in Table 1. The median CPR duration in the ED was 31.0 minutes, and the median number of $EtCO_2$ measurements was eight. A total of 25 (4.6%) patients survived at hospital discharge. There seems to be an increasing trend of survival from low to high $EtCO_2$ trajectory. The comparisons between patients stratified by survival are shown in Supplemental Table 1. During the model development, the 20-min $EtCO_2$ trajectory was fitted as an ordinal variable by the logistic regression analysis and positively associated with survival (odds ratio [OR] 2.25, 95% confidence interval [CI] 1.07–4.74) and ROSC (OR 2.46, 95% CI 1.78–3.41) (Table 2). In other words, compared with the low $EtCO_2$ trajectory, the intermediate trajectory had 2.25 times higher odds of survival to hospital discharge. Similarly, compared with the intermediate trajectory, the high $EtCO_2$ trajectory also had 2.25 times higher odds of survival. When the 20-min $EtCO_2$ trajectory was combined with other variables, the AUCs of the 20-min survival and ROSC models were 0.89 (95% CI 0.86–0.92) and 0.78 (95% CI 0.74–0.81), respectively.

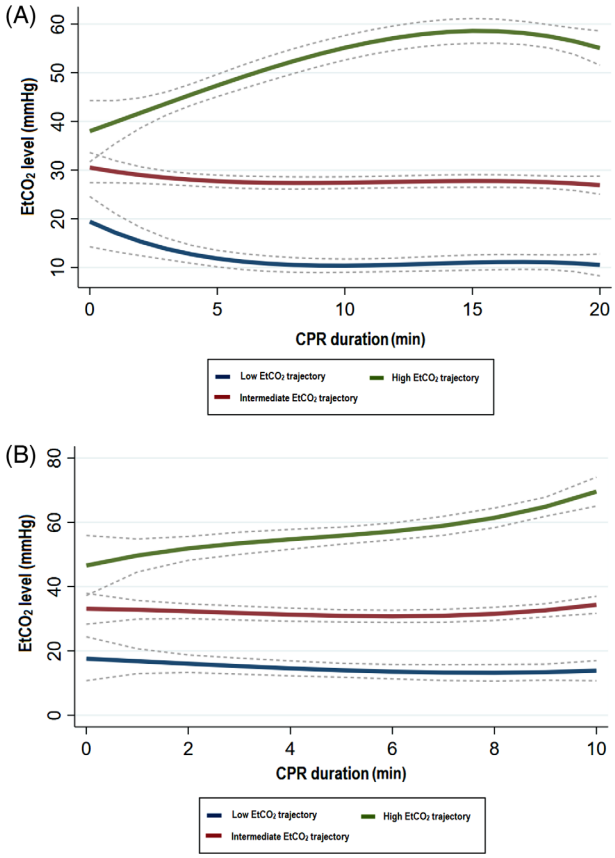

Figure 2. The end-tidal carbon dioxide trajectory. The $EtCO_2$ trajectory groups identified by group-based trajectory modeling in the (A) primary (20 minute) and (B) secondary (10 minute) analysis. Dotted lines indicate 95% confidence intervals.
CPR, cardiopulmonary resuscitation; *EtCO₂*, end-tidal carbon dioxide.

Similarly, in the secondary analysis we identified three $EtCO_2$ trajectories (Figure 2 and Table 3). The median CPR duration in the ED was 30.0 min, and the median number of $EtCO_2$ measurements was four. A total of 34 (6.4%) patients survived at hospital discharge. Significant survival differences were noted among the three $EtCO_2$ trajectories; nonetheless, the survival of intermediate and high $EtCO_2$ trajectories was similar. The survival-stratified comparisons are shown in Supplemental Table 2. During the model-fitting process, the 10-min $EtCO_2$ trajectory was fitted as a categorical variable. As shown in Table 4, compared with the 10-min low $EtCO_2$ trajectory, the 10-min intermediate or high $EtCO_2$ trajectory was significantly associated with

Table 1. Characteristics of patients included in the twenty-minute group stratified by end-tidal carbon dioxide trajectory group.

Variables	Twenty-min group (n = 542)	Twenty-min low $EtCO_2$ trajectory (n = 196)	Twenty-min intermediate $EtCO_2$ trajectory (n = 280)	Twenty-min high $EtCO_2$ trajectory (n = 66)	*P* value
Basic demographics					
Age, year	68.0 (57.0–80.0)	70.0 (58.0–80.0)	67.0 (56.0–81.0)	66.0 (56.0–76.0)	0.45
Male, n	354 (65.3)	111 (56.6)	199 (71.1)	44 (66.7)	0.005
Peri-CPR events					
Transported by EMS, n	507 (93.5)	179 (91.3)	263 (93.9)	65 (98.5)	0.11
Arrest at home, n	296 (54.6)	113 (57.6)	149 (53.2)	34 (51.5)	0.55
Witness by bystander, n	193 (35.6)	56 (28.5)	112 (40.0)	25 (37.9)	0.03
Witness by EMS, n	28 (5.2)	11 (5.6)	12 (4.3)	5 (7.6)	0.52
Witness by bystander or EMS, n	212 (39.1)	61 (31.1)	121 (43.2)	30 (45.4)	0.02
Bystander CPR, n	269 (49.6)	93 (47.4)	140 (50.0)	36 (54.5)	0.60
Prehospital defibrillation by EMS, n	117 (21.5)	17 (8.6)	82 (29.2)	18 (27.2)	<0.001
Initial shockable rhythms at ED arrival, n	37 (6.8)	8 (4.1)	25 (8.9)	4 (6.1)	0.43
Duration of prehospital CPR performed by EMS, min	17.0 (12.0–21.0)	17.0 (10.5–21.0)	17.0 (12.0–21.0)	18.0 (12.0–22.0)	0.30
Procedures during CPR					
SGA use, n	376 (69.4)	134 (68.4)	196 (70.0)	46 (69.7)	0.93
Time to SGA use, min	0 (0–0) (n = 376)	0 (0–0) (n = 134)	0 (0–0) (n = 196)	0 (0–0) (n = 46)	0.12
ETT use, n	531 (98.0)	189 (96.4)	277 (98.9)	65 (98.5)	0.12
Time to ETT use, min	3.0 (2.0–5.0) (n = 531)	3.0 (2.0–6.0) (n = 189)	3.0 (2.0–5.0) (n = 277)	3.0 (1.5–4.0) (n = 65)	0.30
Time-specific $EtCO_2$ levels, mmHg					
0-min $EtCO_2$	29.0 (20.3–36.0) (n = 39)	15.0 (12.5–20.5) (n = 8)	32.0 (25.3–36.0) (n = 27)	32.0 (25.0–50.5) (n = 4)	0.003
1-min $EtCO_2$	24.5 (15.0–38.5) (n = 56)	14.5 (10.5–19.0) (n = 20)	28.0 (22.0–38.3) (n = 25)	36.3 (24.0–68.3) (n = 11)	<0.001
2-min $EtCO_2$	24.0 (5.8–33.0) (n = 113)	14.0 (9.0–23.3) (n = 37)	27.5 (20.0–33.0) (n = 62)	41.0 (24.0–54.0) (n = 14)	<0.001
3-min $EtCO_2$	22.0 (13.5–36.0) (n = 120)	11.5 (6.0–20.0) (n = 46)	30.0 (21.0–39.5) (n = 60)	36.5 (23.0–43.0) (n = 14)	<0.001
4-min $EtCO_2$	22.0 (12.0–33.0) (n = 231)	11.5 (7.0–18.0) (n = 78)	24.0 (18.0–34.8) (n = 123)	44.0 (30.0–52.0) (n = 30)	<0.001
5-min $EtCO_2$	22.0 (12.0–33.0) (n = 121)	10.0 (3.0–14.8) (n = 43)	27.0 (21.0–35.0) (n = 62)	41.0 (30.5–60.0) (n = 16)	<0.001
6-min $EtCO_2$	21.0 (12.0–31.0) (n = 245)	8.0 (3.0–12.0) (n = 75)	24.0 (18.0–31.0) (n = 141)	47.0 (37.8–60.8) (n = 29)	<0.001
7-min $EtCO_2$	18.5 (10.0–32.0) (n = 142)	9.0 (4.0–13.5) (n = 61)	27.0 (18.0–34.0) (n = 62)	44.0 (30.0–62.3) (n = 19)	<0.001
8-min $EtCO_2$	22.0 (11.0–34.0) (n = 282)	9.0 (3.0–12.0) (n = 94)	27.0 (19.0–35.3) (n = 157)	56.0 (45.0–60.8) (n = 31)	<0.001
9-min $EtCO_2$	20.0 (10.0–34.0) (n = 147)	8.5 (3.0–12.0) (n = 58)	27.0 (19.0–36.0) (n = 70)	58.0 (45.0–72.8) (n = 19)	<0.001

(*Continued on next page*)

Table 1. Continued.

Variables	Twenty-min group (n = 542)	Twenty-min low $EtCO_2$ trajectory (n = 196)	Twenty-min intermediate $EtCO_2$ trajectory (n = 280)	Twenty-min high $EtCO_2$ trajectory (n = 66)	*P* value
10-min $EtCO_2$	21.0 (12.0–33.0) (n = 296)	9.0 (3.3–13.0) (n = 103)	27.0 (20.0–34.8) (n = 163)	52.5 (48.0–68.0) (n = 30)	<0.001
11-min $EtCO_2$	21.0 (11.0–36.5) (n = 144)	11.0 (5.0–15.0) (n = 58)	28.0 (21.0–36.0) (n = 63)	60.0 (45.0–65.8) (n = 23)	<0.001
12-min $EtCO_2$	21.0 (12.0–31.8) (n = 331)	10.0 (5.0–14.0) (n = 122)	26.0 (21.0–33.0) (n = 176)	58.0 (43.8–71.3) (n = 33)	<0.001
13-min $EtCO_2$	21.0 (12.0–33.8) (n = 123)	9.5 (7.5–13.5) (n = 48)	26.0 (20.8–33.0) (n = 57)	51.5 (44.0–65.0) (n = 18)	<0.001
14-min $EtCO_2$	21.0 (12.0–33.0) (n = 324)	10.0 (5.0–15.0) (n = 117)	26.0 (21.0–34.0) (n = 173)	53.0 (45.0–69.0) (n = 34)	<0.001
15-min $EtCO_2$	21.0 (11.0–32.0) (n = 143)	9.5 (4.0–14.0) (n = 58)	27.0 (21.0–35.0) (n = 65)	50.0 (43.0–58.5) (n = 20)	<0.001
16-min $EtCO_2$	22.0 (12.0–33.0) (n = 329)	9.0 (6.0–14.0) (n = 114)	26.5 (21.0–33.0) (n = 180)	59.0 (47.3–68.8) (n = 35)	<0.001
17-min $EtCO_{2wp}$	21.0 (12.0–36.0) (n = 139)	9.0 (5.0–13.5) (n = 52)	27.0 (21.0–33.8) (n = 63)	56.0 (45.5–66.5) (n = 24)	<0.001
18-min $EtCO_2$	21.0 (10.8–32.0) (n = 333)	9.0 (3.0–14.0) (n = 125)	26.0 (20.0–33.0) (n = 173)	55.0 (43.0–69.0) (n = 35)	<0.001
19-min $EtCO_2$	21.0 (10.0–34.0) (n = 137)	8.5 (3.0–13.0) (n = 50)	23.0 (20.0–34.0) (n = 68)	50.0 (44.3–62.0) (n = 19)	<0.001
20-min $EtCO_2$	21.0 (11.0–33.3) (n = 329)	9.0 (4.5–14.0) (n = 123)	26.0 (20.0–34.0) (n = 171)	56.0 (50.0–64.5) (n = 35)	<0.001
Available measurements of $EtCO_2$ levels, times	8.0 (6.0–9.0)	8.0 (7.0–9.0)	8.0 (6.0–9.0)	8.0 (7.0–9.0)	0.64
$EtCO_2$ summary parameters, mm Hg					
Initial	23.0 (14.0–36.0)	14.0 (7.0–20.5)	29.0 (20.0–41.0)	41.5 (28.0–61.0)	<0.001
Maximum	36.0 (22.0–50.0)	18.0 (12.0–24.0)	41.0 (34.0–49.0)	69.0 (63.0–79.0)	<0.001
Minimum	13.0 (5.0–21.0)	3.5 (2.0–9.0)	16.0 (12.0–22.0)	30.0 (23.0–41.0)	<0.001
Final	21.0 (11.0–35.0)	9.0 (4.0–14.0)	26.0 (20.0–34.5)	56.0 (46.0–65.0)	<0.001
Average	23.0 (14.0–33.0)	10.0 (6.5–14.0)	26.5 (22.0–33.0)	51.5 (37.0–58.0)	<0.001
Duration of CPR performed in ED, min	31.0 (30.0–35.0)	31.0 (30.0–34.0)	31.0 (30.0–36.0)	31.0 (30.0–33.0)	0.50
Outcome, n					
ROSC	184 (33.9)	32 (16.3)	118 (42.1)	34 (51.5)	<0.001
Survival to hospital discharge	25 (4.6)	3 (1.5)	16 (5.7)	6 (9.1)	0.02

Data are presented as median (interquartile range) or counts (proportion).
CPR, cardiopulmonary resuscitation; *ED*, emergency department; *EMS*, emergency medical services; *mm Hg*, millimeters of mercury; *ETT*, endotracheal tube; *ROSC*, return of spontaneous circulation; *SGA*, supraglottic airway; min, minute.

survival (OR 2.53, 95% CI 1.10–5.81). In addition, compared with the 10-min low $EtCO_2$ trajectory, 10-min intermediate (OR 3.36, 95% CI 2.25–5.04) and high (OR 6.59, 95% CI 3.42–12.69) $EtCO_2$ trajectories were significantly associated with ROSC, respectively. When the 10-min $EtCO_2$ trajectory was combined with other variables, the AUC of the 10-min survival and ROSC models were 0.76 (95% CI 0.72–0.79) and 0.75 (95% CI 0.71–0.79), respectively.

For the 20- and 10-min models, all the predictors remained significantly associated with outcomes after the bootstrapping procedure, indicating the robustness of these models (Supplemental Table 3).

Table 2. Multivariable logistic regression analysis for twenty-minute group to build end-tidal carbon dioxide trajectory-based prediction models.

Variables	Odds ratio (95% confidence interval)	*P* value
Twenty-min survival model		
Twenty-min $EtCO_2$ trajectory	2.25 (1.07–4.74)	0.03
Arrest at home	0.28 (0.10–0.77)	0.01
Prehospital defibrillation by EMS	3.42 (1.34–8.77)	0.01
Initial shockable rhythms at ED arrival	8.36 (3.13–22.31)	<0.001
Twenty-min ROSC model		
Twenty-min $EtCO_2$ trajectory	2.46 (1.78–3.41)	<0.001
Arrest at home	0.54 (0.34–0.85)	0.008
Witness by bystander or EMS	1.72 (1.13–2.63)	0.01
Prehospital defibrillation by EMS	2.72 (1.64–4.53)	<0.001
Initial shockable rhythms at ED arrival	4.97 (2.07–11.90)	<0.001
Duration of prehospital CPR performed by EMS	0.96 (0.93–0.99)	0.003

Twenty-min survival model: goodness-of-fit assessment: n = 542, adjusted generalized $R^2 = 0.32$, estimated area under the receiver operating characteristic curve = 0.89 (95% confidence interval: 0.86–0.92), and Hosmer and Lemeshow goodness-of-fit Chi-Squared test $p = 0.64$; Twenty-min ROSC model: goodness-of-fit assessment: n = 542, adjusted generalized $R^2 = 0.30$, estimated area under the receiver operating characteristic curve = 0.78 (95% confidence interval: 0.74–0.81), and Hosmer and Lemeshow goodness-of-fit Chi-Squared test $p = 0.19$.
CPR, cardiopulmonary resuscitation; *ED*, emergency department; *EMS*, emergency medical services; *ROSC*, return of spontaneous circulation; *min*, minute.

DISCUSSION

Main Findings

By using a prospectively collected database, we identified that the time-specific $EtCO_2$ trajectory was a significant intra-arrest outcome predictor. Time-specific $EtCO_2$ trajectory could be combined with other predictors to assist in intra-arrest prognostication at different time points during CPR. Among all the prediction models, the 20-min $EtCO_2$ trajectory-based survival model achieved the highest discriminative performance (AUC 0.89).

Comparison with Previous Studies

For outcome prediction in OHCA, most models were developed for patients who had already achieved ROSC.[21] There were few, if any, models available for patients who were still undergoing CPR. For predicting ROSC before CPR was performed, the RACA score[18] was one of the most well-validated models, demonstrating AUC ranging from 0.71 to 0.76.[22–24] All the predictors included in the RACA score were baseline variables, such as arrest location and arrest rhythms, which did not consider the treatment effects of CPR. Nonetheless, it was possible that even though the RACA score-predicted ROSC probabilities were similar, the actual outcomes may differ because of different CPR qualities and durations delivered by rescuers. To make individualized intra-arrest prognostication, variables specific to the patient and resuscitation process, such as $EtCO_2$, may be necessary,.

The 2018 ILCOR systematic review[8] indicated that $EtCO_2$ was associated with ROSC probability. Nonetheless, the optimal parameter of $EtCO_2$ for prognostication is still debated.[8] For example, despite its convenience in statistical analysis, average $EtCO_2$ could not differentiate between different $EtCO_2$ trajectories. Ascending and descending $EtCO_2$ trajectories may have similar average $EtCO_2$, but their prognoses may be very different.[25,26] Moreover, the term "initial" $EtCO_2$ may not accurately reflect the $EtCO_2$ level during the early phase of CPR, as the endotracheal tube could potentially be introduced later during the resuscitation. It was reported that the specificity of $EtCO_2$ in predicting ROSC would increase progressively from 50% at 0 min to 60%, 98%, and 100% at 10, 15, and 20 min, respectively.[27] Therefore, for $EtCO_2$ to be a valid predictor, the timing of prognostication should be specified, and its trend during CPR, instead of a single value, should be adopted.

Interpretation of Current Analysis

The 2020 ILCOR consensus[6,7] recommends that $EtCO_2$ measured after 20 min of CPR may be a predictor of survival to discharge. Rosman et al[28] indicated that when higher $EtCO_2$ levels were reached beyond 20 min of CPR they may not lead to ROSC. Progressively worsening ischemia may cause refractoriness to CPR during the metabolic phase of cardiac arrest,[29] and $EtCO_2$ trajectories beyond 20 min may not be prognostic of outcomes. Therefore, CPR for 20 min was used to select the 20-min cohort and identify the 20-min $EtCO_2$ trajectory. The advantage of employing GBTM was that it offered an efficient method to unravel the hidden trajectories that may not be readily recognizable from the

Table 3. Characteristics of patients included in the ten-min group stratified by end-tidal carbon dioxide trajectory group.

Variables	Ten-min group (n = 532)	Ten-min low $EtCO_2$ trajectory (n = 234)	Ten-min intermediate $EtCO_2$ trajectory (n = 240)	Ten-min high $EtCO_2$ trajectory (n = 58)	*P* value
Basic demographics					
Age, year	71.0 (59.5–82.0)	73.0 (60.0–84.0)	70.0 (60.0–81.0)	70.5 (56.0–79.0)	0.22
Male, n	346 (65.0)	143 (61.1)	167 (69.6)	36 (62.1)	0.14
Peri-CPR events					
Transported by EMS, n	500 (94.0)	215 (91.9)	227 (94.6)	58 (100)	0.11
Arrest at home, n	308 (57.9)	144 (61.5)	134 (55.8)	34 (51.7)	0.27
Witness by bystander, n	192 (36.1)	78 (33.3)	89 (37.1)	25 (43.1)	0.35
Witness by EMS, n	26 (4.9)	7 (3.0)	16 (6.7)	3 (5.2)	0.18
Witness by bystander or EMS, n	207 (38.9)	79 (33.8)	101 (42.1)	27 (46.6)	0.08
Bystander CPR, n	276 (51.9)	115 (49.1)	126 (52.5)	35 (60.3)	0.30
Prehospital defibrillation by EMS, n	101 (19.0)	24 (10.2)	60 (25.0)	17 (29.3)	<0.001
Initial shockable rhythms at ED arrival, n	30 (5.6)	11 (4.7)	16 (6.7)	3 (5.2)	0.64
Duration of prehospital CPR performed by EMS, min	17.0 (12.0–21.0)	18.0 (11.0–21.0)	17.0 (12.0–21.0)	18.0 (14.0–22.0)	0.44
Procedures during CPR					
SGA use, n	380 (71.4)	166 (70.9)	172 (71.7)	42 (72.4)	0.97
Time to SGA use, min	0 (0–0) (n = 380)	0 (0–0) (n = 166)	0 (0–0) (n = 172)	0 (0–0) (n = 42)	0.24
ETT use, n	508 (95.5)	219 (93.6)	234 (97.5)	55 (94.8)	0.12
Time to ETT use, min	3.0 (2.0–4.0) (n = 508)	3.0 (2.0–4.0) (n = 219)	3.0 (2.0–4.0) (n = 234)	3.0 (1.3–4.0) (n = 55)	0.48
Time-specific $EtCO_2$ levels, mm Hg					
0-min $EtCO_2$	26.0 (18.0–36.0) (n = 48)	18.0 (14.5–20.5) (n = 16)	31.0 (25.3–38.3) (n = 27)	55.0 (28.5–60.8) (n = 5)	<0.001
1-min $EtCO_2$	24.0 (12.0–38.3) (n = 73)	12.0 (7.0–17.0) (n = 30)	32.5 (22.0–41.0) (n = 34)	56.0 (40.5–69.3) (n = 9)	<0.001
2-min $EtCO_2$	25.5 (17.0–37.5) (n = 148)	17.0 (11.0–23.0) (n = 62)	32.5 (23.0–42.0) (n = 70)	54.5 (45.0–61.5) (n = 16)	<0.001
3-min $EtCO_2$	24.0 (14.0–36.0) (n = 158)	13.5 (9.0–21.0) (n = 70)	34.0 (25.3–43.8) (n = 71)	48.0 (22.8–54.0) (n = 17)	<0.001
4-min $EtCO_2$	23.0 (13.3–35.8) (n = 299)	13.0 (9.0–19.8) (n = 131)	30.0 (22.0–38.0) (n = 132)	51.0 (45.5–62.5) (n = 36)	<0.001
5-min $EtCO_2$	23.0 (12.0–34.0) (n = 153)	12.0 (3.5–17.0) (n = 63)	29.0 (23.0–36.0) (n = 74)	60.0 (42.0–66.5) (n = 16)	<0.001
6-min $EtCO_2$	22.0 (13.0–34.0) (n = 326)	12.0 (7.0–18.0) (n = 142)	28.0 (21.3–38.0) (n = 147)	56.0 (42.8–63.3) (n = 37)	<0.001
7-min $EtCO_2$	23.0 (10.0–36.0) (n = 154)	10.0 (5.5–15.5) (n = 68)	30.0 (24.8–37.0) (n = 69)	55.0 (45.8–64.8) (n = 17)	<0.001
8-min $EtCO_2$	25.0 (13.0–38.0) (n = 343)	12.0 (7.8–17.3) (n = 149)	33.0 (26.0–40.0) (n = 159)	62.0 (56.3–72.5) (n = 35)	<0.001
9-min $EtCO_2$	23.0 (11.0–37.0) (n = 142)	10.0 (4.0–15.8) (n = 63)	30.0 (23.0–37.0) (n = 60)	62.0 (54.5–78.0) (n = 19)	<0.001
10-min $EtCO_2$	23.0 (14.0–39.8) (n = 339)	13.0 (6.0–18.0) (n = 150)	32.0 (24.0–43.0) (n = 154)	68.0 (58.0–79.5) (n = 35)	<0.001

(*Continued on next page*)

Table 3. Continued.

Variables	Ten-min group (n = 532)	Ten-min low $EtCO_2$ trajectory (n = 234)	Ten-min intermediate $EtCO_2$ trajectory (n = 240)	Ten-min high $EtCO_2$ trajectory (n = 58)	*P* value
Available measurements of $EtCO_2$ levels, times	4.0 (3.0–5.0)	4.0 (3.0–5.0)	4.0 (3.0–5.0)	4.0 (4.0–5.0)	0.41
$EtCO_2$ summary parameters, mm Hg					
Initial	25.0 (15.0–40.0)	15.0 (10.0–22.0)	34.0 (25.0–43.5)	55.5 (45.0–65.0)	<0.001
Maximum	34.0 (22.0–50.0)	20.0 (13.0–26.0)	44.0 (36.0–51.0)	71.5 (63.0–89.0)	<0.001
Minimum	16.0 (9.0–24.5)	8.0 (3.0–12.0)	21.5 (17.0–27.0)	41.5 (33.0–54.0)	<0.001
Final	23.0 (13.0–39.0)	12.0 (6.0–18.0)	33.0 (24.0–42.5)	64.0 (57.0–78.0)	<0.001
Average	25.0 (15.0–36.0)	13.0 (8.0–19.0)	32.0 (26.0–37.0)	58.0 (51.0–64.0)	<0.001
Duration of CPR performed in ED, min	30.0 (18.0–32.0)	30.0 (22.0–32.0)	30.0 (17.0–33.0)	20.0 (13.0–31.0)	0.008
Outcome, n					
ROSC	239 (44.9)	64 (27.4)	135 (56.3)	40 (69.0)	<0.001
Survival to hospital discharge	34 (6.4)	8 (3.4)	21 (8.8)	5 (8.6)	0.05

Data are presented as median (interquartile range) or counts (proportion).
CPR, cardiopulmonary resuscitation; *ED*, emergency department; *EMS*, emergency medical service; *mm HG*, millimeters of mercury; *ETT*, endotracheal tube; *ROSC*, return of spontaneous circulation; *SGA*, supraglottic airway.

Table 4. Multivariable logistic regression analysis for ten-minute group to build end-tidal carbon dioxide trajectory-based prediction models.

Variables	Odds ratio (95% confidence interval)	*P* value
Ten-min survival model		
Ten-min intermediate or high $EtCO_2$ trajectory	2.53 (1.10–5.81)	0.03
Witness by bystander	3.00 (1.42–6.33)	0.004
Initial shockable rhythms at ED arrival	5.21 (2.03–13.33)	<0.001
Ten-min ROSC model		
Ten-min intermediate $EtCO_2$ trajectory	3.36 (2.25–5.04)	<0.001
Ten-min high $EtCO_2$ trajectory	6.59 (3.42–12.69)	<0.001
Age between 37 and 69 (year)	1.49 (1.02–2.20)	0.04
Witness by bystander or EMS	1.92 (1.31–2.84)	0.001
Initial shockable rhythms at ED arrival	5.29 (2.04–13.71)	<0.001
Duration of prehospital CPR performed by EMS (min)	0.96 (0.93–0.98)	<0.001

Ten-min survival model: goodness-of-fit assessment: n = 532, adjusted generalized $R^2 = 0.14$, estimated area under the receiver operating characteristic curve = 0.76 (95% confidence interval: 0.72–0.79), and Hosmer and Lemeshow goodness-of-fit chi-squared test $P = 0.79$; ten-min ROSC model: goodness-of-fit assessment: n = 532, adjusted generalized $R^2 = 0.25$, estimated area under the receiver operating characteristic curve = 0.75 (95% confidence interval: 0.71–0.79), and Hosmer and Lemeshow goodness-of-fit chi-squared test $P = 0.65$.
CPR, cardiopulmonary resuscitation; *ED*, emergency department; *EMS*, emergency medical service; *ROSC*, return of spontaneous circulation.

baseline characteristics or initial $EtCO_2$ values. The significantly different $EtCO_2$ levels among $EtCO_2$ trajectories indicated the success of GBTM in distinguishing these hidden clusters (Table 1). Also, in an unbiased manner, GBTM identifies the hidden $EtCO_2$ trajectories only by examining the repeatedly measured $EtCO_2$ without considering baseline variables or outcomes. Whether the identified trajectories were associated with outcomes should be further investigated. For example, compared with patients with low 20-min $EtCO_2$ trajectory, those with intermediate or high 20-min $EtCO_2$ trajectory had higher proportions of bystander-witnessed arrest (Table 1), which may also explain better outcomes in the latter.

In the 20-min survival model, the multivariable logistical regression analysis indicated that the 20-min $EtCO_2$ trajectory was positively associated with survival, demonstrating the trend

of a higher $EtCO_2$ trajectory with increased survival. Studies revealed that for every 10 mm increase in chest compression depth, $EtCO_2$ would increase by 1.4 mm Hg[30] or 4.0%.[31] Higher $EtCO_2$ trajectory may suggest better CPR quality, which may explain the positive association between $EtCO_2$ trajectory and chances of survival. In contrast, arrest etiology may also be a confounding factor in explaining the associations between favorable outcomes and intermediate or high $EtCO_2$ trajectory. Studies have shown that patients with asphyxial arrest[32] or suspected respiratory etiology[33] may have higher $EtCO_2$ levels than those with initial shockable rhythms [32] or suspected cardiac etiology,[33] respectively. Nonetheless, in our cohort, patients of intermediate or high $EtCO_2$ trajectory had higher proportions of prehospital defibrillation by emergency medical services (EMS) (Table 1). Therefore, instead of the arrest etiology, the CPR quality may account for the positive association between 20-min $EtCO_2$ trajectory and survival.

Whether $EtCO_2$, along with other factors, can be used for intra-arrest prognostication was listed by AHA guidelines[2] as an important knowledge gap. In the 20-min survival model, besides $EtCO_2$ trajectory, other baseline variables, including arrest at home, prehospital defibrillation by EMS, and initial shockable rhythms on ED arrival, were also selected as significant predictors. These baseline variables had been well-validated for their predictive performance in previous studies.[18] The 20-min survival model achieved excellent discriminative performance and may first answer the question presented by the AHA.[2] Moreover, we further tested whether the 20-min $EtCO_2$ trajectory could facilitate predicting ROSC. However, the AUC of the 20-min ROSC model was 0.78, lower than that of the 20-min survival model. In our study, ROSC was defined as a palpable pulse for 20 seconds, as used by RACA score.[18] The swift nature of this secondary outcome may render it difficult to be predicted, even though the 20-min ROSC model included more variables than the 20-min survival model.

Finally, we developed the 10-min prediction models to explore whether outcomes could be predicted at an earlier time point during CPR. Nevertheless, the AUCs of both 10-min models were respectively lower than their counterparts of 20-min models. As shown in Figure 2, the 10-min $EtCO_2$ trajectory was slightly different from the 20-min $EtCO_2$ trajectory in the trend pattern. For example, the high $EtCO_2$ trajectory continued to rise within 10 min; it was only evident later in the 20-min window that the trajectory had plateaued. Taken together, these time-specific models varied over time in terms of trajectory shapes and model performance. Earlier trajectories may still be evolving with moderate model performance, while late trajectories may have improved model performance at the cost of more medical recourses consumed. Our data suggested that 20 min after CPR may be the earliest point in time with excellent model performance to predict distant, clinically important outcomes, such as survival to hospital discharge.

Future Applications

For OHCA patients transported to the ED for continuous CPR, emergency clinicians are faced with the problem of balancing the probability of a favorable outcome with the utilization of current and future resources when making important decisions, such as termination of resuscitation or implementation of invasive extracorporeal CPR.[34] Most of these advanced interventions are reserved for patients receiving CPR within a certain duration.[34] Despite the fact that CPR duration is known to be inversely associated with favorable outcomes,[35] it may not be the sole prognostic factor. Quality CPR may facilitate maintaining patients' potential for favorable outcomes and lengthen the time window for advanced interventions to be implemented. Our prediction models demonstrated that time-specific $EtCO_2$ trajectory, taking into account both the CPR duration and quality, could be a significant intra-arrest prognostic factor. In the future, time-specific $EtCO_2$ may be transmitted instantaneously from $EtCO_2$ monitors to mobile devices with the assistance of advanced information and communication technology. The predicted outcomes could be updated instantaneously minute by minute for each individual patient and may not be restricted to a certain time point during CPR, such as 20 min or 10 min, as used in our study.

LIMITATIONS

First, while we had internally validated the prediction models by using the bootstrap method, further external validation in other datasets should be performed. Second, the analyzed $EtCO_2$ dataset was derived from a prospectively collected database of a single ED with a specialized training model for CPR. Further studies are needed to investigate whether these models could be generalized to other EDs or prehospital resuscitation.

CONCLUSION

Time-specific $EtCO_2$ trajectory was a significant predictor of OHCA outcomes, which could be combined with other baseline variables for intra-arrest prognostication. For this purpose, the 20-min survival model achieved the highest discriminative performance in predicting survival to hospital discharge.

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Low Stroke Volume Predicts Deterioration in Intermediate-Risk Pulmonary Embolism: Prospective Study

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Introduction: Prognosis and management of patients with intermediate-risk pulmonary embolism (PE) is challenging. We investigated whether stroke volume may be used to identify the subset of this population at increased risk of clinical deterioration or PE-related death. Our secondary objective was to compare echocardiographic measurements of patients who received escalated interventions vs anticoagulation monotherapy.

Methods: We selected patients with intermediate-risk PE, who had comprehensive echocardiography within 18 hours of PE diagnosis and before any escalated interventions, from a PE registry populated by 11 emergency departments. Echocardiographers measured right ventricle (RV) size, tricuspid annular plane systolic excursion (TAPSE), and stroke volume (SV) using velocity time integral (VTI) by left ventricular (LV) outflow tract Doppler or two-dimensional method of discs (MOD). The primary outcome was a composite of PE-related death, cardiac arrest, catecholamine administration for sustained hypotension, or emergency respiratory intervention during the index hospitalization. Secondary outcome was escalated intervention with reperfusion or extracorporeal membrane oxygenation therapy.

Results: Of 370 intermediate-risk PE patients (mean age 64.0 ± 15.5 years, 38.1% male), 39 (10.5%) had the primary outcome. These 39 patients had lower mean SV regardless of measurement method than those without the primary outcome: SV MOD 36.2 vs 49.9 milliliters (mL), $P < 0.001$; SV Doppler 41.7 vs 57.2 mL, $P = 0.003$; VTI 13.6 vs 17.9 centimeters [cm], $P = 0.003$. Patients with primary outcome also had lower mean TAPSE than those without (1.54 vs 1.81 cm, $P = 0.003$). Multivariable models, selecting SV as predictor, had area under the receiver operating curve of 0.8 and Brier score 0.08. The best echocardiographic predictor of our primary outcome was SV MOD (odds ratio 0.72 [0.53, 0.94], $P = 0.02$). Patients who received escalated interventions had significantly lower SV or surrogate measurements, greater RV dilatation, and lower RV systolic function than patients who received anticoagulation monotherapy.

Conclusion: Low stroke volume was a predictor of clinical deterioration and PE-related death. Low SV may be used to identify a subset of intermediate-risk PE patients, who are higher risk (intermediate-high risk), and for whom escalated interventions should be considered. [West J Emerg Med. 2024;25(4) 533–547.]

INTRODUCTION

Pulmonary embolism (PE) risk stratification tools focus on presence or absence of right ventricle (RV) dysfunction and hemodynamic stability.[1–5] Patients with PE who have RV dysfunction and are hemodynamically stable are classified as intermediate risk (submassive) by the European Society of Cardiology (ESC) and CHEST guidelines.[1,5–8] However, there is a spectrum of disease severity within this classification. While most intermediate-risk patients improve with anticoagulation only, some may need more intensive inpatient monitoring and escalated interventions due to acute clinical deterioration. The challenge is to identify which intermediate-risk patients are at the higher end of the risk spectrum.

Those who are at greater risk for hemodynamic instability or clinical deterioration are classified as ***intermediate-high risk*** (severe submassive) by the ESC and CHEST. This subset is defined by troponin elevation with ESC guidelines; however, this strategy has low positive predictive value.[1,5,9,10] While some PE response teams (PERT) use ESC guidelines, others use clinical signs of hypoxia, episodic hypotension, or elevated shock index to identify intermediate-high risk PE. How intermediate-high risk is classified matters because physician decisions regarding escalated treatments are based on the predicted risk of acute clinical deterioration.

Expert researchers argue that qualitative RV dilatation is insufficient to identify patients suffering from a low-flow state and likely to experience clinical deterioration.[8,9,11] It is physiologically plausible that inadequate left ventricle (LV) filling with reduced stroke volume (SV) may signal more severe PE within the intermediate-risk group than RV dilatation or elevated laboratory measurements of myocardial injury.[12] Reduced SV, a hemodynamic parameter, may identify those at increased risk for acute clinical deterioration (defined herein as cardiac arrest, catecholamine administration for sustained hypotension, or emergency respiratory intervention during the index hospitalization) or PE-related death. The PE literature, however, rarely reports on SV for risk stratification or prognosis of acute clinical deterioration.[6,7,11–14]

Our primary objective was to compare prognostic performance of SV measurements in comparison to RV measurements to characterize the relationship between echocardiographic hemodynamic parameters, including SV, and acute clinical deterioration in emergency department (ED) patients classified as intermediate-risk PE. We hypothesized that those who experienced clinical deterioration would have lower SV at presentation than those who did not. Our secondary objective was to compare initial echocardiographic measurements of patients who received escalated interventions with those who received anticoagulation monotherapy. We hypothesized initial SV measurements would be significantly different between treatment groups.

Population Health Research Capsule

What do we already know about this issue?
Right ventricle dysfunction identifies intermediate-risk pulmonary embolism (PE) but may not predict increased likelihood of hemodynamic instability.

What was the research question?
Do hemodynamic parameters such as stroke volume (SV) predict clinical deterioration in intermediate-risk PE?

What was the major finding of the study?
A predictive model for clinical deterioration in PE patients including stroke volume had AUC 0.81 (95% CI 0.69, 0.92) and Brier score 0.08 (0.06, 0.10).

How does this improve population health?
Low stroke volume may identify intermediate-high risk PE, ie, those at greater risk for clinical deterioration and death.

METHODS

Study Design and Settings

We identified patients from our prospective, observational Clinical Outcomes in Pulmonary Embolism Research Registry (COPERR). The COPERR was populated with patients diagnosed with intermediate- or high-risk PE in any of our health system's 11 EDs between June 2018–August 2022. All COPERR patients had confirmed acute PE with RV to LV basal diameter ratio (RV:LV) ≥ 1.0 by computed tomography (CT) or point-of-care echocardiography, or cardiac biomarker elevation (brain natriuretic peptide [BNP], troponin, or high sensitivity troponin). We used the 2019 ESC PE guidelines to classify COPERR patients as high risk and intermediate-low risk PE[5]; however, we used an institution-specific definition for intermediate-high risk (which was informed by the 2019 ESC guidelines).[5] We classified patients as intermediate-high risk if they had RV dilatation and one or more of the following signs: episodic hypotension (systolic blood pressure [SBP] 90 millimeters of mercury [mm Hg] <15 minutes); sustained shock index >1.0; or pulse oximetry reading <92% on room air with respiratory distress. For the registry, board-certified radiologists reviewed CT images and reported RV dilatation, and sonographers performed comprehensive transthoracic echocardiography (TTE).

The Atrium Health Institutional Review Board approved COPERR and planned analyses (including this study) with a waiver of informed consent. Clinicians were blind to study design and hypothesis and managed patients without guidance or recommendations.

Subjects

We included COPERR patients classified as intermediate risk at ED presentation, who had TTE within 18 hours of PE order set being placed and before any escalated interventions. Atrium Health has a multidisciplinary PERT equipped with an intermediate- and high-risk PE order set within the electronic health record (EHR). The TTE can be ordered separately or as part of the PE order set. Most patients with PERT activations had TTE pre-ordered as part of the PE order set. We excluded patients if any of the following criteria were present: 1) PE was incidental finding on imaging; 2) PE was not the primary diagnosis contributing to patient's clinical presentation to the ED; 3) PE diagnosis secured >2 hours after admission from the ED; 4) non-acute PE with similar filling defects (unchanged or resolving) if previous CT available; 5) hemodynamic instability attributable to PE, including sustained hypotension (SBP below 90 mm Hg >15 minutes) or unstable cardiac rhythms or obstructive shock or cardiac arrest (classification as high risk)[5]; 6) TTE was not completed or was without RV or SV measurements; and 7) escalated intervention performed before TTE.

Data Collection

Data extractors were trained in the explanation of all variables and identification of EHR source documents. Those who completed successful trials of data extraction on test cases were qualified to monitor the EHR for study data entry into Research Electronic Data Capture (REDCap, hosted at Atrium Health's Carolinas Medical Center) case report forms, which had detailed field notes to enhance reliability.[15] Extractors who retrieved echocardiography measurements were blind to patient outcomes. A project manager monitored data accuracy and completeness.

Measurements

Cardiac Biomarkers

Samples and measurements were obtained while patients were in the ED. We used an i-STAT cardiac troponin test cartridge (Abbott Laboratories, Abbott Park, IL), measured in nanograms per milliliter (ng/mL) for troponin I or high-sensitivity troponin assays. Normal values for troponin I were < 0.07 ng/mL. Normal values for high-sensitivity troponin were <12 for females and <20 for males. We used the i-STAT BNP test cartridge (Abbott) measured in picograms (pg)/mL. Normal point-of-care BNP measurements were 90 ng/mL.

Transthoracic Echocardiography

Trained sonographers (blind to research study and patient outcomes) performed TTE measurements following the American Society of Echocardiography guidelines[16,17] at an echocardiography facility accredited by the Intersocietal Commission for the Accreditation of Echocardiography Laboratories. TTE was completed and recorded before the primary outcome or any escalated interventions occurred. Measurements included chamber dimensions and systolic function for left and right ventricles and left ventricular SV. Digital images and video were mapped from echocardiography machines and stored in Merge Cardio (Merative LP, Ann Arbor, MI), an imaging archiving platform. The cardiologist-investigator (blind to patient presentation and outcomes) reviewed ventricular and SV measurements or performed de novo two-dimensional (2D) measurements on the imaging platform.

Ventricular Chamber Size

We used apical 4-chamber or RV focused apical view to measure end-diastolic internal measurements of the RV in short axis (mid and basal levels) and long axis (length). We used parasternal long axis view to measure LV basal diameter. We calculated the RV:LV basal diameter ratio.

Right Ventricle Systolic Function

In the apical view, we used M mode to measure tricuspid annular plane systolic excursion (TAPSE) of the RV free wall tricuspid annulus. We used tissue Doppler to measure peak systolic velocity of the basal RV free wall segment and continuous wave Doppler to measure peak tricuspid regurgitation velocity during systole and to estimate right atrial pressure. Trace or unmeasurable regurgitation velocities were categorized as a discrete response rather than considered missing.

Cardiac Output

We calculated cardiac output (CO) as SV multiplied by heart rate. (The SV is often used as a surrogate of CO.[18,19]) We calculated SV from the LV by 2D method of discs (MOD) or pulsed wave Doppler.[19] In patients who had pulsed wave Doppler tracings recorded, we calculated SV by using left ventricular outflow tract (LVOT) diameter taken in the parasternal long axis and multiplying LVOT area by velocity time integral (VTI) of LVOT using the apical 5-chamber view. The VTI may be used as a surrogate of SV.[20,21] When available, a biplane MOD was also used for apical-4 and apical-2 chamber views to calculate differences between end-diastolic and end-systolic volume. When only an apical-4 chamber view was available, we used MOD. When both views were available, the average of apical-4 and -2 SV measurements was used.

Because 2D methods do not account for mitral regurgitant flow, we reported absence or presence of mitral regurgitation

(MR). If present, MR was graded as mild, moderate, or severe. Body surface area (BSA) was available for indexing of measurements.

Outcomes

The primary outcome was a composite of PE-related death or clinical deterioration, defined as cardiac arrest, catecholamine administration for sustained hypotension, or emergency respiratory intervention during the index hospitalization. The secondary outcome was use of one or more escalated interventions, including reperfusion interventions (systemic thrombolysis [full or reduced dose]), catheter-directed interventions, advanced endovascular interventions, surgical thrombectomy, and extracorporeal membrane oxygenation [ECMO]).

Statistical Analyses

Study sample was determined by the number of registry patients eligible for inclusion. Analyses specific to each objective follow. We used R software (R Project for Statistical Computing, Vienna, Austria) for all analyses.

Primary Objective

For TTE variables, we reported the number of observations, means with standard deviations, or frequencies. We compared differences in means between primary outcome groups using unpaired *t*-tests for continuous variables and chi-square tests for categorical variables. We reported the percentage of missing observations for each variable and used imputation for multivariable analyses. We performed bivariable and multivariable logistic regression to assess associations of echocardiographic measurements with the primary outcome. For patients with SV measured by both Doppler and MOD methods, we determined two-sided 95% confidence intervals (CI) for the Pearson correlation coefficient between SV measurements. Because SV and CO are inherently correlated, including both within the same multivariable model would lead to multicollinearity and variance inflation. Therefore, we fit two separate models for each outcome, one with Doppler-derived SV or CO as a predictor, and a second one with MOD-derived SV or CO as a predictor. Each model contained the same other predictors.

We fit multivariable logistic regression models for our primary outcome, including TTE and non-TTE measurements independently associated with the primary outcome in the univariable models ($P < 0.10$). We fit a multivariable logistic regression model for our primary composite outcome. To select the best fitting model while controlling for key sources of confounding and issues with multicollinearity between clinical predictors of interest, we used least absolute shrinkage and selection operator (LASSO) regression with 10-fold cross validation to select our final logistic regression model. The SV MOD, SV LVOT, CO MOD, and CO LVOT all induced variance inflation due to collinearity when included in the same model. From univariable bivariable logistic models, we determined optimal thresholds for predicting our primary outcome for each TTE metric using Youden's J-statistic.[22,23] We reported performance metrics of these thresholds as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and odds ratios (OR) with 95% CIs for predicting clinical deterioration.

We used the full dataset to fit a random forest (RF) model. We generated a variable importance plot based on mean decrease in accuracy to assess importance of predictors and compare them with the significance of univariable bivariable associations based on *t*-tests. We reported prognostic performance of LASSO and RF with AUC, Brier score, scaled Brier score, calibration intercept, slope, and plot. Finally, to address potential inaccuracies of predicted probabilities with unbalanced data or translation into clinical utility, we reported on net benefit based on decision curve analysis.[27,28]

Secondary Objective

We compared echocardiographic measurements between groups that received anticoagulation monotherapy vs escalated interventions with the unpaired *t*-test.

RESULTS

Of 370 patients who met inclusion criteria, 363 (98.1%) were seen July 2020–August 2022; four patients were from 2018; and three patients from 2019 (Figure). There were no significant differences in demographics between outcome groups (Table 1). Patients with primary outcome had higher respiratory and heart rates at presentation and lower SBP and oxygen saturation than those without. Initial high-sensitivity troponin elevation was not significantly different between primary outcome groups.

As shown in Figure, 39 of 370 patients (10.5%) had the primary outcome. Of 21 (5.7%) patients who died, only 17 (4.6%) PE-related deaths were counted as having the primary outcome. The SV measurement was by LVOT Doppler method in 301 (81.4%) patients and by MOD in 359 (97.0%). In 290 patients, both SV measurement methods were used, with a correlation coefficient of 0.69 (0.63, 0.75). The CO had correlation coefficient of 0.66 (0.59, 0.72). Escalated interventions occurred in 56 (15.1%) patients, with 39 receiving systemic thrombolysis, 15 receiving catheter-directed intervention (CDI), two receiving ECMO, and one receiving surgical embolectomy. One patient had both systemic thrombolysis and CDI. Of 15 patients receiving CDIs, 12 had catheter-directed thrombolysis (10 ultrasound-assisted and two non-ultrasound assisted), and four had aspiration thrombectomy (data not shown).

Table 2 shows that both Doppler- and MOD-derived output measurements were lower for those with than without

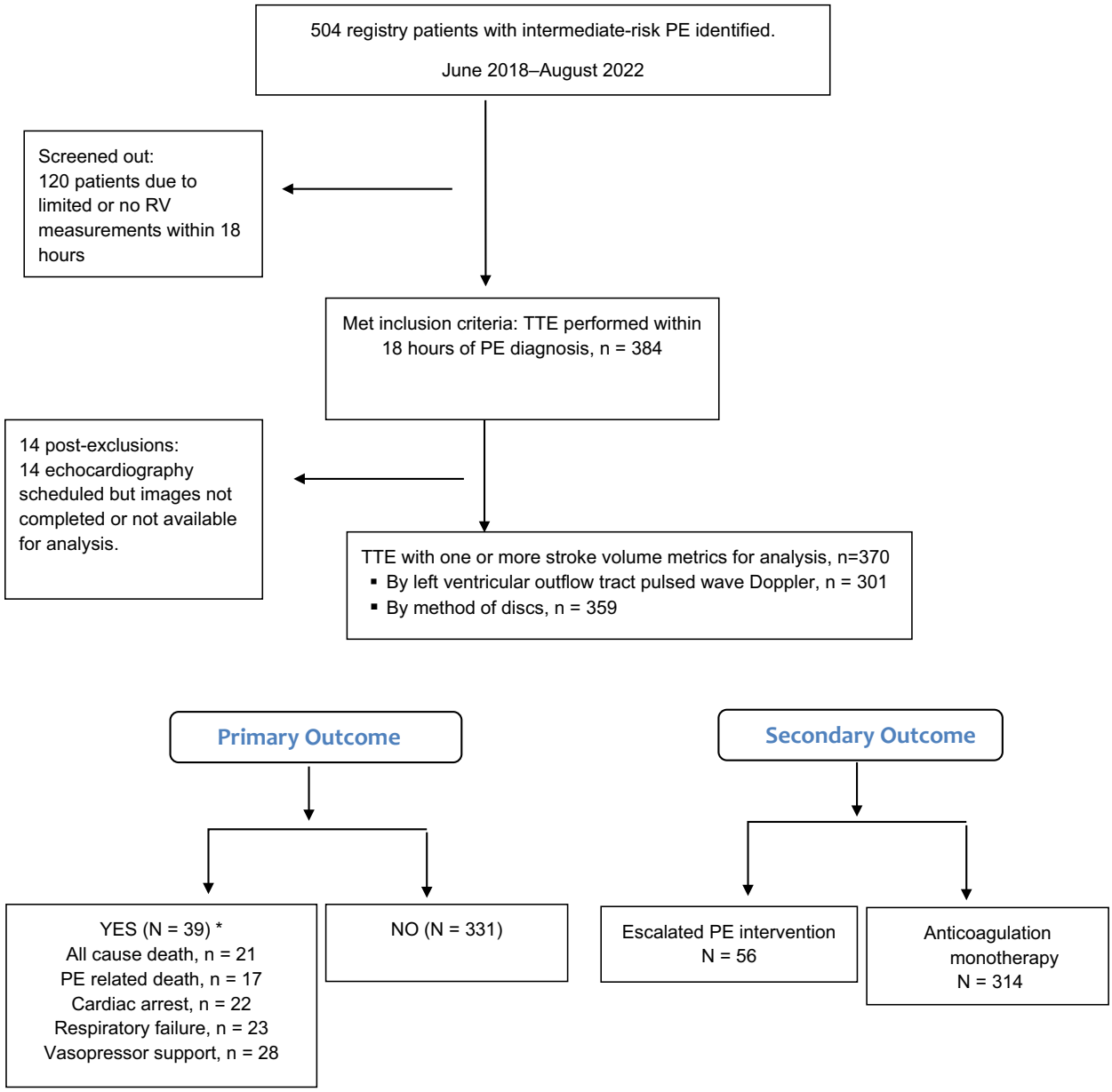

Figure. Screening and patient flow diagram.
PE, pulmonary embolism; *RV*, right ventricle; *TTE*, transthoracic echocardiography.
*Components of the primary composite outcome are not mutually exclusive.

the primary outcome. In contrast, for RV systolic function, mean TAPSE was lower (worse) in those with than without the primary outcome. Most values were lower than mean values for a healthy cohort (Table 2 footnote). There were no significant differences in TTE metrics for RV size, with only RV:LV ratio approaching statistical significance. Both PE cohorts had higher SV measurements by Doppler than SV by MOD (with or without indexing by BSA). Mean SV measurements, irrespective of measurement approach, were statistically reduced in patients who experienced clinical deterioration vs those who did not.

Table 3 shows results from the LASSO model that started with all SV and CO measures considered. It ended with selecting only SV by MOD, among other patient and clinical characteristics that were also predictive. For imputed values, the best predictor was SV by MOD with OR 0.72 (CI 0.53, 0.94; $P = 0.02$). As SV increased, the probability of primary outcome decreased. Recent hospitalization and metastatic solid tumor were other independent predictors. SV Doppler, TAPSE, and RV basal width had non-significant ORs. The SV by MOD was more strongly associated with the primary outcome than SV Doppler. The OR of 0.72 for SV MOD

Table 1. Patient characteristics and clinical presentation by primary outcome.

Patient characteristics	Primary outcome = YES (N = 39)	Primary outcome = NO (N = 331)	Overall (N = 370)	*P*-value
Age, years				
Mean (SD)	66.4 (13.5)	62.3 (16.0)	62.7 (15.8)	0.12
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Race				
African-American	16 (41.0%)	123 (37.4%)	139 (37.6%)	0.36
Other	3 (7.7%)	13 (4.0%)	16 (4.3%)	
White	20 (51.3%)	193 (58.7%)	215 (58.1%)	
Ethnicity				
Hispanic	2 (5.1%)	14 (4.3%)	16 (4.3%)	0.77
Non-Hispanic	37 (94.9%)	312 (94.8%)	351 (94.9%)	
Unknown	0 (0%)	3 (0.9%)	3 (0.8%)	
Gender				
Female	17 (43.6%)	173 (52.6%)	192 (51.9%)	0.31
Male	22 (56.4%)	156 (47.4%)	178 (48.1%)	
Lowest systolic blood pressure within 3 hours of presentation (mmHg)				
Mean (SD)	97.8 (30.7)	122 (23.8)	120 (25.7)	<0.001
Highest heart rate within 3 hours of presentation (beats per minute)				
Mean (SD)	122 (21.1)	107 (22.1)	108 (22.5)	<0.001
Lowest oxygen saturation on room air within 3 hours of presentation (%)				
Mean (SD)	86.6 (15.5)	93.6 (5.34)	92.8 (7.40)	<0.001
Highest respiratory rate within 3 hours of presentation (breaths per minute)				
Mean (SD)	32.5 (13.0)	25.2 (9.17)	26.0 (9.88)	<0.001
Body surface area, m2				
Mean (SD)	1.94 (0.25)	2.08 (0.31)	2.07 (0.31)	0.01
Missing	4 (10.3%)	24 (7.3%)	29 (7.8%)	
Dementia				
No	34 (87.2%)	314 (94.9%)	348 (94.1%)	0.06
Yes	5 (12.8%)	16 (4.9%)	21 (5.7%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Chronic obstructive pulmonary disease				
No	34 (87.2%)	288 (87.0%)	322 (87.0%)	0.99
Yes	5 (12.8%)	42 (12.7%)	47 (12.7%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Metastatic solid tumor				
No	30 (76.9%)	310 (93.6%)	340 (91.9%)	0.001
Yes	9 (23.1%)	20 (6.1%)	29 (7.8%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Any malignancy				
No	33 (84.6%)	285 (86.1%)	318 (85.9%)	0.80
Yes	6 (15.4%)	45 (13.6%)	51 (13.8%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	

(*Continued on next page*)

Table 1. Continued.

Patient characteristics	Primary outcome = YES (N = 39)	Primary outcome = NO (N = 331)	Overall (N = 370)	*P*-value
Prior diagnosis of pulmonary embolism				
No	32 (82.1%)	248 (74.9%)	280 (75.7%)	0.43
Yes	7 (17.9%)	82 (24.9%)	89 (24.1%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Recent hospitalization				
No	26 (66.7%)	290 (87.6%)	316 (85.4%)	0.001
Yes	13 (33.3%)	40 (12.1%)	53 (14.3%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Current prescribed anticoagulation				
No	36 (92.3%)	295 (89.1%)	331 (89.5%)	0.78
Yes	3 (7.7%)	35 (10.6%)	38 (10.3%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Recent trauma				
No	39.0 (100%)	315 (95.2%)	354 (95.7%)	0.39
Yes	0 (0%)	15 (4.5%)	15 (4.1%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Family history of venous thromboembolism				
No	39 (100%)	308 (93.1%)	347 (93.8%)	0.24
Yes	0 (0%)	18 (5.4%)	18 (4.9%)	
Missing	0 (0%)	5 (1.5%)	5 (1.4%)	
Hormonal replacement therapy				
No	38 (97.4%)	315 (95.2%)	353 (95.4%)	1.00
Yes	1 (2.6%)	15 (4.5%)	16 (4.3%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Tobacco use				
Current	9 (23.1%)	65 (19.6%)	74 (20.0%)	0.16
Ex smoker (smoked >100 cigarettes in their lifetime but has not smoked in the last 28 days but less than 12 months)	4 (10.3%)	11 (3.3%)	15 (4.1%)	
Ex smoker for >12 months	4 (10.3%)	56(16.9%)	60 (16.2%)	
Never	22 (56.4%)	197 (59.5%)	219 (59.2%)	
Missing	0 (0%)	2 (0.6%)	2 (0.5%)	
Severe renal disease				
No	35 (89.7%)	293 (88.5%)	328 (88.6%)	1.00
Yes	4 (10.3%)	37 (11.2%)	41 (11.1%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Congestive heart failure				
No	33 (84.6%)	297 (89.7%)	330 (89.2%)	0.27
Yes	6 (15.4%)	33 (10%)	39 (10.5%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	
Hemi- or paraplegia				
No	38 (97.4%)	323 (97.6%)	361 (97.6%)	0.60
Yes	1 (2.6%)	7 (2.1%)	8 (2.2%)	
Missing	0 (0%)	1 (0.3%)	1 (0.3%)	

Table 2. Bivariable analysis of echocardiographic measurements compared by primary outcome.*

Echocardiographic measurements	Primary outcome = YES (N = 39)	Primary outcome = NO (N = 331)	Overall (N = 370)	*P*-value
Internal diameter of LVOT (cm)				
Mean (SD)	2.1 (0.2)	2.1 (0.2)	2.1 (0.3)	0.63
Velocity time integral at LVOT (cm)				
Mean (SD)	13.6 (8.0)	17.9 (6.0)	17.5 (6.3)	0.003
Stroke volume as determined at LVOT (mL)				
Mean (SD)	41.7 (28.0)	57.2 (27.0)	55.7 (27.4)	0.004
Missing	10 (25.6%)	57 (17.3%)	69 (18.6%)	
Stroke Volume Index at LVOT (mL/m^2)				
Mean (SD)	21.2 (13.4)	27.5 (12.2)	26.9 (12.4)	0.001
Cardiac output as determined at LVOT (mL/min)				
Mean (SD)	3860 (2290)	4890 (2150)	4790 (2180)	0.02
Missing	10 (25.6%)	57 (17.3%)	69 (18.6%)	
Cardiac output index as determined at LVOT (mL/min/m^2)				
Mean (SD)	1970 (1100)	2340 (953)	2300 (972)	0.05
Stroke volume, by MOD (mL)				
Mean (SD)	36.2 (15.8)	49.9 (20.1)	48.4 (20.1)	< .001
Missing	0 (0%)	11 (3.3%)	11 (3.0%)	
Stroke Volume index by MOD, (mL/m^2)				
Mean (SD)	18.8 (8.7)	24.0 (8.9)	23.4 (9.0)	0.001
Cardiac output, by MOD (mL/min)				
Mean (SD)	3460 (1310)	4320 (1760)	4230 (1740)	0.003
Missing	0 (0%)	11 (3.3%)	11 (3.0%)	
Cardiac Output Index by MOD (mL/min/m^2)				
Mean (SD)	1760 (734)	2070 (741)	2040 (746)	0.02
Severity of mitral regurgitation, if present				
None	20 (51.3%)	170 (52%)	192 (51.9%)	0.36
Mild	14 (35.9%)	123 (37.2%)	137 (37.0%)	
Moderate	1 (2.6%)	10 (3.0%)	11 (3.0%)	
Severe	1 (2.6%)	1 (0.3%)	2 (0.5%)	
Missing	3 (7.7%)	25 (7.6%)	28 (7.6%)	
LV basal width (cm)				
Mean (SD)	4.0 (0.9)	4.2 (0.8)	4.2 (0.8)	0.07
Missing	0 (0%)	6 (1.8%)	6 (1.6%)	
LV ejection fraction, estimated (%)				
Mean (SD)	53.9 (14.7)	54.7 (10.9)	54.6 (11.4)	0.66
Missing	0 (0%)	2 (0.6%)	2 (0.5%)	
RV basal width (cm)				
Mean (SD)	4.3 (0.9)	4.2 (0.8)	4.3 (0.8)	0.87
Missing	2 (5.1%)	13 (4.0%)	15 (4.1%)	
RV:LV basal width ratio				
Mean (SD)	1.1 (0.3)	1.1 (0.3)	1.1 (0.3)	0.09
Missing	2 (5.1%)	18 (5.4%)	20 (5.4%)	

(*Continued on next page*)

Table 2. Continued.

Echocardiographic measurements	Primary outcome = YES (N = 39)	Primary outcome = NO (N = 331)	Overall (N = 370)	*P*-value
RV mid width (cm)				
Mean (SD)	3.6 (0.9)	3.7 (2.6)	3.7 (2.5)	0.80
Missing	4 (10.3%)	22 (6.6%)	26 (7.0%)	
RV major length (cm)				
Mean (SD)	7.0 (0.9)	7.2 (3.7)	7.2 (3.5)	0.68
Missing	5 (12.8%)	31 (9.4%)	36 (9.7%)	
Peak tricuspid regurgitant jet velocity (m/s)				
Mean (SD)	2.9 (0.6)	2.9 (0.7)	2.9 (0.7)	0.15
Missing	15 (38.5%)	92 (28.0%)	107 (28.9%)	
TAPSE (cm)				
Mean (SD)	1.5 (0.5)	1.8 (0.5)	1.8 (0.5)	0.003
Missing	8 (20.5%)	52 (15.7%)	60 (16.2%)	
RV annulus peak systolic velocity S' (cm/s)				
Mean (SD)	10.7 (5.2)	11.5 (4.4)	11.4 (4.5)	0.37
Missing	10 (25.6%)	68 (20.5%)	78 (21.1%)	
Initial high-sensitivity troponin (ng/L)				
Mean (SD)	237 (332)	175 (378)	182 (374)	0.34
Missing	2 (5.1%)	4 (1.2%)	6 (1.6%)	
Initial BNP level (pg/mL)				
Mean (SD)	435 (661)	290 (387)	304 (424)	0.05
Missing	3 (7.7%)	14 (4.2%)	17 (4.6%)	

*Normal Values are provided for comparison: The World Alliance of Societies of Echocardiography Study[19] published normal values for two echocardiographic assessments (Doppler and MOD) for variables in the calculation of cardiac output for adult subjects without diseases. By Doppler, normal values are velocity time integral 20.2 ± 3.6 mm, stroke volume 68.7 ± 17.0 ml, SV indexed by body surface area 38.7 ± 8.1 ml/m^2, cardiac output 4.58 ± 1.12 L/min/m^2, and cardiac index 2.6 ± 0.58 L/min/m^2. By two-dimensional echocardiography, normal values are: SV 58.4 ± 15.4 ml, SV indexed 32.7 ± 6.8 ml/m^2, cardiac output 3.88 ± 1.00 L/min, and cardiac index 2.18 ± 0.48 L/min/m^2.
The American Society of Echocardiography[16] reports the following values as abnormal: RV basal diameter > 4.2 cm, TAPSE < 1.6 cm, pulse Doppler peak velocity, S' < 10 cm/s.
LVOT, left ventricular outflow tract; *MOD*, method of discs; *LV*, left ventricle; *RV*, right ventricle; *TAPSE*, tricuspid annular planar systolic excursion; *BNP*, brain natriuretic peptide.

implies that for every 10 mL increase in SV, there was 28% decreased odds of the primary outcome. That is, person A with SV of 60 mL had 0.72 times the odds of the outcome relative to person B with an SV of 50 mL (ie, 1.0 – 0.72 = 0.28).

Table 4 shows Youden's index of the optimal cut-off values for TTE indices to maximize sensitivity and specificity. The most significant predictors were SV MOD, VTI, and SV Doppler, with best predictive performance for acute clinical deterioration in terms of balance between sensitivity and specificity. For common metrics of RV size and systolic function, highest AUC was the TAPSE cut-off.

The RF model determined independent predictors of our primary outcome and generated a variable importance plot (Supplemental Figure). The SV by MOD, VTI, and CO by MOD were the highest ranking TTE predictors for the primary outcome. Performance metrics for LASSO and RF models included AUC 0.8 and Brier score 0.08 (Table 5). Calibration and decision-curve analysis plots are included in the Appendix.

Table 6 shows patients who received escalated interventions had significantly lower SV or surrogate measurements, greater RV dilatation, and lower (worse) RV systolic function than patients who received anticoagulation monotherapy.

DISCUSSION

In our cohort of 370 intermediate-risk patients identified in the ED, both early TTE metrics for SV were strongly associated with acute clinical deterioration. By both

Table 3. Least absolute shrinkage and selection operator (LASSO) regression results using imputed values.

Predictors	Primary composite outcome		
	Odds ratios	*Confidence interval*	*P*-value
Stroke volume as determined at MOD (mL)	0.72	0.52–0.98	0.04
Lowest systolic blood pressure within 3 hours of presentation (mmHg)	0.98	0.96–1.00	0.02
Lowest oxygen saturation within 3 hours, %	0.95	0.91–1.00	0.06
Highest respiratory rate within 3 hours (breaths per minute)	1.03	0.99–1.07	0.09
Initial heart rate (beats per minute)	1.01	0.99–1.04	0.35
Velocity time integral determined at LVOT (cm)	0.96	0.87–1.05	0.38
Metastatic solid tumor: Yes	3.32	1.16–9.03	0.02
Recent hospitalization: Yes	4.68	1.87–11.65	< .001
Observations		370	
R^2 Tjur		0.265	

LVOT, left ventricular outflow tract; *MOD*, method of discs; *RV*, right ventricle; *TAPSE*, tricuspid annular planar systolic excursion.

bivariable and multivariable analyses, TTE metrics for SV indices and RV systolic function were better predictors of the primary outcome than RV size or troponin levels. The two methods of measuring SV were correlated but not interchangeable. Echocardiographic parameters (SV by MOD, VTI, CO by MOD, and SV LVOT) were identified among the 20 highest ranking predictors of all candidate variables for the primary outcome. Intermediate-risk patients subsequently treated with escalated interventions had significantly larger basal RV size, lower RV systolic function (TAPSE and S'wave), and lower SV parameters (VTI, SV MOD, and SV Doppler) than those treated with anticoagulation monotherapy. Even with tradeoffs and limitations of determining optimal cut-off values on combined sensitivity and specificity (Table 4), SV, VTI, and CO predictors had the best predictive ability. Optimal cut-offs shown in Table 4 may discriminate between patients at risk of subsequent deterioration vs those at low risk. High NPVs among these metrics would suggest low-risk patients were correctly identified.

Our cohort had lower mean SV than normal values for healthy adults. The World Alliance of Societies of Echocardiography identified normal mean SV in adults as VTI 20.2 ± 3.6 centimeters (cm), SV Doppler 68.7 ± 17.0 mL, and SV MOD 58.4 ± 15.4 mL.[19] Means for our cohort were: VTI 17.5 ± 6.3 cm, SV Doppler 55.7 ± 27.4 mL, and SV MOD 48.4 ± 20.1 mL. Mean SV was even lower for our patients who had primary outcome (VTI 13.6, SV Doppler 41.7, SV MOD 36.2 mL).

The strength of this study is identification of a possible predictor with a plausible physiological mechanism for acute clinical deterioration that has been minimally reported in the PE medical literature. Abrupt arterial occlusion on PE may lead to increased RV afterload. Worsening PE-provoked physiology involves key steps of decreased RV systolic function, reduced RV output, LV underfilling, reduced LV CO, decreased blood pressure, and reduced RV perfusion and oxygen delivery before obstructive shock and death.[5,29] Although it is premature to determine causality of single SV metrics, reduced LV CO and its surrogates (SV and VTI) represent an advanced stage on the pathway toward hemodynamic instability or death from acute PE.[5,29] In patients with RV dilatation, low SV might suggest subclinical shock, inadequate LV filling and output, and suggest this patient be treated as ***intermediate-high risk***. Thus, SV may identify a subgroup of intermediate-risk patients with a more favorable risk profile for 11escalated interventions.[30]

Although bivariable and multivariable analyses showed mean vital signs were associated with the outcome-positive group (eg, lowest SBP, highest heart rate, and highest respiratory rate), the mean values themselves did not lead to reassignment from intermediate risk to high risk; they merely disqualified patients from being considered low risk by PE severity index (PESI)/simplified PESI (sPESI).[31,32] At presentation, our patients were without cardiac arrest, obstructive shock, or persistent hypotension and thus were not classified as high risk by ESC criteria despite having higher heart rates and lower SBP (<100 mm Hg but >90 mm Hg).[5] In normotensive PE patients, we believe lower SV measurements provide more information about subclinical or impending shock in more severe cases than RV dilatation alone.

Existing PE studies that report SV use various techniques, outcomes, and timepoints. Few report SV being predictive of clinical deterioration when intermediate risk is defined by presence of RV abnormalities. Some studied CO surrogates using RV outflow tract or LV CO, or combined RV pressure

Table 4. Prognostic performance of optimal echocardiography cut-off points for the primary outcome.

Variable	Cut-off point	*P*-value	Sensitivity	Specificity	PPV	NPV	AUC	Odds ratio
Internal diameter of LVOT	2.0	0.63	84 (68, 100)	23 (17, 29)	10 (5, 14)	94 (87, 100)	0.54 (0.4, 0.7)	1.6 (0.5, 5.7)
RV major length (cm)	6.3	0.69	85 (73, 97)	26 (21, 31)	12 (8, 16)	94 (89, 99)	0.52 (0.4, 0.6)	2.1 (0.8, 5.5)
RV basal width (cm)	4.9	0.88	24 (1, 38)	85 (81, 89)	16 (6, 26)	91 (87, 94)	0.51 (0.4, 0.6)	1.8 (0.8, 4.2)
RV mid width (cm)	4.5	0.80	43 (26, 59)	65 (60, 70)	12 (6, 18)	91 (87, 95)	0.49 (0.4, 0.6)	1.4 (0.7, 2.9)
LV basal width (cm)	5.4	0.07	51 (36, 67)	74 (69, 78)	19 (12, 27)	93 (89, 96)	0.63 (0.5, 0.7)	3.0 (1.5, 5.8)
RV: LV basal width ratio	1.0	0.08	65 (49, 80)	55 (50, 61)	15 (9, 20)	93 (89, 97)	0.58 (0.5, 0.7)	2.3 (1.1, 4.7)
Peak tricuspid regurgitant jet velocity (m/s)	3.2	0.63	67 (48, 86)	45 (38, 51)	11 (6, 16)	93 (88, 98)	0.53 (0.4, 0.7)	1.6 (0.7, 3.9)
LV ejection fraction, estimated (%)	55.0	0.66	21 (8, 33)	87 (84, 91)	16 (6, 26)	90 (87, 93)	0.48 (0.4, 0.6)	1.8 (0.8, 4.1)
TAPSE (cm)	1.8	0.00	81 (67, 95)	47 (41, 53)	15 (9, 20)	96 (92, 99)	0.67 (0.6, 0.8)	3.7 (1.5, 9.4)
RV annulus peak systolic velocity S' (cm/s)	16.10	0.35	34 (17, 52)	88 (84, 92)	24 (11, 38)	92 (89, 96)	0.59 (0.5, 0.7)	3.9 (1.7, 9.2)
Stroke volume, by MOD (mL)	54.3	0.00	69 (55, 84)	66 (61, 71)	20 (13, 27)	95 (92, 98)	0.72 (0.6, 0.8)	4.3 (2.1, 8.9)
Stroke volume indexed by BSA, by MOD (mL/m^2)	27.2	0.02	57 (36, 77)	75 (7, 80)	14 (7, 22)	96 (93, 98)	0.65 (0.5, 0.8)	3.9 (1.6, 9.2)
Cardiac output, by MOD (mL/min)	5,916	0.00	36 (21, 51)	86 (83, 90)	25 (13, 36)	92 (89, 95)	0.64 (0.6, 0.7)	3.6 (1.7, 7.4)
Cardiac output indexed by MOD, $mL/min/m^2$	2,820.7	0.19	39 (19, 59)	86 (82, 90)	17 (7, 28)	95 (92, 98)	0.58 (0.4, 0.7)	4.0 (1.6, 9.7)
Velocity time integral at LVOT, cm	19.0	0.00	76 (58, 94)	67 (60, 74)	21 (12, 30)	96 (93, 99)	0.72 (0.6, 0.8)	6.7 (2.3, 18.8)
Velocity time integral, indexed by BSA, cm/m^2	13.1	0.28	33 (7, 60)	90 (86, 95)	19 (2, 36)	95 (92, 98)	0.60 (0.4, 0.8)	4.6 (1.2, 16.7)
Stroke volume as determined at LVOT (mL)	73.0	0.00	72 (56, 89)	67 (61, 73)	19 (12, 26)	96 (93, 99)	0.70 (0.6, 0.8)	5.3 (2.3, 12.5)
Stroke volume indexed, at LVOT, ml/m^2	37.4	0.06	47 (25, 70)	86 (82, 90)	19 (8, 30)	96 (94, 98)	0.64 (0.5, 0.8)	5.6 (2.1, 14.6)
Cardiac output as determined at LVOT (mL/min)	4,284	0.02	79 (65, 94)	47 (41, 53)	14 (9, 19)	96 (92, 99)	0.66 (0.6, 0.8)	3.5 (1.4, 8.8)
Cardiac output indexed at LVOT ($mL/min/m^2$)	3,022	0.23	47 (25, 70)	81 (76, 85)	14 (6, 23)	96 (93, 98)	0.59 (0.4, 0.8)	3.78 (1.5, 9.8)

PPV, positive predictive value; *NPV*, negative predictive value; *AUC*, area under the curve; *LV*, left ventricle; *RV*, right ventricle; *MOD*, method of discs; *LVOT*, left ventricular outflow tract; *TAPSE*, tricuspid annular planar systolic excursion.

Table 5. Performance and calibration of prediction models.*

Model	Discrimination	Calibration			
	Sensitivity vs 1- specificity plot AUC (95% CI)	Brier score	Scaled Brier	Calibration intercept	Calibration slope
Logistic model**	0.81 (0.69, 0.92)	0.08 (0.06, 0.10)	0.17 (0, 0.36)	0.02 (−0.54, 0.51)	0.83 (0.37, 1.59)
Random forest†	0.79 (0.71, 0.85)	0.08	0.15	−0.08 (−0.44, 0.27)	1.12 (0.73, 1.51)

*Using a scale of 0 to 1, indicators of better performance metrics are: AUC (closer to 1), Brier score (lower), scaled Brier (closer to zero), calibration intercept (closer to zero), calibration slope (closer to 1).[26]
**Due to issues of collinearity, LASSO regression was for variable selection based on 10-fold cross validation and selecting variables based on the lambda minimum. For the LASSO selected variables, we used Monte Carlo cross validation across 500 iterations with a 70/30 split between training and test data to fit repeated logistic models for the primary outcome. To assess discrimination, performance, and calibration, we reported the averages across iterations and 95% coverage intervals (ie, the 2.5th and 97.5th quantile from the 500 iterations).
†For comparison to the random forest (RF) fitted model, we estimated the same metrics based on out-of-bag samples from the RF fitted model, and calibration plot based on out-of-bag predicted probability estimates.
AUC, area under the receiver operating curve; *CI*, confidence interval.

assessments with LV SV assessments.[18,20,21,33,34] For example, Kamran et al studied 343 PE patients evaluated by a PERT, who had pulmonary artery systolic pressure (PASP) and LV outflow tract SV measurements.[34] A PASP/SV ratio ≥1.0 mm Hg/mL was associated with an increased risk of their primary outcome (death, cardiac arrest, and escalated interventions).

We and other researchers argue that RV dilatation is insufficient to distinguish which intermediate-risk PE patient is suffering from a low-flow state and likely to experience clinical deterioration.[8,9,11] While a meta-analysis concluded RV parameters were associated with poor clinical outcomes, the authors cautioned of methodological issues with low-quality evidence for most included studies.[12] Also, RV dysfunction definitions vary, and TTE measurement thresholds are not commonly incorporated into decision-making for intermediate-risk PE patients.[8,12] In this study, SV had greater prognostic value than RV size or troponin in distinguishing the transition to hemodynamic or clinical instability.

A retrospective study of intermediate-risk PE patients by Prosperi-Porta et al reported superior performance of SV index over RV measurements for anticipating PE-related adverse events (similar to our primary outcome).[18] Unlike our study, they included patients without RV abnormalities because they defined intermediate risk as sPESI >zero. Their cohort had lower acuity overall than ours. In contrast, our definition of intermediate risk included abnormal RV by CT or elevated cardiac biomarkers. Given our cohort had higher severity, our challenge was to identify unique predictors among patients with PE-associated cardiac dysfunction. Our outcome event rate (10.5%) was more than twice that reported by Prosperi-Porta et al.

Yuriditsky et al used VTI measured at the LVOT as an SV surrogate and defined low VTI as <15 cm.[20] Patients who died or had cardiac arrest had lower mean VTI than patients who did not (13.4 [3.9] and 18.3 [5.0] cm, respectively). Patients who experienced shock or needed reperfusion had lower mean VTI than those who did not (12.8 [3.2] and 18.6 [4.8] cm, respectively). Babes et al studied normotensive patients with PE and RV:LV of ≥1 and showed VTI <15 cm had PPV and NPV of 75% and 95%, respectively, for clinical deterioration.[35] We had similar findings.

In our study, patients with the primary outcome had lower mean VTI than those who did not (13.6 [8.0] and 17.9 [6.0] cm, respectively). Patients who received escalated interventions had lower mean VTI than those who did not (13.96 [7.4] and 17.9 [6.0] cm, respectively). In our study, intermediate-risk patients who received escalated interventions had lower VTI, SV, and RV systolic function and larger RV chambers than adults without disease.[16,19,36] Patients who concerned clinicians enough to receive escalated interventions had significantly lower SV and VTI, greater RV dilation, and lower (worse) RV systolic function than patients treated with anticoagulation monotherapy. We believe these differences identify the subgroup of patients with current or impending subclinical shock.

The clinical relevance of our study findings is that SV measurements may be used to 1) identify a subgroup of intermediate-risk patients at increased risk for clinical deterioration, and 2) determine candidacy for escalated interventions. The SV can be easily measured, incorporated into clinical practice, and used to inform prompt treatment with escalated interventions for intermediate-high risk PE patients in the ED. Ultrasound use is integral to training and practice of emergency medicine (EM) and is a required skillset of physicians certified by the American Board of Emergency Medicine. The near future involves more emergency clinicians acquiring and using clinically indicated ultrasound.[37] In addition, automated VTI, SV, and CO

Table 6. Bivariable analysis of echocardiographic measurements compared by treatment group.*

Echocardiographic measurements	Immediate or delayed escalated PE interventions (N = 56)	Anticoagulation monotherapy watch and wait (N = 314)	Mean difference (95% confidence interval)	*P*-value
Velocity time integral at LVOT, cm				
Mean (SD)	14.0 (7.4) n = 27	18.0 (6.0) n = 179	−3.9 (−6.5, −1.4)	0.002
Velocity time integral LVOT indexed by BSA, cm/m^2				
Mean (SD)	6.7 (4.0) n = 27	8.9 (3.5) n = 156	−2.2 (−3.9, −0.5)	0.004
Stroke volume as determined at LVOT (mL)				
Mean (SD)	44.4 (23.4) n = 46	57.8 (27.6) n = 255	−13.3 (−21.6, −4.8)	0.002
Stroke volume as determined at LVOT indexed by BSA, mL/m^2				
Mean (SD)	21.3 (11.3) n = 46	27.9 (12.3) n = 255	−6.60 (−10.2, −2.9)	<0.001
Stroke volume, by MOD (mL)				
Mean (SD)	39.3 (16.3) n = 55	50.1 (20.3) n = 304	−10.8 (−16.4, −5.1)	<0.001
Stroke volume, by MOD indexed by BSA, mL/m^2				
Mean (SD)	19.0 (7.4) n = 52	24.3 (9.0) n = 278	−5.30 (−7.6, −3.0)	<0.001
RV basal width (cm)				
Mean (SD)	4.6 (0.8) n = 54	4.2 (0.8) n = 301	0.4 (0.2, 0.7)	<0.001
RV: LV basal width ratio				
Mean (SD)	1.2 (0.3) n = 52	1.0 (0.3) n = 298	0.2 (0.13, 0.29)	<0.001
TAPSE (cm)				
Mean (SD)	1.4 (0.4) n = 45	1.8 (0.5) n = 265	−0.4 (−0.6, −0.3)	<0.001
RV annulus peak systolic velocity S' (cm/s)				
Mean (SD)	9.3 (2.8) n = 44	11.8 (4.6) n = 248	−2.5 (−3.9, −1.1)	0.001

*Normal values are provided for comparison: The World Alliance of Societies of Echocardiography Study[19] published normal values for two echocardiographic assessments (Doppler and MOD) for variables in the calculation of cardiac output for adult subjects without diseases. By Doppler, normal values are velocity time integral 20.2 ± 3.6 mm, stroke volume 68.7 ± 17.0 ml, SV indexed by body surface area 38.7 ± 8.1 ml/m^2, cardiac output 4.58 ± 1.12) L/min/m^2 and cardiac index 2.6 ± 0.58 L/min/m^2. By two-dimensional echocardiography, normal values are: SV 58.4 ± 15.4 ml, SV indexed 32.7 ± 6.8 ml/m^2, cardiac output 3.88 ± 1.00 L/min and cardiac index 2.18 ± 0.48 L/min/m^2.
The American Society of Echocardiography[16] reports the following values as abnormal: RV basal diameter >4.2 cm, TAPSE <1.6 cm, pulse Doppler peak velocity, S' <10 cm/s.
PE, pulmonary embolism; *BSA*, body surface area; *LVOT*, left ventricular outflow tract; *MOD*, method of discs; *LV*, left ventricle; *RV*, right ventricle; *TAPSE*, tricuspid annular planar systolic excursion.

measurements are emerging in point-of-care cardiac ultrasound applications by vendors and becoming available to clinicians with basic/intermediate advanced cardiac ultrasound skills.[38]

Given the knowledge gap in RV failure research, this study supports further investigation into the impact of SV on clinical outcomes and decision-making.[11,30] Future studies may be designed to include SV as a predictor or include

changes in SV as an efficacy outcome of PE interventions. Such reports may provide evidence to support or refute the use of SV metrics to indicate candidacy for escalated interventions or inform decision-making in EDs, including the need to provide intensive care or transfer to a healthcare facility with a PERT. The end result may be inclusion of SV in risk stratification tools used by PERTs.

LIMITATIONS

First, we did not report on aortic insufficiency as a confounder of LVOT VTI and SV Doppler measurements. The SV Doppler assessments will be limited by outflow tract obstruction and measurements affected by conditions such as hypertrophic cardiomyopathy and hypovolemia. Accuracy of SV assessment may be affected by dysrhythmias and underestimation of forward flow by aortic and mitral valvular insufficiency. Second, treatment teams were not blinded to TTE results. However, most were agnostic to the hypothesized clinical significance of the measurements. It is unlikely treating physicians incorporate metrics on RV size, systolic function, pressure, and SV in their clinical decision-making. There are no established thresholds for TTE metrics or recommendations to trigger early use of escalated interventions. Third, we did not perform inter-rater reliability measures. Finally, although discrimination and calibration metrics show SV as a predictor of clinical deterioration, there was no external validation to further address usefulness and impact.

CONCLUSION

Echocardiographic hemodynamic parameters were among the best predictors of clinical deterioration. Low stroke volume preceded and predicted clinical deterioration. Lower SV was found in patients treated with escalated intervention than in those without. We recommend further inquiry into incorporating SV into pulmonary embolism risk stratification, prognosis, and decisions on patient disposition and clinical management.

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Role of the Critical Care Resuscitation Unit in a Comprehensive Stroke Center: Operations for Mechanical Thrombectomy During the Pandemic

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Introduction: Standard of care for patients with acute ischemic stroke from large vessel occlusion (AIS-LVO) includes prompt evaluation for urgent mechanical thrombectomy (MT) at a comprehensive stroke center (CSC). During the start of the coronavirus 2019 pandemic (COVID-19), there were reports about disruption to emergency department (ED) operations and delays in management of patients with AIS-LVO. In this study we investigate the outcome and operations for patients who were transferred from different EDs to an academic CSC's critical care resuscitation unit (CCRU), which specializes in expeditious transfer of time-sensitive disease.

Methods: This was a pre-post retrospective study using prospectively collected clinical data from our CSC's stroke registry. Adult patients who were transferred from any ED to the CCRU and underwent MT were eligible. We compared time intervals in the pre-pandemic (PP) period between January 2018– February 2020, such as ED in-out and CCRU arrival-angiography, to those during the pandemic (DP) between March 2020–May 31, 2021. We used classification and regression tree (CART) analysis to identify which time intervals, besides clinical factors, were associated with good neurological outcome (90-day modified Rankin scale 0–2).

Results: We analyzed 203 patients: 135 (66.5%) in the PP group and 68 (33.5%) in the DP group. Time from ED triage to computed tomography (difference 7 minutes, 95% confidence interval [CI] −12 to −1, $P < 0.01$) for the DP group was statistically longer, but ED in-out was similar for both groups. Time from CCRU arrival to angiography (difference 9 minutes, 95% CI 4–13, $P < 0.01$) for the DP group was shorter. Forty-nine percent of the DP group achieved mRS ≤ 2 vs 32% for the PP group (difference −17%, 95% CI −0.32 to −0.03, $P < 0.01$). The CART identified initial National Institutes of Health Stroke Scale, age, ED in-and-out time, and CCRU arrival-to-angiography time as important predictors of good outcome.

Conclusion: Overall, the care process in EDs and at this single CSC for patients requiring MT were not heavily affected by the pandemic, as certain time metrics during the pandemic were statistically shorter than pre-pandemic intervals. Time intervals such as ED in-and-out and CCRU arrival-to-angiography were important factors in achieving good neurologic outcomes. Further study is necessary to confirm our observation and improve operational efficiency in the future. [West J Emerg Med. 2024;25(4)548–556.]

INTRODUCTION

Prior research has shown that patients who sustain acute ischemic stroke from large vessel occlusion (AIS-LVO) face high rates of mortality and morbidity[1] if they do not receive timely reperfusion therapy. Multiple studies have demonstrated that mechanical thrombectomy (MT) can improve neurologic outcomes for patients with AIS-LVO,[2–4] and since 2015 MT has become the standard of care. Throughout the US, however, the technology and expertise required to perform MT are only available at approximately 216 comprehensive stroke centers (CSC),[5] which also manage these critically ill patients in a specialized neurocritical care unit (NCCU). Therefore, patients with AIS-LVO who initially present to a hospital without MT capability require transfer to a CSC. Given the widely accepted association of time to reperfusion with neurologic outcomes (the adage "time is brain" very much applies), it is essential that both interhospital transfer and transfer to the interventional suite following arrival at the CSC are expeditious.[6]

The University of Maryland Medical Center (UMMC) in Baltimore, MD, is a CSC offering MT to patients with AIS-LVO throughout the state. To increase access to MT and avoid unnecessary delay of transfer due to bed unavailability at the NCCU, patients with AIS-LVO are transferred directly to the UMMC Critical Care Resuscitation Unit (CCRU), a six-bed resuscitation unit created to expedite transfer of patients with critical illness or time-sensitive diseases such as AIS-LVO.[7,8] We have previously demonstrated that the CCRU is able to directly admit a majority of patients with AIS-LVO for MT when the NCCU at UMMC does not have available beds, while providing initial resuscitation and outcomes similar to patients who were transferred directly to the NCCU. Prior to the coronavirus 2019 (COVID-19) pandemic, up to 68% of patients transferred to UMMC for AIS-LVO were admitted first to the CCRU, while 32% were admitted directly to the NCCU.[9]

The onset of the COVID-19 pandemic affected the US healthcare system in many ways. During the early phase of the pandemic, staff shortages, personal protective equipment (PPE) requirements, and the lack of COVID-19 testing resulted in delays in the process of care for patients. Patients' length of stay in the emergency department (ED) was longer than in the pre-pandemic period.[10,11]According to a Korean study, the essential time interval from ED triage to neuroimaging studies for patients with ischemic stroke was delayed when compared to the pre-pandemic period.[10] This delay in the ED process of care is likely to have affected the outcome of patients transferred to CSCs for MT. It is not known whether the process of care for these patients with AIS-LVO transferred through the CCRU, which is specialized to expedite the transfer and treatment of patients with time-sensitive diseases, was also delayed during the pandemic.

Population Health Research Capsule

What do we already know about this issue?
During the pandemic (DP), the processes of care for patients in EDs were significantly delayed, compared to the pre-pandemic (PP) time.

What was the research question?
We sought to determine whether the process of care for patients with acute ischemic stroke from large vessel occlusion in the ED and the critical care resuscitation unit (CCRU) was affected during the pandemic.

What was the major finding of the study?
Total time in ED was similar at 157 minutes both PP and DP ($p = 0.74$), while DP time in the CCRU was 9 minutes shorter than PP.

How does this improve population health?
In-out ED time was one of the top predictors for outcome. Clinicians should expedite transfer of patients to thrombectomy.

In this pre-post pandemic study, we sought to compare the process of care for patients with AIS-LVO for both the ED and the CSCs, from ED triage to the CCRU, and subsequently to the MT suite. Acknowledging that the time interval from patients' last-known-well period to the time of reperfusion (recanalization) is essential,[12] we also investigated which time intervals following arrival to the ED were most important in determining patients' neurological outcomes.

METHODS

Patient Selection

This was a retrospective study among adult patients transferred from any ED to the CCRU between January 1, 2018–May 31, 2021 for MT. Data for these patients with AIS-LVO was collected prospectively for our institutional stroke registry. We compared patients transferred between January 1, 2018–February 29, 2020 (pre-pandemic) with those who were transferred between March 1, 2020–May 31, 2021 (during the pandemic). The study was exempted from formal consent by the UMMC Institutional Review Board.

Study Settings

The CCRU is a six-bed, intensive care unit (ICU)-based resuscitation unit that was created in July 2013 to expedite

the transfer of patients with time-sensitive conditions[13] to UMMC, a quaternary academic medical center offering a variety of time-sensitive interventions for critical patients, including MT, emergency cardiac and aortic surgery, extracorporeal membrane oxygenation, and neurosurgery. The CCRU has facilitated the transfer of over 1,500 patients per year, or up to 20% of total transfers, to our institution.[8] Prior research has demonstrated that transfer through the CCRU was associated with more rapid transfer, defined as shorter intervals from transfer request to arrival at UMMC, than direct transfer to traditional inpatient critical care units.

The unit is staffed at all times by an onsite attending physician who is board certified in both emergency medicine (EM) and critical care medicine and an advanced practice practitioner (APP) with postgraduate training or experience in critical care. Fellow and resident physicians often rotate through the CCRU and work under the direct supervision of the CCRU attending. The nursing staff is composed of one charge nurse and four bedside nurses with at least two years of ICU experience; the charge nurse often participates in patients' initial resuscitation and clinical care in addition to serving an administrative role. During the pandemic, there was no change in the basic staffing model of the CCRU.

Since the opening of the CCRU, patients with AIS-LVO who are considered candidates for MT by the Stroke Neurology team at UMMC are transferred to the NCCU or the CCRU (if there is no NCCU bed available, staffed, and ready at the time of transfer). Any regional emergency physician who has diagnosed a patient with an AIS-LVO and does not have in-house MT capabilities can directly connect to a multidisciplinary team responsible for determining eligibility for MT and coordinating appropriate care before, during, and after the procedure through the Maryland Access Center (MAC), which handles all transfers from other hospitals to the UMMC. This team includes the on-call attending physicians for the stroke neurology team, the NCCU, neuroradiology, and the CCRU.

During this discussion, eligibility for MT is determined, recommendations for initial care prior to thrombectomy (both at the sending facility and upon arrival at UMMC) are discussed, and—for eligible patients—arrangements for urgent thrombectomy and post-thrombectomy care (including "activation" of on-call but offsite teams during off hours) are initiated. For eligible patients, arrangements are made for prompt bed assignment in either the NCCU or the CCRU, depending on NCCU bed availability, and transport is arranged in conjunction with the referring facility, often coordinated by the MAC.

On CCRU arrival, patients are assessed immediately by the CCRU and stroke neurology teams. The CCRU team assesses hemodynamic stability and the need for airway protection, establishes adequate intravascular (and at times arterial) access, and initiates treatment of hypertension for patients who received thrombolytics prior to transfer. The stroke neurology team performs an initial National Institutes of Health Stroke Scale (NIHSS) assessment and confirms eligibility for MT. If eligibility is confirmed the patient, once stabilized, is transferred to the neuroradiology angiography suite for MT. Following thrombectomy, the patient is transferred either to the NCCU or the CCRU for further intensive stroke care. The patient is ultimately transferred to the NCCU when an appropriate bed is available.

This process, as well as the staffing and protocols of each involved medical team, had been maintained since before the pandemic and continued throughout the COVID-19 pandemic. During the pandemic, all patients transferred to the CCRU with thrombotic disease (such as ischemic stroke) were treated as a patient under investigation (PUI) for COVID-19 and remained so until results of a polymerase chain reaction (PCR) test became available. However, patients were still taken to the angiography suite immediately as indicated. When caring for any PUI, clinicians were required to use full PPE, including gowns, powered air-purifying respirators, and supplied-air hoods. Following a negative PCR, PPE requirements relaxed to require only gowns and N95 masks.

Outcome

The primary outcome was the time interval between CCRU arrival and transfer to the angiography suite. This was selected a priori as a modifiable risk factor that reflects the process and efficiency of care within the CCRU. Our secondary outcome was the percentage of patients who achieved good neurologic recovery, defined as 90-day modified Rankin scale (mRS) score ≤ 2. The 90-day mRS score was collected prospectively by our stroke neurology team as part of required clinical stroke care for a CSC. For our intention-to-treat analysis, we categorized any patients who were lost to follow-up, such as patients in skilled nursing facilities, as mRS >3.

Data Collection

Patient demographic data (age, gender, past medical history) was extracted from our electronic health records. Clinical data during the initial ED stay at the sending facility, such as initial vital signs, ED triage time, and time from triage to computed tomography (CT), was extracted using the paper records accompanying patients as part of the transfer process. Prior to data extraction, junior investigators who were not blinded to the study hypothesis were trained to collect data in sets of 10 patients' charts until inter-rater agreement reached 90%. Data disagreement was adjudicated by a senior investigator. Data was extracted and entered into

a standardized Excel spreadsheet (Microsoft Corporation, Redmond, WA).

Data Analysis

We used descriptive analysis to express patient data as mean (±SD), median (interquartile [IQR]), or percentage. Prior to analysis, we assessed and analyzed histograms of continuous data distribution patterns with the Student *t*-test or Mann-Whitney U test as appropriate. Categorical data was analyzed via the Pearson chi-square test.

We performed time series analyses to examine the correlation of certain time intervals with new or cumulative cases of COVID-19. Data for global cases of COVID-19 was obtained from the website Statista.com on September 1, 2022.[14] We performed analyses of different median time intervals to assess trends of different time intervals during the pandemic. The trend with the smallest values of mean absolute percentage error, mean absolute deviation, and mean squared deviation among four different algorithms (linear, quadratic, exponential growth, S-curve) was considered as having the best fit for the time series. To further assess the impact of the pandemic on operations of each stage of the patient's care (from ED arrival to the angiography suite), we created a dummy variable, "presenting during pandemic," for patients presenting between March 1, 2020–May 31, 2021.

We used the classification and regression tree (CART) method to identify predictors associated with patients' neurological outcomes. The variables for the CART (Appendix 1) were identified a priori as known clinically important factors for patient outcome, according to literature and clinical consensus. The CART is a supervised, machine-learning technique that uses repetitive partitioning to identify a series of dichotomous splits (eg, 90-day mRS ≤2 vs 90-mRS ≥3) until the algorithm achieves "purity" where no further split is possible. The CART generated a tree of decision from the interactions between all the independent variables that we defined a priori. The algorithm assigns the most influential independent variable a relative variable importance (RVI) of 100%. Other important variables are assigned subsequent RVIs as percentages of the most important factor.

We assessed the discriminatory capability of the CART model using the area under the receiver operating curve (AUROC) analysis. An AUROC of 1.0 would have perfect discriminatory capability of predicting the dichotomous outcome. Our CART algorithm was performed with 10-fold cross-validation, a minimum of three counts per terminal node, and a maximum depth of 30 layers and 30 terminal nodes. The optimal tree was selected according to a balance between number of nodes and lowest miscalculation cost.

Additionally, we performed sensitivity analysis to assess whether the time intervals were important factors when analyzed with different groups of variables. In this sensitivity analysis, instead of using separate segments of time intervals, such as CCRU-to-angiogram suite, angiogram suite-to-groin puncture, and groin puncture -to-recanalization, we divided the overall time interval into ED in-and-out (covering the time from ED triage to transfer) and CCRU arrival-to-recanalization (Appendix 2).

We performed all descriptive analyses, time series and CART analyses via Minitab version 20 (Minitab LLC, State College, PA). All P-values < 0.05 were considered statistically significant.

RESULTS

The study identified 225 patients during the study period; 22 patients did not meet inclusion criteria, and 203 were included in the final analysis (Figure 1). One hundred thirty-five (66.5%) patients with AIS-LVO were transferred from an ED to the CCRU between January 2018–February 2020 pre-pandemic, while 68 (33.5%) were transferred between March 2020–May 2021 during the pandemic. The mean age was 67 (±15) years (Table 1). Patients' median NIHSS at CCRU arrival in the pre-pandemic period was similar to that of patients during the pandemic period (Table 1). Patients during the pandemic period had a higher percentage of occlusion from middle cerebral artery (59/68, 87%), compared to patients in the pre-pandemic period (97/143, 72%, difference 15%, 95% CI −0.26 to −0.04). A higher percentage of patients in the pandemic period achieved good 90-day neurological recovery (33/68, 49%) compared to patients in the pre-pandemic group (41/143, 32%, difference 17%, 95% CI −0.32 to −0.03).

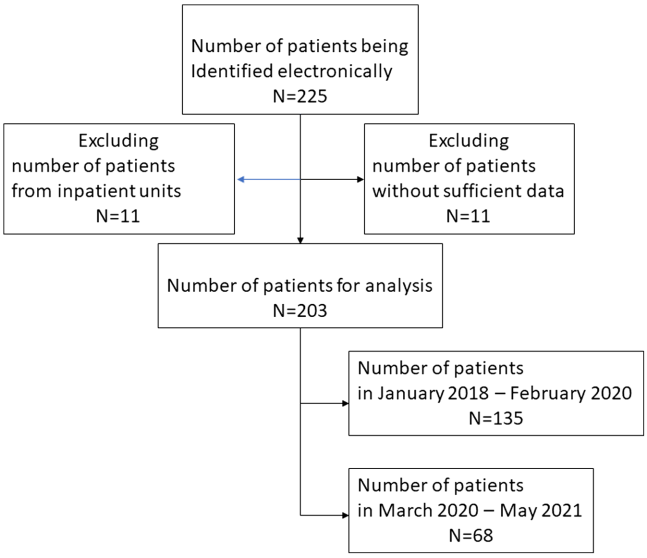

Figure 1. Patient selection diagram.

Table 1. Patients' demographics.

Variables	All patients	Pre-pandemic (1/2018–2/2020)	Pandemic (3/2020–5/2021)	Difference between groups		*P*-value
	N = 203	N = 135	N = 68	N	95% CI	
Age, mean (SD)	67 (15.15)	66 (14.94)	68 (15.57)	−1.89	(−6.42, 2.63)	0.41
Gender						
Female, N (%)	111 (55)	72 (53)	39 (57)	−0.04	(−0.18, 0.10)	0.66
Male, N (%)	92 (45)	63 (47)	29 (43)	0.04	(−0.10, 0.18)	0.66
IV thrombolysis, N (%)	89 (44)	63 (47)	26 (38)	0.08	(−0.06, 0.23)	0.3
NIHSS in ED, median [IQR]	17 [12–21]	17 [12–21]	16 [10–21]	1	(−1, 3)	0.35
NIHSS on CCRU arrival, median [IQR]	17.5 [12–21.25]	18 [14–21]	16 [11–23]	0	(−2, 2)	0.71
Occluded vessels, N (%)						
Internal carotid artery only	19 (9)	16 (12)	3 (4)	0.07	(0, 0.15)	0.12
Middle cerebral artery only	156 (77)	97 (72)	59 (87)	−0.15	(−0.26, −0.04)	0.02
Multiple vessels	28 (14)	22 (16)	6 (9)	0.07	(−0.02, 0.17)	0.2
Laboratory values, mean (SD)						
Sodium (mEq/L)	138 (3.29)	138 (3.16)	137 (3.36)	1.35	(0.38, 2.32)	0.007
Creatinine (mg/dL)	0.96 (0.81)	0.91 (0.34)	1.04 (1.32)	−0.13	(−0.46, 0.19)	0.41
International normalized ratio	1.14 (0.25)	1.15 (0.25)	1.11 (0.25)	0.03	(−0.04, 0.11)	0.37
Outcomes						
TICI 2c/3, N (%)	132 (65)	85 (63)	47 (69)	−0.06	(−0.2, 0.08)	0.44
90-day mRS 0–2, N (%)	74 (38)	41 (32)	33 (49)	−0.17	(−0.32, −0.03)	0.02
Mortality, N (%)	46 (24)	30 (23)	16 (24)	0	(−0.13, 0.12)	0.99

CI, confidence interval; *CCRU*, critical care resuscitation unit; *ED*, emergency department; *IV*, intravenous; *mEq/L*, milliequivalent per liter; *mg/dL*, milligrams per deciliter; *mRS*, modified Rankin scale; *NIHSS*, National Institute of Health Stroke Scale; *TICI*, thrombolysis in cerebral infarction; *TICI 2c*: near complete perfusion except for slow flow; *TICI 3*: complete antegrade reperfusion of the previously occluded target artery.

Time Intervals

Overall, median interval (minutes) from last known well time to recanalization was similar for both groups (462 [326–986] vs 557 [371–984], difference 40, 95% CI −119 to 32), although last known well time to CCRU arrival (327 [221–682] vs 472 [279–869], difference 80, 95% CI 20–157, $P = 0.001$) and groin puncture (370 [270–752] vs 512 [332–911], difference 80, 95% CI 20–154, $P = 0.01$) were significantly longer in the pandemic group.

Patients in the pandemic group had a statistically longer time from ED triage to CT (difference 7 minutes, 95% CI −12 to −1) (Table 2). However, ED in-and-out times were similar in both groups (Table 2). During the pandemic, patients had statistically shorter time (minutes) between arrival at the CCRU and leaving the CCRU for the angiography suite (difference 9, 95% CI 4–13). Similarly, median interval (in minutes) from groin puncture to recanalization was statistically shorter during the pandemic (difference 9, 95% CI 2–17).

We plotted median values of different time intervals with the number of total global cases of COVID-19 (Figure 2A) or total number of global new cases (Figure 2B). This time series suggested that the ED in-and-out time was most parallel with the number of new cases (Figure 2B, line 1 and line 2). Figures 2C–2F display different trend analyses for different time intervals between January 2020–May 2021. Overall, a downward trend of all time intervals toward May 2021 was observed.

Classification and Regression Tree (CART) Analysis

The CART analysis identified that patients' NIHSS at arrival at the CCRU was the most important predictor for poor neurological recovery at 90 days, as NIHSS was assigned a RVI of 100% (Figure 3A). The ED in-and-out time and CCRU arrival-to-angiography time were identified by the CART analysis as the third and sixth most important factors for good neurologic outcome, with reported RVI of 25% and 16.5%, respectively (Figure 3A). Patient's NIHSS at CCRU arrival was responsible for the first split in the decision tree (Node 1, Figure 3B). If a patient's age was greater than 69.5 years (Node 2), the patient was more likely to have poor neurologic recovery (Terminal node 3, Figure 3B). The only modifiable risk factors identified as "important" were median ED in-and-out and CCRU

Table 2. Comparison of various time intervals for patients with cerebrovascular accident due to large vessel occlusion presenting for mechanical thrombectomy prior to or during the COVID-19 pandemic.

Variables	All patients	Pre-pandemic (1/2018–2/2020)	Pandemic (3/2020–5/2021)	Difference between groups		*P*-value
	N = 203	N = 135	N = 68	N	95% CI	
Intervals from LKW						
LKW to CCRU arrival	361 [243–724]	327 [221–682]	472 [279–869]	−80	(−157, −20)	0.001
LKW to groin puncture	403 [294–784]	370 [270–752]	512 [332–911]	−80	(−154, −20)	0.01
LKW to recanalization	483 [340–986]	462 [326–986]	557 [371–984]	−40	(−119, 32)	0.25
ED time intervals (minutes), median [IQR]						
Triage to CT scan results	25 [14–40]	21 [13–37]	30.5 [18.3–47]	−7	(−12,−1)	0.02
Triage to neurology consult at UMMC	65 [40–110]	68 [46–119]	57.5 [36–91.5]	11	(−1, 24)	0.09
Triage to IV thrombolysis (N = 91)	48 [31–72]	48 [29–70.5]	51 [33.5–74]	−1	(−13, 12)	0.79
Triage to leaving ED (ED in-out)	157 [125–211]	157 [119–221]	157 [131.3–202.8]	−3	(−20, 16)	0.74
Transfer request to CCRU arrival	111 [92–139]	106 [86–131]	121.5 [100–149]	−14	(−24, −3)	0.01
Time intervals after arrival at CCRU (minutes), median [IQR]						
CCRU arrival to thrombectomy suite	28 [18–40]	32 [21–44]	20.5 [14–33.8]	9	(4, 13)	0.01
Thrombectomy suite to groin puncture (minutes), median [IQR]	14 [11–19]	13 [10–17]	18.5 [13.25–22.75]	−5	(−7, −3)	0.01
Groin puncture to recanalization (minutes), median [IQR]	40 [23–70]	44 [27–73]	37 [19.25–55]	9	(2, 17)	0.01

CCRU, critical care resuscitation unit; *CT*, computer tomography; *ED*, emergency department; *IQR*, interquartile range; *IV*, intravenous; *LKW*, last known well; *UMMC*, University of Maryland Medical Center.

arrival-to-angiography times. The AUROC for the CART's training dataset was good (0.72), as was the AUROC for the test dataset (0.58); misclassification cost was 0.63.

DISCUSSION

Our findings suggest that despite previously noted impacts of the COVID-19 pandemic on multiple aspects of emergency and critical care, the care processes used to facilitate treatment with MT for patients with AIS-LVO were relatively unaffected, as were patient outcomes. Given the spoke-and-hub model of comprehensive stroke care frequently employed throughout the US, including at our center, treatment with MT requires rapid coordination of multiple teams and resources, often across multiple resources. We found that the only time interval during which patients experienced statistically significant delays was that from ED triage to CT scanner (although with a mean difference of only 7 minutes, it is unclear whether this delay conferred clinical significance). This suggests that once an LVO was identified, the care coordination systems previously developed to facilitate rapid transfer and treatment of these patients were able to operate efficiently despite the ongoing pandemic.

The philosophy that "time is brain" continues to be the prime consideration in the treatment of patients with AIS-LVO, and has led to a nationwide emphasis on efficiency, organization, and protocolization of stroke identification and treatment at each stage of care: in the community (via education initiatives promoting stroke recognition); among emergency medical services (EMS) professionals; in the ED; and in in-hospital settings across the country. The importance of these systems and organized care have been emphasized in clinical studies and national guidelines.[15,16] The findings presented in this study support this emphasis as well: our CART analysis identified the time interval between CCRU arrival and arrival in the angiography suite and that between ED triage and departure for transfer as the most important modifiable risk factors in patients' neurologic outcomes.

Although our finding is consistent with current consensus,[6] it was in contrast to a previous study about time interval metrics in the ED.[5] Scheving et al[5] suggested that time intervals in the ED were not associated with patients' 90-day outcome. However, the study by Scheving et al was restricted by a smaller number of ED patients undergoing MT and retrospective calculation of mRS. Our institution uses a highly coordinated and protocolized approach to facilitate prompt identification, transfer, and treatment of patients presenting to surrounding primary stroke centers who are candidates for MT. The expeditious transfer of

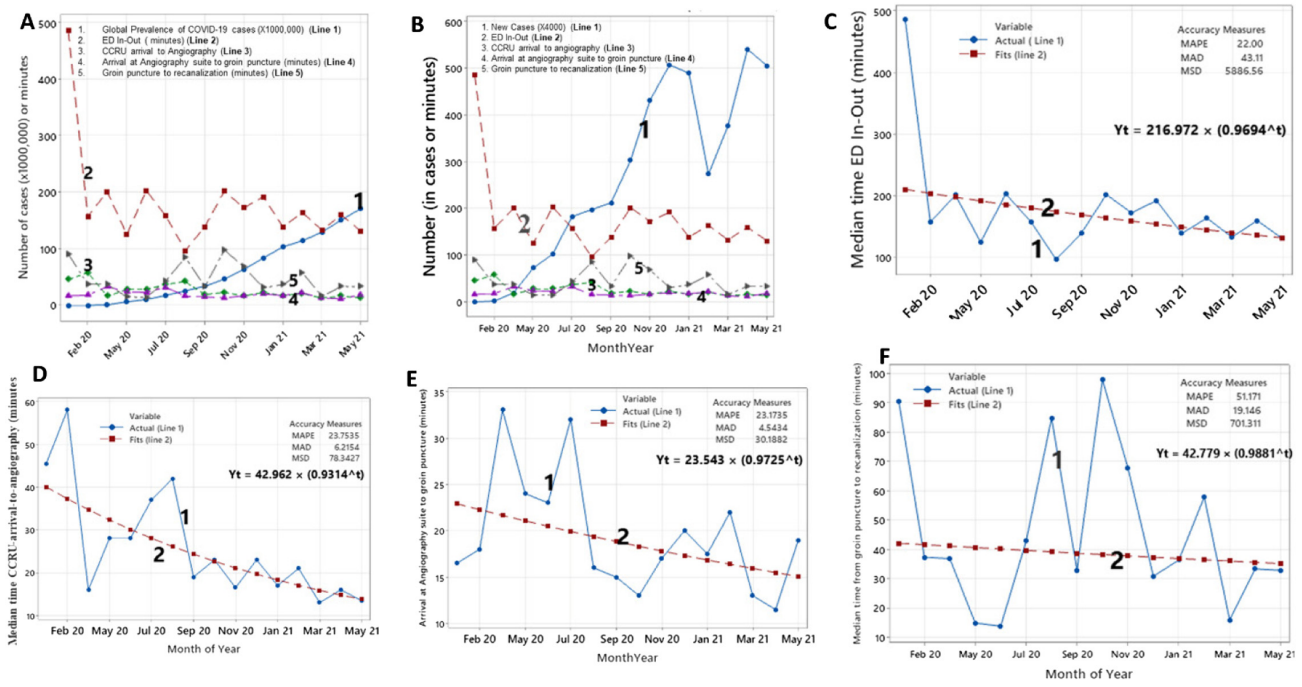

Figure 2. Time series analysis of different time intervals for patients with cerebrovascular accident due to large vessel occlusion (LVO) presenting for mechanical thrombectomy during the COVID-19 pandemic. Figure 2A. Time series analysis comparing different time intervals for treatment of cerebrovascular accident due to LVO and global prevalence of COVID-19 cases. Figure 2B. Time series analysis of prevalence of new COVID-19 cases and different time intervals for treatment of cerebrovascular accident due to LVO. Figure 2C. Trend analysis of time interval of ED in-and-out time for patients with cerebrovascular accident due to LVO over the course of the COVID-19 pandemic. Figure 2D. Trend analysis of time interval between CCRU arrival and arrival in the angiography suite for patients with cerebrovascular accident due to LVO presenting during the COVID-19 pandemic. Figure 2E. Trend analysis of time interval from arrival at the angiography suite to groin puncture for patients with cerebrovascular accident due to LVO occlusion presenting during the COVID-19 pandemic. Figure 2F. Trend analysis of time interval from groin puncture to recanalization for patients with cerebrovascular accident due to LVO presenting during the COVID-19 pandemic.

CCRU, critical care resuscitation unit; *COVID-19*, coronavirus disease 2019; *ED*, emergency department; *MAPE*, mean absolute percentage error; *MAD*, mean absolute deviation; *MSD*, mean squared deviation; *IR*, interventional radiology.

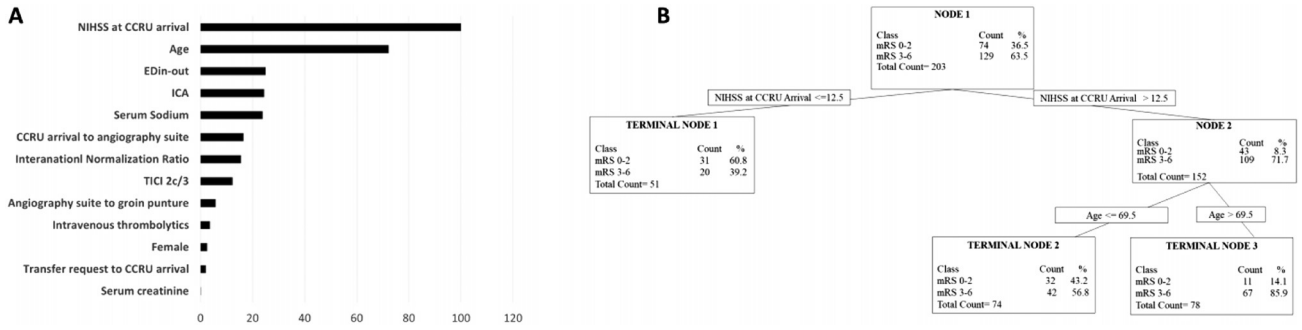

Figure 3. Relative variable importance (RVI) values and the tree diagram from the classification and regression tree (CART) analysis. Figure 3A. RVI from the CART analysis. The CART was used to assess important clinical factors and patients' neurological outcome, defined as 90-day modified Rankin scale (mRS) 0–2. Figure 3B. The tree diagram from the CART analysis. The CART was used to assess important clinical factors and patients' neurological outcome, defined as 90-day mRS 0–2.

patients with time-sensitive illness is a primary mission of the CCRU,[13] and our group has previously demonstrated that the CCRU model is associated with shorter transfer times for patients with AIS-LVO to our institution.[9]

Our findings not only support previous recommendations that protocolized and organized care systems should be prioritized given an association with improved outcomes but highlight that such systems can promote standardized and

efficient care even in the setting of large-scale disruptions and disasters, such as the COVID-19 pandemic. Patients transferred to our facility during the pandemic did not experience worse outcomes than those presenting pre-pandemic and—apart from time from ED triage to CT imaging, as noted above—did not experience significant delays in their care following ED arrival. Our time-series analysis found that, except for an initial slowdown in ED in-and-out time at the very beginning of the pandemic, which we believe is consistent with healthcare access issues experienced by patients during this early period and the outsized operational impact of the outbreak,[10,11] each step of care for patients with AIS-LVO proceeded at a relatively constant (to slightly improving) rate following ED arrival, regardless of prevalence of total or new COVID-19 cases. While these trends were likely, at least in part, due to the relatively small number of AIS-LVO patients presenting to EDs during the early COVID-19 period, we believe they also reflect the resilience of stroke care protocols across multiple care settings.

Within certain areas of the hospital, the COVID-19 pandemic prompted the introduction of new care and coordination processes to meet the demands of an increasing volume of critically ill patients and ensure the safety of care team members when caring for patients with a highly communicable disease. These processes may have improved care coordination for patients without COVID-19 as well. For example, during the height of the COVID-19 pandemic, all transport clinicians were required to notify the CCRU team of their estimated time of arrival, to give team members time to don their PPE in preparation to receive the patients. For patients transferred for AIS-LVO, the stroke neurology and neuro-interventional teams received the same advanced notice, which allowed them to be present at the bedside when the patient arrived. After a quick assessment, eligible patients were then quickly moved from the CCRU to the angiography suite by the neuro-interventional team. Our study demonstrated relative reductions in the median times from CCRU arrival to angiography suite, and from CCRU arrival to recanalization overall, which may in part reflect the impact of these new protocols.

While we found that stroke processes of care in the ED and within the hospital were relatively unaffected by the pandemic, we did observe a significant increase in time from last known wellness to arrival at the CSC during COVID-19, highlighting the breakdown in the first step of the stroke "chain of survival"—activation of EMS. This is unsurprising given the emphasis on social distancing and resultant isolation during the pandemic. Although this risk factor is modifiable through improved public education and outreach, it is not a time interval that can be meaningfully impacted by hospital and ED processes, and thus was not included in our CART analysis. Multiple prior studies have demonstrated delays in presentation for stroke during the COVID-19 pandemic across the globe, thought to be related to delays in recognition of stroke symptoms or calling for help due to social isolation as well as fear of contracting COVID-19 in a healthcare setting.[17–20] We anticipate that this breakdown may have had an even greater impact outside the scope of this study by reducing the percentage of AIS-LVO patients presenting within the "window" for MT. Because our study population included only patients transferred for thrombectomy, those patients would not be captured here.

LIMITATIONS

Given the unique model of the CCRU as a well-resourced resuscitation unit dedicated to facilitating rapid transfer and critical care for patients with time-sensitive conditions, our results may not be generalizable. The pre-thrombectomy care provided in our CCRU population would be likely to occur in the ED at other facilities that do not have similar models, which may be more subject to the constraints imposed by COVID-19 (although our findings do not suggest this). However, our population was derived from more than 50 referring EDs within the regions; therefore, the time metrics from the ED to arrival to recanalization should still be applicable to other institutions. Since almost all our patients were transferred from other hospitals, a large percentage of the patients did not have Alberta Stroke Program Early CT (ASPECT) scores; therefore, we decided not to report the ASPECT score or use it in our analysis. The number of patients being transferred to the CCRU during the study period was relatively smaller than in the pre-pandemic period, which lowered the AUROC of our CART algorithm during the testing phase. Neither did we assess the COVID-19 vaccination status among patients and staff, which might have affected the CCRU staff's preparedness when receiving patients.

CONCLUSION

This study showed that the outcomes and initial care of patients with acute ischemic stroke from large vessel occlusion treated with mechanical thrombectomy were not affected by the COVID-19 pandemic at our comprehensive stroke center. This initial care spanned from ED arrival through identification of LVO, coordination of transfer to a CSC, and facilitation of rapid mechanical thrombectomy. Besides the patients' intrinsic factors (NIHSS at arrival, age), the time intervals from ED arrival to transfer, and from CCRU arrival to arrival in the angiography suite, were identified as important, independent risk factors associated with 90-day modified Rankin scale. This highlights the importance of streamlined and protocolized care for patients with AIS-LVO eligible for mechanical thrombectomy and illustrates the role of a critical care resuscitation unit in promoting these care systems.

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Assessing Team Performance: A Mixed-Methods Analysis Using Interprofessional *in situ* Simulation

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Introduction: Optimizing the performance of emergency department (ED) teams impacts patient care, but the utility of current, team-based performance assessment tools to comprehensively measure this impact is underexplored. In this study we aimed to 1) evaluate ED team performance using current team-based assessment tools during an interprofessional in situ simulation and 2) identify characteristics of effective ED teams.

Methods: This mixed-methods study employed case study methodology based on a constructivist paradigm. Sixty-three eligible nurses, technicians, pharmacists, and postgraduate year 2–4 emergency medicine residents at a tertiary academic ED participated in a 10-minute in situ simulation of a critically ill patient. Participants self-rated performance using the *Team Performance Observation Tool* (TPOT) 2.0 and completed a brief demographic form. Two raters independently reviewed simulation videos and rated performance using the TPOT 2.0, *Team Emergency Assessment Measure* (TEAM), and *Ottawa Crisis Resource Management Global Rating Scale* (Ottawa GRS). Following simulations, we conducted semi-structured interviews and focus groups with in situ participants. Transcripts were analyzed using thematic analysis.

Results: Eighteen team-based simulations took place between January–April 2021. Raters' scores were on the upper end of the tools for the TPOT 2.0 (R1 4.90, SD 0.17; R2 4.53, SD 0.27, IRR [inter-rater reliability] 0.47), TEAM (R1 3.89, SD 0.19; R2 3.58, SD 0.39, IRR 0.73), and Ottawa GRS (R1 6.6, SD 0.56; R2 6.2, SD 0.54, IRR 0.68). We identified six themes from our interview data: team member entrustment; interdependent energy; leadership tone; optimal communication; strategic staffing; and simulation empowering team performance.

Conclusion: Current team performance assessment tools insufficiently discriminate among high performing teams in the ED. Emergency department-specific assessments that capture features of entrustability, interdependent energy, and leadership tone may offer a more comprehensive way to assess an individual's contribution to a team's performance. [West J Emerg Med. 2024;25(4)557–564.]

INTRODUCTION

Patient care in the emergency department (ED) depends on highly effective interprofessional teams. ED teams are dynamic, complex to train, and subject to the preparedness of individual team members while caring for critically ill patients. Although team training has been championed by

the National Academy of Medicine to reduce adverse events, the fluid nature of ED teams makes such training complex.[1] Additionally, individual team member contributions can influence the readiness of an ED team. Previous research has shown that individual performance and communication failures are substantial contributors to adverse events,[2,3] affecting the interdependent nature of team-based care.[4,5] Therefore, evaluating how well existing team performance assessments are at capturing individual and team-based performance is necessary to ensure accurate measurement of teams under the direst circumstances.

The Agency for Healthcare Research and Quality and the US Department of Defense rigorously developed measures that evaluate teamwork.[1] The most widely used tool for assessing team performance and patient safety is the Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) *Team Performance Observation Tool* (TPOT), now with a second version, TPOT 2.0. This 23-item instrument integrates five areas of competence: team leadership; team structure; situation monitoring; mutual support; and communication.[6] The *Team Emergency Assessment Measure* (TEAM) is an alternate 12-item tool that also measures team performance, but it was designed specifically for team assessment in the ED setting.[7] The *Ottawa Crisis Resource Management Global Rating Scale* (Ottawa GRS) is another tool that assesses crisis resource management skills of leader-team member interactions.[8] Although these tools have some validity evidence,[8–13] the extent to which they reliably and accurately measure team-based performance in various contexts warrants further investigation to understand how to best assess an individual's contributions to ED team performance.

Further complicating team assessment is the critical role of dyads[14] and the interdependence of individuals within teams.[4,15] Interprofessional members of the ED team are inseparably tied to one another, and often there is no choice whether someone becomes part of the team. In the ED, teams are formed out of necessity to provide acute care for critically ill patients. These circumstances essentially require immediate entrustment among individual team members, which is not always feasible or realistic. Underlying the theory of interdependence is the idea that some pairings of team members will be more effective than others; therefore, identifying key factors that influence team member dynamics is critical.[14,15] This conceptual framing has implications for how ED team-based performance (ie, where teams rapidly form to meet the emergent needs of patients) is assessed.

Due to our incomplete understanding of the important elements that contribute to individual and team performance, we set out to explore the effectiveness of current team-based performance assessment tools in the ED setting. Using an interprofessional, in situ simulation, we aimed to do the following in this study: 1) evaluate the effectiveness of TPOT 2.0, TEAM, and Ottawa GRS team-based assessment tools in the ED setting; and 2) identify characteristics of effective teams that are attributable to individuals and may not be captured within existing team-based assessments.

Population Health Research Capsule

What do we already know about this issue?
Emergency department teams are dynamic and complex, with both individual and team factors that impact patient care.

What was the research question?
We aimed to understand the ability of performance tools to assess ED teams as well as identify characteristics of effective teams.

What was the major finding of the study?
ED teams in the simulation were rated highly on all tools with good interrater correlations 0.46, 0.68, and 0.72 for each of the tools.

How does this improve population health?
A better understanding of interdependent team factors will allow us to educate and train more effective patient care teams.

METHODS

We used mixed-methods case study methodology in the context of a team-based, in situ simulation to explore the effectiveness of team-based assessments and explore the relationship between team dynamics and individuals' team-based performance.[16,17] We used a constructivist paradigm, which holds that an individual's perspective is the basis for reality and that multiple, socially constructed realities can exist at once for this research.[18,19] We chose case study methodology to understand the various perspectives of team participants and observers in the context of an ED-based simulation.

All ED nurses, technicians, pharmacists, and postgraduate year (PGY) 2–4 emergency medicine residents within one academic health system were eligible to participate in this study. We excluded PGY-1 residents due to their limited experience leading resuscitations. The study took place in a large, suburban, academic ED at a tertiary care facility. We conducted simulations twice per week during low-volume hours; strict policies for cancellation were followed based on ED volume and patient care needs. The Stanford University Institutional Review Board approved this study (#55327).

Quantitative Study Design and Data Collection

Using convenience sampling, we solicited volunteers to participate in simulations held over a four-month period (January–April 2021). Each simulation included a nurse, a resident, a pharmacist and, in some cases, an ED technician. Attendings were not included to ensure that patient care would not be disrupted. Prior to the simulated case, the 63 participants received a two-minute pre-brief from an in-person facilitator on expectations for the simulation, goals of the session, and confidentiality. We obtained written consent for study participation and video recording of the simulations, and participants could opt out of the study at any time.

We conducted a simulated case of a patient presenting with sepsis and an arrhythmia using the high-fidelity HAL patient simulator (Gaumard Scientific Company Inc, Miami, FL) and equipment props that are typically available in an ED patient room. The ED pharmacist supplied simulated critical care medications for use during the scenario. We recorded the simulation for asynchronous rating. The case was followed by a 10–15 minute debrief with all team members, which was not recorded to protect the psychological safety of participants. After the debrief, the participants completed a self-rating for the entire team using the TeamSTEPPS TPOT 2.0 to increase familiarity with the components of TeamSTEPPS, as well as a brief demographic form that included training year/years of work experience, age, and gender. We omitted items 2d, 5c, and 5d on the TPOT 2.0, as these were not relevant to our study protocol.

We recruited two board-certified emergency physicians from outside institutions to assess the simulation video recordings. The two raters underwent a two-hour training session where they were introduced to the project and the three instruments. The facilitator also reviewed an example case, which the reviewers independently scored and were then calibrated against each other. The raters subsequently watched an example video and deliberated each item on the scoring sheet until they arrived at a consensus. Raters then independently reviewed all recorded simulations for which consent was provided by all team members. Raters assessed team performance with the TPOT 2.0 and TEAM. They assessed leadership by completing the leadership categories on TPOT and TEAM, as well as the Ottawa GRS. Only the TPOT 2.0 assessment by the raters was used for comparative data analysis to use objective third-party ratings rather than the self-assessment from participants.

Qualitative Study Design and Data Collection

We invited all volunteer staff participants via email who completed the simulation component of the study to participate in an individual, semi-structured interview via Zoom (Zoom Video Communications, San Jose, CA). A total of 10 ED staff members volunteered to participate in the semi-structured interview, including five nurses, four pharmacists, and one ED technician, and each participant received a $25 gift card as compensation for their time. We also conducted two focus groups with five resident team leaders. Each session lasted 30–60 minutes. A single female interviewer (AR) conducted all interviews and focus groups with predetermined questions that were then allowed to progress to open dialogue.

Data Analysis - Quantitative

We collected demographic information and calculated measures of central tendency for each group. We also analyzed rater's average scores and standard deviations for each of the tools. We performed a correlation analysis of the within-rater and between-rater scores on each tool. We also compared team-based leader performance based on the Ottawa GRS with the leadership subset on the TEAM and TPOT 2.0. We generated validity evidence[20,21] for the TPOT 2.0 using content validity, internal structure, and relationship to other variables. Content validity was assessed by examining which performance measures participants thought should be included in an assessment tool. We examined internal structure by assessing correlations between the inter-rater reliability and self vs rater scores. Relationship to other variables was manifested as concurrent validity by comparing the tools. We performed data analysis using IBM SPSS v 27 (SPSS Inc, Chicago, IL) and Microsoft Excel v 16.6 (Microsoft Corporation, Redmond, WA).

Data Analysis - Qualitative

Of the 63 participants, 15 (24%) agreed to the interview. We transcribed and anonymized the interviews using the HIPAA-compliant software TranscribeMe! (TranscribeMe Inc, Oakland, CA) program. Two coders (VJ and DR) who were not involved in either the simulation or interview process underwent qualitative training consisting of pre-reading on thematic analysis and completion of a Dedoose webinar v 9.0.17 (Dedoose, Manhattan Beach, CA) webinar. Coders completed a one-hour training session using an excerpt of a transcript to demonstrate the coding process. A second excerpt was done in real time. The coders were then given five days to code the first transcript. This was reviewed by both coders and other members of the research team to discuss and identify patterns. Coders then read all transcripts prior to starting the first coding round. In accordance with Braun and Clarke's six phases of analysis,[22] after complete read-through of the coded transcripts, coders then generated initial codes on the second review.

After the initial round, two researchers (VJ and DR) discussed and refined all independently created codes. Consensus was achieved with review of each transcript on a unified code list. Two other members of the research team (AR and SW) then reviewed the transcripts and codes to develop themes. Investigator triangulation of themes, with attention to the quantitative findings, was performed by a

third member of the research team (SS). Initial code and excerpt to theme categorization resulted in 67% independent agreement between the two secondary reviewers. Coding was then revised, consolidated, and modified based on consensus. Two researchers (AR and SW) performed a round of focused re-coding and theme generation, and a final reviewer (AR) performed the last round of code review and edits within existing themes.

Regarding reflexivity, both coders (DR and VJ) had significant experience with healthcare teams and crisis resource management as prior simulation technicians, but were not employed full-time in the ED. While this limited their context for some of the qualitative analysis, it allowed them to focus on teamwork and leadership features without preconceived notions. The code reviewers (AR and SW) are emergency physicians who practice at the academic health center where the study was conducted. Both code reviewers have been involved in residency program leadership. AR facilitated all the interviews but was blinded to the identity of residents and staff during coding.

RESULTS

Quantitative Analysis

We completed 18 simulations with 63 participants from January–April 2021. Some cases had a pharmacist who had participated in multiple simulations (due to the limited number of clinical pharmacists employed in the ED); otherwise, participants were part of a scenario only once. Participant demographics are listed in Table 1 along with the mean self-rated TPOT 2.0 score. Missing data points were omitted from the analysis.

The descriptive statistics of rater scores on each scenario were on the upper end of the scale for each of the tools. The two raters' scores clustered high for the five-point TPOT 2.0 (R1 4.90, SD 0.17; R2 4.53, SD 0.27), the four-point TEAM tool (R1 3.89, SD 0.19; R2 3.58, SD 0.39), and the seven-point Ottawa GRS tool (R1 6.6, SD 0.56; R2 6.2, SD 0.54). All three scales were noted to have scores that crowded around the maximum. There were high correlations of total score for a given case reviewed within the same rater, particularly for TEAM and Ottawa GRS. Inter-rater correlations were 0.46, 0.68, and 0.72, respectively, for the TPOT 2.0, Ottawa, and TEAM (Table 2). Year in residency (PGY-2, PGY-3, PGY-4) was not correlated to raters' scores on each of the tools.

Qualitative Analysis

We identified six themes related to the individual and team-based performance (Table 3), including the following: 1) *team member entrustment*; 2) *interdependent energy*; 3) *leadership tone*; 4) *optimal communication*; 5) *strategic staffing*; and 6) *simulation empowering team performance*.

The concept of entrustment stems from the competency-based medical education literature.[23] In the setting of

Table 1. Demographic characteristics and mean score on Team Performance Observation Tool 2.0.

Group	Years of experience	Male	Female	Mean score on self-rated TPOT
Residents	PGY-2 (7 residents) PGY-3 (5 residents) PGY-4 (6 residents)	14	4	84
Nurses	8 (3–30)	5	11	93
Techs	3 (1–10)	5	7	90
Pharmacists	5 (1–17)	11	6	88

PGY, postgraduate year; *TPOT*, Team Performance Observation Tool.

Table 2. Inter-rater correlations for each team and leader performance tool.

Rater and tool	Rater 1 TPOT	Rater 2 TPOT	Rater 1 Ottawa	Rater 2 Ottawa	Rater 1 TEAM	Rater 2 TEAM
Rater 1 TPOT	1.00					
Rater 2 TPOT	0.46	1.00				
Rater 1 Ottawa	0.89	0.35	1.00			
Rater 2 Ottawa	0.44	0.52	0.68	1.00		
Rater 1 TEAM	0.71	0.27	0.92	0.69	1.00	
Rater 2 TEAM	0.45	0.54	0.66	0.94	0.73	1.00

TPOT, Team Performance Observation Tool; *Ottawa*, Ottawa Crisis Resource Management Global Rating Scale; *TEAM*, Team Emergency Assessment Measure.

Table 3. Themes reflecting effective leadership and team performance.

Theme	Description	Exemplary quotes
Team member entrustment	The expectation of team members to competently execute their interprofessional tasks without supervision or interjection and have a substantial cross-understanding of roles to provide support of other team member tasks through anticipation and automaticity.	• *I guess having trust, also, that, for example, we need IV access. I need to give epinephrine or whatever. Just having that trust that your team members are going to be able to carry that out, and that you don't have to worry about, "Okay. Is this happening? Is this not happening?" So having that interpersonal trust between you, your provider, your other teammates is really important. RN, participant E* • *People are that well trained and things happen automatically, right? You don't need the doctor to be like, "Hey, can we get an IV line? Can you put them on the monitor?" It happens automatically. So in that sense, I think there is a very good understanding, at least in my situation, of where everyone falls into place. Pharmacist, participant H*
Interdependent energy	The ability for one individual to influence others with non-verbal cues and general disposition that in turn impacts the energy and performance of team members.	• *So if they're, I guess, I don't want to say outgoing, but if they're soft spoken, it tends to be a little bit more of a struggle. And then I think that if they are– yeah. I think generally, if they're a warmer person, the team tends to rally around with a little bit more excitement or a little bit more energy versus someone with a more flat affect, then everyone comes in kind of to match that. Pharmacist, participant J* • *That is a skill, for you to kind of see someone going through a very critical situation, to be able to transform the energy into something positive. RN, participant C*
Leadership tone	The ideal demeanor of a leader that balances collaborative and decisive actions while maintaining continuous open communication and vulnerability with the team.	• *I think having a demeanor that's sort of open and makes people comfortable to speak up, whether it's with an idea they have or something they see that someone else is not doing right or anything, just feeling comfortable speaking up. ED tech, participant B* • *I don't know if saying a sense of humility is the right way of saying this for the team leader but realizing that you may not know everything in every single moment. Resident, participant K*
Optimal communication	Communication that is individualized and spoken in an appropriate tone at an appropriate time to contribute to the shared mental model.	• *You're saying the same words. It's just your tone is all that's different. It takes the same amount of time. You're not saving any time, but your tone is imparting a sense of urgency for whatever reason. And I think that breaks down teamwork when people are having tone issues. ED tech, participant B* • *Back to communication for me, so making sure – I don't know how I would rate it or how I would word it, but whether there was clear instruction and clear feedback, I guess, so that way, you can determine how well something was understood or communicated between people. RN, participant E*
Strategic staffing	Team sizes should be designed to meet the needs of the patient care scenario, with smaller teams helping to optimize noise and space.	• *I think that really depends on the resuscitation you are doing. So for the scenario in our simulation in particular, I think the size of the team was perfect. You usually only need one physician and maybe a nurse, and then plus or minus pharmacy just depending on how your institution runs. But if you are running a complex traumatic resuscitation, then you're going to need more hands, especially with CPR. Resident, participant L* • *Oh, definitely having a smaller team with more specific defined role, definitely in the aspect of crowd control it made it a lot easier. Pharmacist, participant D*

(*Continued on next page*)

Table 3. Continued.

Theme	Description	Exemplary quotes
Simulation empowering team performance	Simulation is perceived as a safe environment to practice skills and critically reflect during the debrief to build up team member entrustment	• *I think that all helped us learn what people's feelings are during a scenario like that and how we can help make a difference for those people when we're kind of taking care of sick patients, especially patients that can change their clinical status quickly, and that that particular element can help you better take care of those patients, having that team that understands everybody else's needs and thoughts as well. Resident, participant M* • *Yeah, I actually really did enjoy that simulation. I felt I was a bit unprepared when I was coming into it. But just being able to freely work in a safe environment, that's not really with the patient with someone's life in the balance, I think that's really a great opportunity for us to be able to grow and just smooth out any kinks there, get better with our skills. RN, participant A*

team-based performances, *team member entrustment* means trusting that a team member will be able to complete a role-specific task without oversight or specific direction. Such entrustment decisions may need to be made rapidly in the setting of ad hoc ED teams and is critical for building relationships that drive team dynamics.

Within our data, characteristics such as age and gender of team members were not perceived to impact entrustment. Our participants noted that personality and previous experience with someone managing a critically ill patient was important for team member entrustment. In the following quote, one participant comments that witnessing a leader's ability to manage critically ill patients inspired entrustment in their leadership role. "*I don't think it's necessarily a number of shifts. What I think it is, it's severity of cases. So, you might have one shift with someone and just have a killer of a day with ESI [Emergency Severity Index] 1s and 2s and watched this person rock it, and you're like, "Okay, I know they're on it." (Participant G, RN)* As this team member describes, familiarity was an indicator used by participants to make quick entrustment decisions in the ED setting.

Interdependent energy was described as the influence of confidence and demeanor that an individual team member has during a performance that appeared to alter team dynamics and impact team synergy. Several participants also mentioned the importance of tone-setting for a collaborative environment and finding a balance of humility and confidence, as highlighted by this comment about *leadership tone*. *"I have never worked with that doctor before. But I can tell just by his demeanor and his tone that he knew. He was pretty confident on what was going on. So that made me relax and kind of confident as well." (Participant F, RN)*

Optimal communication was also noted as a key factor. This includes appropriate timing, directed toward a specific individual, execution using a reasonable tone, and facilitation of a shared mental model. *Strategic staffing*, specifically small teams, was described by participants to optimize performance, with examples such as keeping the noise level low and allowing for direct communication to individuals. Finally, *simulation empowering team performance* reflects that the simulation was described by participants as a way to practice skills and subsequently reflect upon the experience during an interprofessional team debrief. The session allowed team members to foster relationships, provide feedback, and build entrustment.

DISCUSSION

We used an interprofessional, in situ simulation to evaluate team performance using multiple instruments. A mixed-methods approach allowed us to gather quantitative ratings of performance and qualitatively identify features of optimal interprofessional team performance. We found the two team assessment tools, TPOT 2.0 and TEAM, poorly discriminated when teams were assessed as functioning well together. This leaves little opportunity for capturing individual contributions to team performance for subsets of individuals within the team. Our qualitative findings also suggest that these performance measures do not capture some of the dynamic interdependent team features that drive team functionality.[5] Moving forward, finding a way to capture dynamic features of team relationship building and interdependence can comprehensively provide a more accurate assessment of team performance.

Our findings suggest that the TPOT 2.0 lacks sufficient validity evidence for use in the ED. The overall clustering of high scores may suggest either strong performers within our sample, items that are too easy, or vague anchor points that made it difficult for raters to discriminate. Alternatively, this tool may not be optimized for differentiating individual performance within high-performing teams. The inter-relater reliability IRR of the TPOT was low at 0.46 (Table 2), which may reflect limited rater agreement and, therefore, reliability of the tool. Finally, we identified several features of team performance that participants felt were not sufficiently

captured in the assessment tool, mainly entrustment features related to anticipation and automaticity, leadership tone, and interdependent energy.

Additionally, our qualitative analysis provided insight on the features of team dynamics that may be important for optimizing performance. Entrustment among fellow team members occurs when individuals serving in various interprofessional roles are trusted to function within the scope of their practice. Entrustment in our qualitative analysis was largely driven by strong role competence, anticipation, and automaticity. While competence may come from training and experience, anticipation and automaticity are uniquely important for each member of a rapidly forming ad hoc team in high-stakes situations like the ED. Because every resuscitation is slightly different, automaticity and anticipation cannot be based on an algorithm but rather on pattern-recognition and creation of shared understanding, an innately interdependent process. While anticipation is reflected in the TEAM tool, neither is explicitly represented in the TPOT. Other features that are highly important to ED teams to emphasize in performance tools included interdependent energy and tone of communication.

Situating these findings in the broader literature, ED teams are interdisciplinary action teams that task multiple, highly specialized professionals with a critical situation.[24] Fernandez et al proposed a robust model for EM teamwork taxonomy to capture the process as well as the outcome.[25] This includes the stages of planning processes, action processes, reflection processes, and supporting mechanisms. According to this model, teams will go back and forth between *action processes* focused on goals and *transition processes* that allow for planning. Both stages are highly dependent upon interpersonal factors between team members.

Two of the action processes—"backup behavior" of managing team members' tasks and "coordination" of the inherently interdependent order of activities—are fundamentally dependent on this described construct of team member entrustment.[25,26] This idea resonates with the concept of collaborative interdependence[15] in which team members come together and leverage the strengths of one another. Entrustment may be a necessary step toward establishing a team's collaborative interdependence as its absence may lead to a breakdown in team functioning. Our study helped discern team member actions and factors that may contribute to rapid entrustability and guide these action processes, even in ad hoc teams, including demonstration of role competency, automatic fulfillment of duties, and anticipation of next actions. To improve interprofessional team performance assessment, we need more granular resuscitation-specific performance measures that capture team member entrustment,[23] leadership tone, and interdependence.[4,23]

Educational Implications

Our finding that postgraduate year (PGY) level did not correlate with team performance scores highlights the challenge of assessing resuscitation leadership due to the interdependent nature of team performance.[5,27–28] In the move toward competency-based education and implementation of Entrustable Professional Activities in the workplace,[29] this is critically important. A PGY-2 may, for instance, be falsely assessed as fully entrustable based on the resuscitation of a patient in the clinical setting, when in fact their performance was highly influenced by other experienced team members. This underscores the inherent challenges of resident assessment in the clinical setting, due to the constant interdependent workflows with other team members. We propose that future team assessment skills involve leadership tone and energy as played out in the interdependent workflow of the team. This can only be accurately assessed in the context of interprofessional teams in the workplace through collection of both observations and gathering team member experience of tone, energy, and entrustment.

LIMITATIONS

We performed this study at a single academic institution and, thus, the findings represent the culture and characteristics of that setting. Further research is needed to assess the transferability of our findings to other contexts. The study participants were from a convenience sample, which may limit the generalizability of these results. Furthermore, the nursing staff was noted to be very experienced with a median of eight years in practice; this may have positively influenced team performance and contributed to the high scores we observed across the tools. It is also possible that filming the scenarios may have contributed to a Hawthorne effect. While all participants were offered an opportunity to participate in the qualitative interviews, only a smaller subset did, which limits the transferability of our findings as those choosing to participate may be different than those who did not. Finally, the case used a mannequin instead of a real patient, which offers a blanket of psychological safety that a real clinical scenario does not.

CONCLUSION

This mixed-methods study identified limitations of current tools for assessing team-based performance and offers opportunities for improvement. Future tools assessing team performance should focus on capturing entrustment, leadership tone, and interdependence.

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A Measure of the Impact on Real-Time Patient Care of Evidence-based Medicine Logs

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Introduction: Evidence-based medicine (EBM) is a critical skill for physicians, and EBM competency has been shown to increase implementation of best medical practices, reduce medical errors, and increase patient-centered care. Like any skill, EBM must be practiced, receiving iterative feedback to improve learners' comprehension. Having residents document patient interactions in logbooks to allow for residency program review, feedback, and documentation of competency has been previously described as a best practice within emergency medicine (EM) to document practice-based learning (PBL) competency. Quantifying how residents use the information they query, locate, evaluate, and apply while providing direct patient care can measure the efficacy of EBM education and provide insight into more efficient ways of providing medical care.

Methods: Practice-based learning logs were surveys created to record resident EBM activity on-shift and were placed into our residency management software program. Residents were required to submit 3–5 surveys of EBM activity performed during a 28-day rotation during which additional information was sought. This study included all PBL logs completed by EM residents from June 1, 2013–May 11, 2020. Using qualitative methodology, a codebook was created to analyze residents' free-text responses to the prompt: "Based on your research, would you have done anything differently?" The codebook was designed to generate a three-digit code conveying the effect of the researched information on the patient about whom the log was written, as well as whether the information would affect future patient care and whether these decisions were based on scientific evidence.

Results: A total of 10,574 logs were included for primary analysis. In total, 1,977 (18.7%) logs indicated that the evidence acquired through research would affect future patient care. Of these, 392 (3.7%) explicitly stated that the EBM activity conducted as part of our project led to real-time changes in patient care in the ED and would change future management of patients as well.

Conclusion: We present a proof of concept that PBL log activity can lead to integration of evidence-based medicine into real-time patient care. While a convenience sample, our cohort recorded evidence of both lifelong learning and application to patient care. [West J Emerg Med. 2024;25(4)565–573.]

INTRODUCTION

Medical diagnostics and treatments are constantly changing, making it difficult for physicians to stay current with the care they provide. Evidence-based medicine (EBM), which is the process of researching and applying new medical information, falls under the broader educational category of practice-based learning (PBL).[1,2] Evidence-based medicine is a critical skill for physicians, and EBM competency increases implementation of best medical practices, reduces medical errors, and improves patient-centered care[3,4]. EBM is frequently used to generate policies and guidelines to improve the quality of care delivered.[5] Thus, it is crucial to learn and apply EBM skills throughout medical training. Like any skill, EBM must be practiced, receiving iterative feedback. Prior literature has demonstrated the value of the use of logbooks to document resident progression toward competency.[6]

The Accreditation Council on Graduate Medical Education (ACGME) has mandated that residency programs monitor resident performance in multiple areas, including EBM, within the PBL competency.[1] Resident competence is measured by observable and measurable ACGME Milestone behaviors.[7] Specific approaches to these requirements are not externally defined; rather they are left to both the program director and the appointed program evaluation committee (PEC).[1] Having residents document patient interactions in logbooks to allow for residency program review, feedback, and documentation of competency has been previously described as best practice within EM to document PBL competency.[8] Prior study of EBM has demonstrated that postgraduate experience and gender both impact the learning needs of residents.[9]

Evidence-based medicine consists of four key steps: asking an answerable question; efficiently searching for evidence; appraising the evidence for reliability; and applying that evidence.[10] A 2010 survey of EM program directors and faculty reported that the most important EBM skillsets developed by residents were the ability to appraise the reliability of evidence they find and apply research findings to patient care.[8] Resident surveys can be used to record how each individual approaches EBM, although this approach has the same inherent limitations of all survey studies. The Fresno test of EBM is a standardized means of assessment and feedback on the topic.[11] The test takes around 40 minutes to complete and 12 minutes to grade.[12] However, none of these EBM education studies measure its impact on direct patient care, despite Kirkpatrick's hierarchy placing impact on patient care at the top of the educational evaluation pyramid.[13]

Prior research has demonstrated that real-time EBM may lead to implementation of best care practices.[14] Quantifying how residents use the information they query, locate, evaluate, and apply when providing direct patient care can measure the efficacy of EBM education and yield insight into more efficient ways to provide medical care.[15] Our purpose in this study was to review residents' PBL patient logs as a measure of EBM activity among residents and to determine the direct impact of this EBM activity on both current and future patient care.

Population Health Research Capsule

What do we already know about this issue?
Quantifying how residents use information retrieved from scientific evidence is an important subject in need of further investigation.

What was the research question?
Does evidence found by residents impact their current or future clinical practices?

What was the major finding of the study?
18.7% of logs showed that the EBM search would affect future patient care, and 3.7% stated it changed ED patient care in real time.

How does this improve population health?
More effective quantification of evidence-based clinical practice changes will allow instructors to identify educational gaps and close them.

METHODS

This was an institutional review board-approved retrospective review of self-reported learning conducted at an ACGME-approved postgraduate year (PGY) 1–4 EM residency program, which trains approximately 14 residents per year. The program is located at an independent academic center within an integrated healthcare network. The EBM curriculum at this institution was taught primarily within interactive journal clubs based on PGY and was supplemented with didactics that involved real-time audience response questions, in accordance with best practices.[9] The core journal club (attended by PGY-1 and -2 residents) measured educational efficacy with the Fresno test of EBM and had topics based on its content.[11] Residents took the Fresno test of EBM and received feedback on their performance on that instrument during protected time in grand rounds in May or June at the end of PGY-2. Senior journal club (attended by PGY-3 and -4 residents) focused on critical appraisal, knowledge translation, and implementation science. The senior journal clubs contained

separate learning goals and assignments. Depending on grand round didactic scheduling and faculty availability, the audience response system questions and interactive discussions occurred both in large group (all residents PGY 1–4) and small groups-based settings (PGY 1, 2 in one room, and PGY 3, 4 in another). Both journal clubs used a recurring 12-month curriculum containing standardized EBM teaching articles paired with topical clinical exercises (Table 1). Core journal club materials were assigned to the PGY-1 and -2 residents and senior materials to the PGY-3 and -4 residents.

Supplemental materials were used by all residents during two one-hour EBM didactics held outside journal club. In the fall, the lecture covered 2x2 grids/likelihood ratios/Bayesian logic. In the spring, the lecture reviewed commonly used research methodologies. The clinical content of the December and June journal clubs was rapid abstract review from the most recent meetings of the American College of Emergency Physicians (December) and the Society for Academic Emergency Medicine (June). The clinical content for the remaining journal clubs was selected from recent literature to highlight the core topic being taught that month.

After review and approval by the PEC, residents were required to document EBM activity in the program's procedure recorder. These records, referred to as PBL logs, were developed from patient follow-up logs disseminated by the Council of Residency Directors in Emergency Medicine (CORD).[7,16] Table 2 demonstrates the elements of the PBL

Table 1. The evidence-based medicine curriculum administered to residents over the course of a year.

Month/Topic (Fresno question)	Evidence-based medicine core teaching article	Senior and supplemental materials
July PICO question (1a, 1b)	Guyatt G, Meade MO, Agoritsas T, et al. (2015). What is the question? In Guyatt G, Rennie D, Meade MO, Cook DJ (Eds.), *Users' Guides to the Medical Literature: A Manual for Evidence-Based Clinical Practice, 3rd ed*. (1–9) New York, NY: McGraw Hill.	Senior journal club: Resident as teacher. Barrett NF, Gopal B. Using the five microskills with different learning preferences. *Fam Med*. 2008;40(8):543–5.
August Hierarchy and locations of evidence (2, 3, 11, 12)	Bhandari M, Giannoudis PV. Evidence-based medicine: What it is and what it is not. *Injury*. 2006;37(4):302–6.	Senior journal club: Knowledge translation Lang ES, Wyer PC, Haynes RB. Knowledge translation: closing the evidence-to-practice gap. *Ann Emerg Med*. 2007;49(3):355–63.
September Search strategies (2, 3, 4)	McKibbon A, Wyer P, Jaeschke, R, et al. (2002). Finding the evidence. In Guyatt G, Rennie D, Meade MO, & Cook DJ (Eds.), *Users' Guides to the Medical Literature: A Manual for Evidence-Based Clinical Practice 2nd ed.* (29–58). New York, NY: McGraw-Hill Medical.	Senior journal club: Implementation science de Wit K, Curran J, Thoma B, et al. Review of implementation strategies to change healthcare provider behaviour in the emergency department. *CJEM*. 2018;20(3):453–60.
October External validity (5)	Rothwell PM. External validity of randomised controlled trials: "to whom do the results of this trial apply?". *Lancet*. 2005;365(9453):82–93.	Supplemental articles on 2x2 grids: Loong TW. Understanding sensitivity and specificity with the right side of the brain [published correction appears in BMJ. 2003 Nov 1;327(7422):1043]. *BMJ*. 2003;327(7417):716–9. Gallagher EJ. Evidence-based emergency medicine/ editorial. The problem with sensitivity and specificity. *Ann Emerg Med*. 2003;42(2):298–303.
November Likelihood ratios (8)	Hayden SR, Brown MD. Likelihood ratio: a powerful tool for incorporating the results of a diagnostic test into clinical decisionmaking. *Ann Emerg Med*. 1999;33(5):575–80.	Supplemental lecture: Bayesian logic. This additional lecture outside of journal club introduces basic 2x2 grid concepts and extends them into how to use EBM on shift to achieve clinical diagnosis. Slawson DC, Shaughnessy AF. Teaching information mastery: the case of baby Jeff and the importance of Bayes' theorem. *Fam Med*. 2002;34(2):140–2.
December Number needed to treat (9)	Cordell WH. Number needed to treat (NNT). *Ann Emerg Med*. 1999;33(4):433–6.	No supplemental materials given this month. Both resident groups used core materials indicated immediately to the left.

(*Continued on next page*)

Table 1. Continued.

Month/Topic (Fresno question)	Evidence-based medicine core teaching article	Senior and supplemental materials
January Significance (7)	Singer AJ, Thode HC Jr, Hollander JE. Research fundamentals: selection and development of clinical outcome measures. *Acad Emerg Med*. 2000;7(4):397–401.	Senior journal club: Sources of critical appraisal. These sources are used for the critical appraisal forms throughout the year. Forms include *Annals of Emergency Medicine* (https://www.annemergmed.com/content/ebemform) and the Centre for Evidence Based Medicine, which has a collection in multiple languages (https://www.cebm.ox.ac.uk/resources/ebm-tools/critical-appraisal-tools).
February Critical appraisal: diagnostics	Schranz DA, Dunn MA. Evidence-based medicine, part 3. An introduction to critical appraisal of articles on diagnosis. *J Am Osteopath Assoc*. 2007;107(8):304–9.	Supplemental article on methodology: Thompson CB, Panacek EA. Research study designs: experimental and quasi-experimental. *Air Med J*. 2006;25(6):242–6.
March Critical appraisal: therapeutics	Cardarelli R, Virgilio RF, Taylor L. Evidence-based medicine, part 2. An introduction to critical appraisal of articles on therapy. *J Am Osteopath Assoc*. 2007;107(8):299–303.	Supplemental lecture: Review of Methodology This lecture is given outside of journal club to review and reinforce the hierarchy of evidence and the internal validity of articles.
April Communication	Montori VM, Devereaux PJ, Straus S, et al. (2002). Advanced topics in moving from evidence to action: decision making and the patient. In Guyatt G, Rennie D, Meade MO, & Cook DJ (Eds.), *Users' Guides to the Medical Literature: A Manual for Evidence-Based Clinical Practice 2nd ed.* (643–61). New York, NY: McGraw-Hill Medical.	No supplemental materials given this month. Both resident groups used core materials indicated immediately to the left.
May (OPEN EBM topic, research day)	Note: Topic determined by EBM Track Residents Note 2: Question 6 on the Fresno (internal validity) is reviewed in the appraisal of articles in each journal club.	No supplemental materials given this month. Both resident groups used core materials indicated immediately to the left.
June Confidence intervals (10)	Young KD, Lewis RJ. What is confidence? Part 1: The use and interpretation of confidence intervals. *Ann Emerg Med*. 1997;30(3):307–10.	No supplemental materials given this month. Both resident groups used core materials indicated immediately to the left.

PICO, population, intervention, control, and outcomes; *EBM*, evidence-based medicine.

logs' associated expectations, and areas of feedback by PGY. These logs were from a convenience sample of EBM activity and were not a record of all patients seen. One faculty member reviewed every log, and each resident was provided with individualized feedback from the same faculty member.

Residents were required to create their PBL logs during rotations in the emergency department (ED). These logs were

Table 2. Practice-based learning logs and expectations, stratified by postgraduate year. The top row indicates practice-based learning log categories, while rows 2–4 indicates the expected capabilities of residents.

PGY	Clinical question	Clinical question answer	Method of obtaining information	Based on your research, would you have done anything differently?
1	PICO question, search strategy		Identify source of information and verify reliability	
2	Search strategy	Evidence found		Identify significance of the information
3 + 4		Evidence found		Critical appraisal of information reliability, application of information to practice

PGY, postgraduate year; *PICO,* population, intervention, control, and outcomes.

subsequently placed into our residency management software program (New Innovations Inc, Uniontown, OH). Residents were required to submit surveys of EBM activity performed during 28-day EM rotations. The number required per rotation by the PEC varied between the academic years included in this study from a high of five at the beginning of the cohort down to three at the end. The annual number of EM rotations varied by PGY, from six (PGY 1) to eight (PGY 4). The number of residents per class at the beginning of the cohort was 13, and the complement increased to 16 during the study.

We included all PBL logs completed by EM residents from June 1, 2013–May 11, 2020. Records were anonymized to PGY year and gender, in accordance with Hadley et al.[9] No other identifiers were included in this study. Using qualitative methodology described by MacQueen, we created a codebook to analyze residents' free-text responses to the prompt: "Based on your research, would you have done anything differently?"[17] The goal of the codebook was to categorize and quantify the effect of each log on a resident's patient care. Each log was assigned a three-digit code based on the answer to three questions. The first digit of the code corresponded to the answer to the question, "Did the research affect the care of the current patient about which the log was written?" The second digit represented participant answers to the question, "Will information researched change the future care of patients?" Lastly, the third digit represented the answer to the question, "Were the changes described in digit two in concordance with the research they found?" Digits were assigned to answer each of these questions (Table 3).

Logs were coded by three individuals with a single overriding adjudicator. All individuals involved in coding logs met to code the first 200 logs together to create a consensus for grading and met throughout the entirety of the project to review logs with unclear coding. Inter-rater reliability was not formally measured. We conducted subgroup analysis based on PGY and resident gender via the chi-square test to assess for differences in log coding. If the resident did not specify their gender or PGY, we excluded the log from the respective subgroup analysis.

RESULTS

A total of 11,145 logs were entered during the study period. These logs were submitted by 137 residents, of whom 48 (37%) were female. We excluded a total of 571 logs from analysis: 298 were incomplete, and 273 were duplicates. After these exclusions, 10,574 logs answered the prompt, "Based on your research, would you have done anything differently?" and were included in primary analysis (Figure).

The five most common log codes accounted for approximately 85.4% (n = 9,034) of the total logs. The most common log code was 231 in 3,343 logs (31.6%), which signified self-directed learning without application of knowledge to the current patient and without specifying application of knowledge to future patients. The second most common code was 331 in 2,263 logs (21.4%), which similarly recorded self-directed learning without specification of application of knowledge to the current or future patients. Research confirming residents' plans of care was coded as 221 and totaled 1,319 logs (21.4%). The next highest count was 211in 1,062 logs (10.0%), which represented logs that did not change the care of the corresponding patient but reportedly would change the care of future patients. The code 131 accounted for 1,047 (9.9%) logs, which changed the care of the corresponding patient and may or may not change future care of patients.

The most impactful logs were those that specifically stated that the research conducted would change future management of patients (eg, coded as 111, 211, 311, 411). In total, 1,977 logs (18.7%) indicated the evidence acquired through research would affect future patient care. Of these,

Table 3. Practice-based learning log codebook. The answers to these three questions were coded to generate a three-digit number describing the impact a resident's research had on their performance.

	Digit 1: Did research affect care?	Digit 2: Will research affect care in the future?	Digit 3: Is the change in future care based on the researched evidence?
Incomplete log	9	N/A	N/A
Duplicate log	8	N/A	N/A
Yes	1	1	1
No	2	2	2
Maybe	3	3	3
Action influenced by outside force (eg, attending physician preference, state protocol, did not have access to medication, etc)	4	4	4
Undecipherable answer	5	5	5
Insufficient or conflicting data	N/A	N/A	7

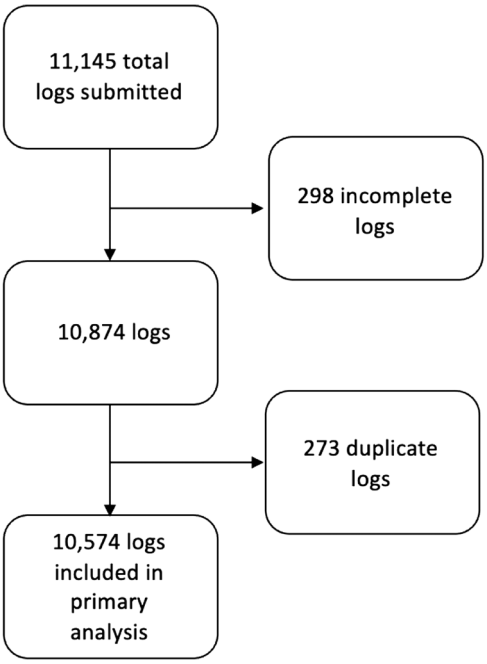

Figure. Practice-based learning log study inclusion criteria and selection process.

392 (3.7% of entire study sample) explicitly stated that the EBM activity conducted as part of our project led to real-time changes in patient care in the ED and would change future management of patients as well. A full list of the 10 most common codes can be found in Table 4.

Postgraduate year subgroup analysis found first-year residents recorded the most logs (602, 23.3%) that indicated research would lead to a future change in patient management (all codes including 1 as the second digit). There was a significant difference in these logs between PGY ($P < 0.001$), and a trend was seen where increasing PGY was associated with decreased chance of a log changing future patient care. The number of logs indicating future care changes increased in PGY 4, potentially due to dedicated feedback received on their PBL logs. There was no significant difference in the number of logs that recorded both real-time change and future management change between PGY ($P = 0.70$). Subgroup analysis of resident gender found no significant difference in current or future patient care resulting from evidence found. While not meeting the study's significance criterion of $\alpha < 0.05$, more males indicated real-time and future care change in their logs (254), as compared to their female counterparts (106, $P = 0.05$). Subgroup analysis can be seen in Table 5.

Table 4. The 10 most commonly reported practice-based learning log counts, stratified by postgraduate year.

Code	Total (%)	PGY1 (%)	PGY2 (%)	PGY3 (%)	PGY4 (%)
231	3,343 (31.6)	880 (26.3)	877 (26.2)	679 (20.3)	907 (27.1)
331	2,263 (21.4)	450 (19.9)	522 (23.1)	512 (22.6)	779 (34.4)
221	1,319 (12.5)	278 (21.1)	311 (23.6)	298 (22.6)	432 (32.8)
211	1,062 (10.0)	348 (32.8)	249 (23.4)	202 (19.0)	263 (24.8)
131	1,047 (9.9)	246 (23.5)	221 (21.1)	230 (22.0)	350 (33.4)
311	443 (4.2)	134 (30.2)	114 (25.7)	82 (18.5)	113 (25.5)
111	392 (3.7)	97 (24.7)	92 (23.5)	92 (23.5)	111 (28.3)
431	265 (2.5)	57 (21.5)	67 (25.3)	59 (22.3)	82 (30.9)
227	97 (0.9)	21 (21.6)	22 (22.7)	20 (20.6)	34 (35.1)
411	80 (0.8)	23 (28.8)	22 (27.5)	12 (15.0)	23 (28.8)
Other	263 (2.5)	53 (20.2)	68 (25.9)	61 (23.2)	81 (30.8)

PGY, postgraduate year.

DISCUSSION

Evidence-based medicine forms the cornerstone of modern clinical practice, and effectively teaching residents to conduct their own EBM information acquisition and appraisal is paramount in graduate medical education. While both the ACGME and CORD require that EBM be taught throughout residency, there is little data assessing the impact and relative benefit to residents of EBM search methods. Our analysis included 10,574 PBL logs from 137 residents across eight academic years. Our results showed that 18.7% of logs indicated that residents acquired new evidence-based medical information and applied that knowledge in real-time to change the current or future care of their patients. These positive educational logs were found more often in the logs of PGY-1 and -4 residents than in those of PGY-2 and -3 residents. This observation may be related to background searches leading to new knowledge (PGY 1) and the ability to critically appraise (PGY 4). Changing learning styles in residency has been shown to be linked to the number of hours worked, and in our training program the PGY-2 and -3 residents have more intense rotations than in PGY-1.[18] Another contributing factor to the increase seen in PGY-4 residents could be the dedicated feedback on this component of the PBL log, which is provided to PGY-3 and -4 residents (Table 2).

Evidence-based medicine, like other residency procedures, is a learned skill that must be practiced.[19] Logs are consistently used across residency programs to track progress of traditional skills; however, there is limited literature

Table 5. Distribution of practice-based learning logs and their effects, stratified by gender and postgraduate year.

	Total number of logs (%)	Future care change (eg, 111, 211, etc) (%)	*P*-value	Real-time and future care change (eg, 111 only) (%)	*P*-value
Gender					
Female	3,505 (34.3)	617 (33.1)	0.27	106 (29.4)	0.05
Male	6,705 (65.7)	1,246 (66.9)		254 (70.6)	
Total	10,210 (100.0)	1,863 (100.0)		360 (100.0)	
Postgraduate year					
1	2,587 (24.5)	602 (30.5)	<0.001	97 (24.7)	0.70
2	2,565 (24.3)	477 (24.1)		92 (23.5)	
3	2,247 (21.3)	388 (19.6)		92 (23.5)	
4	3,175 (30.0)	510 (28.3)		111 (28.3)	
Total	10,574 (100.0)	1,977 (100.0)		392 (100.0)	

describing how to track EBM skill progression.[20] Some elements of teaching, particularly providing feedback to learners, are acknowledged as beneficial to skill development.[21] The approach described here, using a program's traditional log and faculty feedback to assess EBM like other procedural competencies, has been described as a best practice.[8,21] In addition to the discussion and demonstration of EBM skills including appraisal that occurred in journal club, individual feedback was given by a single faculty member (as shown in Table 2) of all logs in the clinical competency committee meetings and in residents' semi-annual evaluations. Minimal literature exists wherein the effect of resident EBM activity on patient care was measured. Friedman et al did investigate this question; however, the study was criticized for not offering a way for residents to improve their appraisal skills.[22,23]

By conducting EBM learning in an interactive journal club setting, supplemented with didactics that involved real-time audience response questions, students were able to engage with their instructors and receive more comprehensive feedback on their methods and the implications of their findings. In addition, we used an electronic tool that directly linked EBM resources to the electronic health record to ease access during rotations. These expanded functionalities also allowed us to monitor the implementation of residents' newly acquired knowledge more directly. By specifically asking how the activity impacted patient care, the PBL logs enabled the residency program to gather information on ACGME Phase 3 Outcomes data.[24]

A key finding of our study was the high number of logs that demonstrated real-time learning. While only 18.7% of logs explicitly stated a real-time or planned future change in patient care, over 65% of logs reported that research led to information learned. This is an important finding, as self-directed learning is a growing academic topic. The most recent iteration of the ACGME Milestones for EM included EBM within two PBL categories.[7] Practice-based learning 1 (Evidence-based and Informed Practice) has at levels 1, 2, 3, and 4 behaviors that can be measured with the PBL logs. Further, PBL 2 (Reflective Practice and Commitment to Personal Growth) has as behavioral anchors the ability to self-identify gaps and determine ways to close them. The PBL logs, by measuring self-directed learning, contribute to measuring these behaviors in an effective way. As the Liaison Committee on Medical Education has made "self-directed learning" (Standard 6.3) a mandated part of undergraduate medical education, the approach to EBM described here can effectively extend and measure that behavior.[25] There are currently no existing resources to do so; thus, our study model provides a novel way for residency programs to track self-directed learning of EBM via PBL logs.

LIMITATIONS

Despite our large study population, our study had multiple limitations. The EBM curriculum offered and described in Table 1 may differ from that offered at other academic sites. Therefore, the way that residents used information may not be representative of EM residents at other institutions. The recorded EBM activity was a requirement for our residents, including a minimum number of PBL logs using peer-reviewed, published sources of medical information. This cohort, therefore, had the general limitations of convenience sampling, as well as the possibility of bias, as EBM activities were not as thoroughly documented as procedural attempts. To that end, the logs presented likely represent only a fraction of the EBM activity performed during the study period as only a limited number of logs (3–5) were required for each 28-day EM block. Finally, our qualitative methodology required the interpretation and categorization of EBM logs, which introduced the possibility for interpretation bias in our

results. However, the large number of logs, the use of multiple research team members with a single arbiter, and the coding schema developed minimized these concerns.

CONCLUSION

We present a proof of concept that practice-based learning log activity can lead to integration of evidence-based medicine into real-time patient care. Additionally, we provide a framework for qualitative measurement of EBM research and application skills among learners. Our cohort recorded evidence of both lifelong learning and application to patient care. This approach can easily be generalized to other EM residencies to allow for both monitoring of resident PBL competency and ACGME reporting.

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What the *Fika*? Implementation of Swedish Coffee Breaks During Emergency Medicine Conference

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Introduction: In this study we aimed to investigate the effects of incorporating Swedish-style *fika* (coffee) breaks into the didactic schedule of emergency medicine residents on their sleepiness levels during didactic sessions. Fika is a Swedish tradition that involves a deliberate decision to take a break during the workday and usually involves pastries and coffee. We used the Karolinska Sleepiness Scale to assess changes in sleepiness levels before and after the implementation of *fika* breaks.

Methods: The study design involved a randomized crossover trial approach, with data collected from emergency medicine residents over a specific period. This approach was done to minimize confounding and to be statistically efficient.

Results: Results revealed the average sleepiness scale was 4.6 and 5.5 on *fika* and control days, respectively ($P = 0.004$).

Conclusion: Integration of *fika* breaks positively influenced sleepiness levels, thus potentially enhancing the educational experience during residency didactics. [West J Emerg Med. 2024;25(4)574–578.]

INTRODUCTION

Emergency medicine (EM) residency is known for its demanding schedules and high-stress environment. The intensity of residency training can lead to stress, fatigue, and reduced well-being.[1] At the same time, didactics play a crucial role in providing residents with the necessary knowledge and skills to deliver high-quality patient care and are a key component of learning advancement. Weekly conference sessions may vary in length from program to program but typically comprise five hours of protected time devoted to learning fundamental EM content every week. Much work has been done in recent years to improve the quality of these conferences, such as implementing shorter lectures, interactive sessions, team-based learning, and flipped classrooms.[2] However, little work has focused on mitigating resident fatigue and decreased attention at the end of the conference session. Research in adult learning data reveals that the attention span of the adult learner decreases dramatically after 15–20 minutes.[3] Consequently, it is not difficult to assume that after three or four hours of conference, the attention span of the average adult learner has been spent. One possible way to address these challenges is to incorporate breaks in conference days inspired by the Swedish custom of *att ta en fika*, or simply *fika* (coffee), into conference days.

Introducing *fika* breaks can provide residents with much-needed opportunities for relaxation and self-care. The Swedes are known for having a highly beneficial work and

life balance compared to people in other countries.[4] One proposed explanation is the culture of conscientiously taking regularly scheduled breaks, known as *fika*, during the workday to relax and regroup.[5] That logic could be extrapolated into resident education. If residents could participate in *fika* and engage in pleasant conversations with time away from the intense learning environment, it could help alleviate stress, boost morale, and improve mental well-being.

In this study we explored the potential advantages of taking 15-minute *fika* breaks in conjunction with monitoring sleepiness levels using the Karolinska Sleepiness Scale (KSS). For the purposes of this study, four EM residency programs implemented *fika* breaks during resident conferences to assess whether taking a 15-minute *fika* break after the second hour of didactics impacted resident alertness. Our goal was to explore the concept of *fika* and how it may improve EM residents' alertness during weekly conference.

Population Health Research Capsule

What do we already know about this issue?
While interactive sessions and flipped classrooms have been implemented to optimize learning during residency conferences, little is known about how to optimize breaks.

What was the research question?
Does implementation of a Swedish fika break improve the level of alertness for emergency medicine residents during conference?

What was the major finding of the study?
Average sleepiness on the Karolinska Sleepiness Scale improved from 5.5 on control days to 4.6 on fika days ($p = 0.004$).

How does this improve population health?
This study highlights the importance of structured conference breaks leading to more alert residents and hopefully a higher quality learning environment.

METHODS

Study Design and Setting

We conducted a multicenter, randomized crossover trial from August 25, 2022–January 5, 2023 to determine the association between resident fatigue during conferences with and without a *fika* break among EM residents. Four EM residencies participated in this study, which was reviewed and approved by each hospital's respective institutional review board. Table 1 outlines defining characteristics of the four sites.

For fatigue assessment we used the KSS, a validated self-assessment tool used to measure an individual's level of sleepiness or alertness at a given moment.[6] Decreased levels of alertness using the KSS score have been associated with deceased performance and cognitive function.[7,8] Developed by researchers at the Karolinska Institute in Sweden, the scale consists of a series of levels, typically ranging from 1–9, where each level corresponds to a different degree of sleepiness.[6] Participants are asked to rate their current level of sleepiness based on the descriptions provided for each level. Lower numbers on the scale indicate higher levels of alertness (1 = extremely alert), while higher numbers indicate increasing levels of sleepiness (9 = very sleepy, great effort keeping awake, fighting sleep).[5] The KSS is often used in sleep research, clinical settings, and studies related to fatigue and sleep disorders to gain insights into people's subjective perception of their own alertness or drowsiness.[6]

Instructions were provided during intervention (*fika*) and control dates, asking the EM residents to circle the number that represented their perceived level of sleepiness at that point in time. An additional unrelated wellness question was included in the questionnaire to keep this study blind. During the first phase of the study, the four sites were split randomly into two groups. The two groups were then randomly assigned two control dates and two intervention dates. One group started with control dates, followed by intervention dates. The second group started with intervention dates,

Table 1. Participating residency program's baseline characteristics.

Site number	Number of EM residents	Length of conference in hours	Scheduled breaks	Interactive sessions (small groups, flipped classes)
1	18	5	Yes	Yes
2	29	5	Yes	Yes
3	39	4–5	No*	Yes
4	24	4	Occasionally	Yes

*Food was available during conference.
EM, emergency medicine.

Table 2. Dates of control and intervention by site.

Site number	Date of control	Date of intervention (Fika)
1	September 28, October 5	September 14, October 12
2	September 21, October 5	September 1, December 15
3	August 25, January 5	September 1, December 15
4	October 13, December 8	October 20, November 3

followed by control dates. This was done to help offset possible fatigue differences due to the passage of time. Table 2 demonstrates the control and intervention dates of each site.

During the intervention days, a 15-minute Swedish-style *fika* break was added into the EM conference schedule after the second hour of conference. The fika breaks were to be held in a location outside the lecture area where EM residents were provided with coffee, non-caffeinated beverages, pastries, and snacks. Residents were instructed that there should not be any work-related discussion, as this break serves to encourage socialization and relaxing conversation. On control days, normal breaks occurred as scheduled during EM conference. During both phases, the survey was conducted before the last hour of conference.

Selection of Participants

Study participants were EM residents across the four participating hospitals. There were 25 postgraduate (PGY) year-1 residents, 18 PGY-2 residents, 16 PGY-3 residents, and 4 PGY-4 residents for a total of 98 residents. A total of 64 residents participated in at least one survey during both the control and *fika* sessions to allow paired comparison.

Interventions

The intervention in this study consisted of implementing a 15-minute *fika* break after the second hour of lecture where coffee, non-caffeinated beverages, pastries, and snacks were made available. This was conducted twice over several months. On control days, participating sites had instructions to not change any regular scheduled curriculum breaks or limit the food and drink that were normally present. Normal breaks at participating sites ranged from 10–15 minutes, and all programs had food and caffeinated drinks available on control days.

Data Analysis

We compiled the numerical data obtained from the KSS surveys taken by the EM residents from the control and *fika* sessions for analysis and separated it into two subgroups, consisting of a residency site subgroup and a PGY subgroup. The residency site subgroup was broken down into each respective participating residency program, and the PGY subgroup was broken down into each PGY class (1–4). We used a paired sample *t*-test to compare the mean KSS of the resident cohort both before and after implementation of *fika*. This was done for individual EM residency programs and for all EM residency programs participating as a larger cohort.

RESULTS

Sleepiness on *Fika* vs Control Days

Figure 1 presents the mean results of the sleepiness measured on days where *fika* was implemented vs control. The average sleepiness was 4.6 on *fika* days and 5.5 on control days with standard deviation of 2.2 and 2.1, respectively, P-value = 0.004. This indicates that residents were more awake on days when *fika* was implemented, and this result was statistically significant. Figure 2 demonstrates

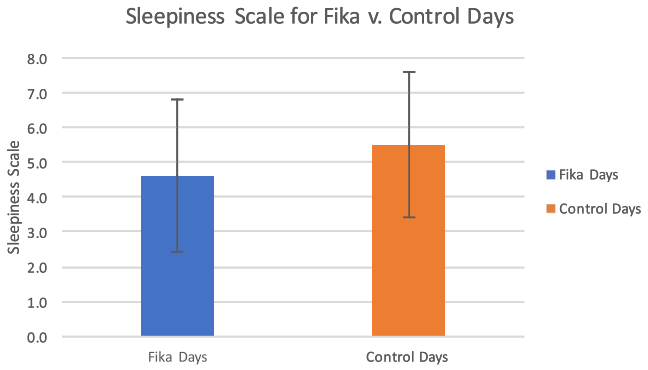

Figure 1. Mean Karolinska Sleepiness Scale scores for *Fika* vs control days. Mean sleepiness on days when *fika* was implemented was improved compared to control. Average sleepiness scale was 4.6 (SD 2.2) and 5.5 (SD 2.1), respectively, on *fika* and control days, respectively.

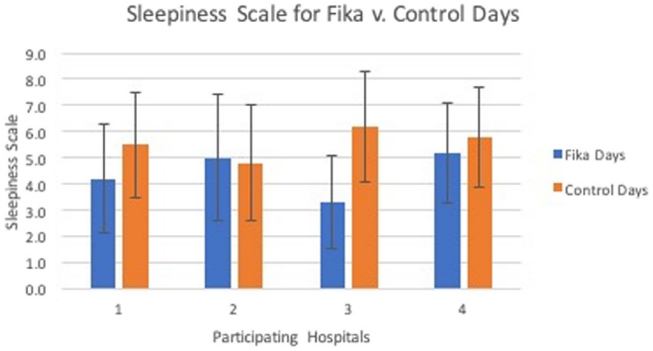

Figure 2. Results of self-reported Karolinska Sleepiness Scale scores on *fika* days vs control days, separated by participating residencies. Site 3 showed most improvement of sleepiness from the Fika intervention, with 3.3 (SD 2.1) on *fika* days vs 6.2 (SD 2.0) on control days, while Site 2 showed the opposite effect, with 5 (2.4) on *fika* days vs 4.8 (SD 2.2) on control days, although the difference was not statistically significant.

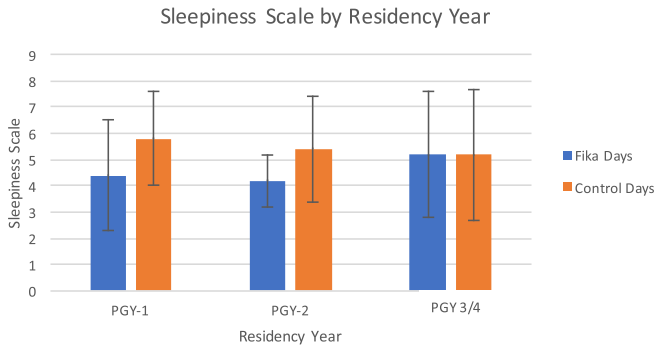

Figure 3. Sleepiness scale by residency year. Results show *fika* intervention had greatest improvement in sleepiness among PGY-1 residents, with sleepiness of 4.4 (SD 2.1) on *fika* days and 5.8 (SD 1.8) on control days, although this effect was not statistically significant due to small sample size.

the results of the KSS separated by participating residency programs. Site 3 had the biggest improvement in sleepiness (3.3 on *fika* days vs 6.2 on control days). Site 2 had the least improvement in alertness and actually showed that *fika* intervention increased sleepiness in residents (5.0 on *fika* days vs 4.8 on control days), although the difference was not statistically significant.

Figure 3 depicts the alertness by residency year from all participating residency programs. We found that improvement in alertness was more visible in first- and second-year residents compared to third- and fourth-year residents. Due to low sample size, however, this difference was likely by chance and not statistically significant.

DISCUSSION

The findings suggest that the inclusion of *fika* breaks into the EM residency didactics positively influenced participants' sleepiness levels. The reduced sleepiness during conference sessions could potentially enhance residents' attention, engagement, and knowledge retention, leading to improved educational outcomes.

Improved Learning Outcomes

While the primary goal of residency conferences is to impart medical knowledge and skills, the effectiveness of learning can be enhanced by incorporating *fika* breaks and monitoring sleepiness levels with KSS. Studies have shown that brief breaks during learning sessions can improve attention and retention of information. By stepping away from conference lecture sessions and using the KSS, we were able to assess residents' levels of sleepiness and determine the effectiveness of the breaks in reinvigorating their focus. These findings can be used to optimize the timing and duration of *fika* breaks, ensuring that they contribute to improved learning outcomes and better knowledge retention.

Fostered Social Interactions

Building a strong sense of community and fostering social interactions is vital for resident overall well-being.[9] *Fika* breaks provide an ideal platform for residents to connect on a more personal level, share experiences, and develop supportive relationships with their peers and faculty members. These informal interactions encourage open communication, collaboration, and mentorship opportunities. By also considering the sleepiness levels with KSS during these breaks, organizers can tailor the frequency and structure of *fika* sessions to promote optimal social interactions while mitigating the risk of residents becoming excessively fatigued or drowsy.

LIMITATIONS

The study has several limitations, including a relatively small sample size and a short intervention period. Future research could involve larger studies with extended intervention periods to further explore the long-term effects of *fika* breaks on EM residency conference days. During control days, residents could have consumed coffee or soda that contained caffeine. Lasty, the effect of different type of breaks could also be considered, such as a walk or other intentional break, to determine whether that activity has the same effect. All participating sites on control days had slight variations in the nature and length of breaks.

CONCLUSION

Incorporating Swedish-style *fika* breaks into emergency medicine residency conferences improved the overall alertness in EM residents. Residency programs should consider this unique approach to prioritize resident wellness and optimize educational experiences. Further research can explore the long-term effects of *fika* breaks and Karolinska Sleepiness Scale monitoring on resident burnout, performance, and career satisfaction in EM residency programs.

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Sued, Subpoenaed or Sworn in: Use of a Flipped-Classroom Style Medicolegal Workshop for Emergency Medicine Residents

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Background: It is an unfortunate truth that Emergency Medicine (EM) physicians will, at some point, have contact with the medicolegal system. However, most EM residency training programs lack education on the legal system in their curriculum, leaving EM physicians unprepared for litigation. To fill this gap, we designed a high-yield and succinct medical legal workshop highlighting legal issues commonly encountered by EM physicians. We aimed to determine the effectiveness of this curriculum by measuring pre and post knowledge questions.

Methods: A two-hour session included a case-based discussion of common misconceptions held by physicians about the legal system, proper steps when interacting with the legal system and review of legal documents. This session was developed with the involvement of our hospital legal counsel and discussed real encounters. The effectiveness of the session was determined using pre- and post-session surveys assessing participant knowledge and comfort approaching the scenarios.

Results: A total of 34 EM residents had the opportunity to complete this workshop as a part of their conference curriculum. A total of 26 participants completed the pre-survey and 19 participants completed the post-survey. No participants had previous training in the legal aspects of medicine, including handling a subpoena, serving as a witness, or giving a deposition.

The pre-survey demonstrated that there was significant uncertainty surrounding the processes, definitions, and the legal system interaction. Many participants stated they would not know what to do if they received a subpoena (85.71%), were called as a witness in a trial (96.43%) or receive correspondence from a lawyer (96.43%).

The post survey revealed an increased knowledge base and confidence following the session. 100% of residents reported knowing what to do after receiving a subpoena, being called as a witness and understanding the process involved in giving a deposition. All residents reported that the session was beneficial and provided crucial information.

Conclusion: EM residents have limited baseline understanding of how to approach common legal scenarios. Educational materials available for this curriculum topic are limited. Based on the rapid knowledge increase observed in our residents, we believe our workshop could be adapted for use at other residency programs. [West J Emerg Med. 2024;25(4)579–583.]

BACKGROUND

Emergency physicians (EP) are at the frontline of acute care and as a result have frequent interactions with the United States medicolegal system. Physicians in specialties considered "high risk," including emergency medicine (EM), experience a higher rate of malpractice claims than average, with 99% of physicians in these specialties experiencing malpractice litigation by the age of 65.[1] However, only 18% of EM residency programs devote more than four hours per year of curriculum time to medicolegal topics, including items such as medical malpractice and risk management education.[2] In a survey of Australian EPs, 41% of respondents reported receiving training in this area. Also, while 71% had attended court as an expert witnesses, only 23% considered themselves skilled in participating in courtroom trials.[3]

While similar data does not exist evaluating the preparation of EPs in the US, previous studies support that lack of medicolegal education impairs a physician's ability to assist the court and form an accurate opinion.[3] A solid educational foundation in the legal aspects of medicine is especially important for EPs, who often interact with patient populations requiring interaction with the medicolegal system. These situations include abuse, assault, domestic or gun violence, other traumatic injury, and forensic toxicology. Historically, training focused on this area happened in real time, with few institutions implementing forensic medicine training to better address their patients' forensic needs.[4]

Much of the current literature pertaining to medicolegal education is from countries outside the US. In an Australian EM training program, a six-month forensic medicine rotation improved the technical, assessment, and clinical skills of their EM residents.[5] In the US, few residency programs have implemented direct simulations of trial scenarios, educational lectures, and case-based discussions to improve their residents' ability to interact with the legal system. These programs historically have consumed substantial time, with a range of six hours to several months in duration. Partnerships with local law schools have allowed EM residents to receive hands-on experience with malpractice litigation and have been shown to improve their confidence in navigating the legal system.[6,7] The American Board of Emergency Medicine has included understanding legal concepts in its "Model of the Clinical Practice of Emergency Medicine."[8] However, it is still to be determined how best to cover these topics as part of the EM training curriculum.

OBJECTIVES

We aimed to determine whether a two-hour, case-based curriculum developed with our hospital legal counsel would efficiently improve our residents' comfort with approaching three common legal scenarios encountered by EPs and strengthen resident understanding of their own rights within the medicolegal system.

CURRICULAR DESIGN

After repeated instances of our residents' receiving subpoenas, we reached out to our hospital legal counsel regarding the need to develop a curriculum focused on common scenarios encountered by EPs. A short, 30-minute, didactic review was developed, and three case scenarios were introduced. Our legal counsel was able to modify actual documents and forms that had been sent to physicians whom he had previously represented and use them to create small-group discussions surrounding how to best approach these scenarios (see Supplement). Topics covered by the three case scenarios included responding to a subpoena, serving as a witness, and being involved in a deposition. This session was held in August 2021.

The learners were given time to review the documents and answer discussion questions regarding the case as a small group. They then returned to the larger group to review their findings and receive feedback from EM faculty and our legal counsel regarding their conclusions.

IMPACT/EFFECTIVENESS

Prior to the beginning of the workshop, participants were asked to complete an anonymous, voluntary survey. Residents were asked to complete an identical survey immediately following the completion of the workshop. The survey included nine multiple-choice questions aimed at evaluating the residents' baseline medicolegal knowledge and five questions assessing trainee comfort with each topic highlighted in the session, using a Likert scale. Examples of knowledge questions included the following: "The differences between being deposed and testifying in court are____"; and "If I am subpoenaed to testify for a patient I saw, what should my next step be?" Approval for this study was obtained from the Quality Improvement/Quality Assessment Review Committee of the Department of Emergency Medicine at the Medical College of Wisconsin and was deemed institutional review board-exempt.

A total of 34 postgraduate year 1–3 EM residents had the opportunity to complete this workshop as a part of their weekly conference curriculum. The pre-survey was started by 29 participants with 26 completing all questions. The post-survey was completed by 19 participants. All the participants stated that they did not have previous training in the legal aspects of medicine, including handling a subpoena, being called as a witness, or giving a deposition. Postgraduate year of training was not asked on the survey to avoid identification of the participants, given the small sample size.

The pre-survey demonstrated there was significant uncertainty surrounding the processes, definitions, and intentions of the legal system (Figure 1). A large majority of participants stated they would not know what to do if they

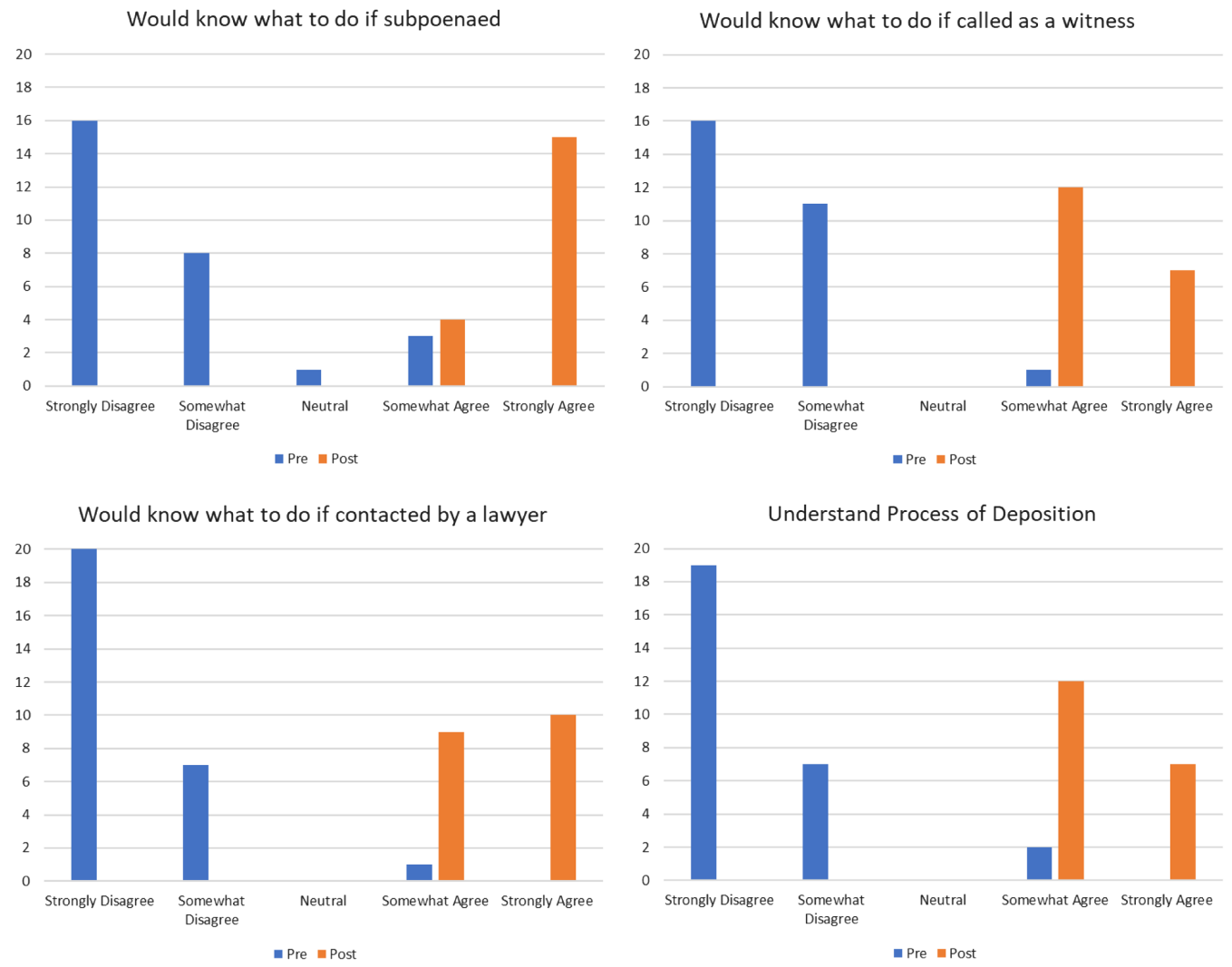

Figure 1. Pre- and post-survey scenario results demonstrate improvement in self-reported knowledge of emergency residents on how to approach several common legal scenarios.

received a subpoena (85.71%), were called as a witness in a trial (96.43%), or received correspondence from a lawyer (96.43%). Responses revealed uncertainty with the goal of deposition and how it differed from trial, with only 40.74% of residents indicating that practice for trial was not an included goal and 56.26% knowing that only one person is being questioned during deposition.

Residents left the workshop with a deeper understanding of their legal rights and the proper steps to take when contacted regarding litigation. On the post-survey, 100% of residents reported knowing what to do after receiving a subpoena, being called as a witness for a trial, and understanding the process involved in giving a deposition, and 94.74% agreed that they were aware of the policy statements by the American College of Emergency Physicians surrounding acting as an expert witness. When the session was evaluated overall, 100% "strongly agreed" the session was helpful. These pre- and post-session changes in self-assessment of knowledge (questions noted in Figure 1) were found to be statistically significant ($P < 0.05$) when a chi-squared analysis was performed.

Regarding knowledge related to the goal of a deposition, differences between a deposition and a trial, obligations to respond to a lawyer, residents' correct-response rate improved after the session (Figure 2). These differences were not found to be statistically significant. However, when we performed a chi-squared analysis we found a statistically significant improvement in knowledge related to being contacted by a lawyer ($P < 0.05$).

At the end of the workshop, there was a distinct shift from residents lacking a basic understanding of the medicolegal system, or what role physicians serve, to being well prepared for the deposition process and how to properly respond to a legal correspondence. Residents were provided with the

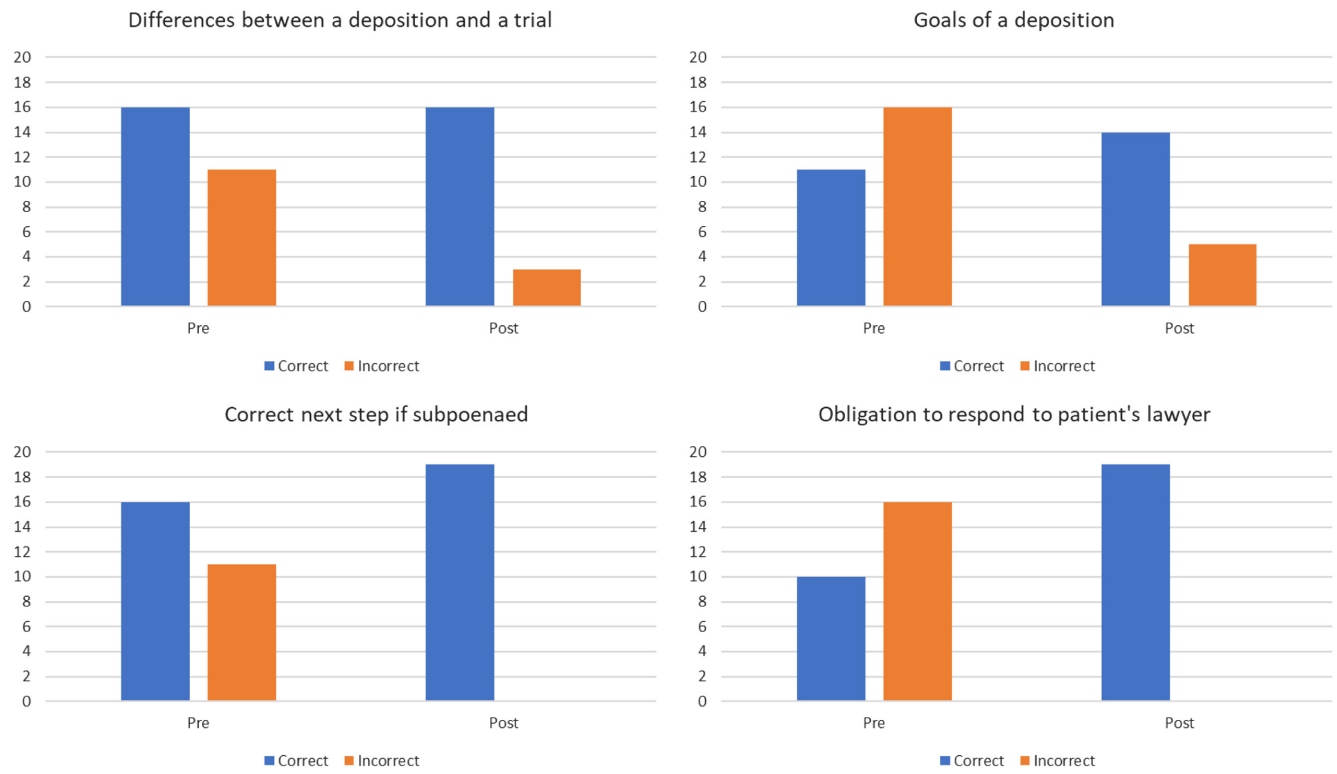

Figure 2. Knowledge-based questions assessed before and after the session demonstrate an increase in correct response, although the majority were not statistically significant.

framework required to navigate litigation and provided a space to discuss common medicolegal scenarios that EPs face. These results were achieved in a relatively brief time frame, which indicates that short, case-based scenarios can be implemented to effectively improve resident knowledge and provide them with information that can be immediately applied. Based on the success of this workshop, we believe that similar medicolegal sessions could be adapted for other residency programs to reduce the gap between experience and education.

Our workshop model did have limitations including limited sample size and utilization of a single training site. Because each state within the US has its own legal nuances, no legal curriculum can be universally applied to all residency programs. Additionally, we observed a 27% drop in participation on the post-survey when compared to the pre-survey. Sustainability of the impact we observed has not yet been assessed in a delayed fashion.

Moving forward, integrating methods used by other programs, including expanding to multiple sessions, leveraging partnerships with local law schools, using mock trial scenarios, or creating forensic science electives, may further bolster this curriculum. We identify that the number of topics covered in this curriculum are limited. Certainly, additional work can be done to further expand this basic legal education to cover the scenarios EPs routinely encounter.

CONCLUSION

Based on the current literature and the experiences of our residents, EM trainees are unprepared for their encounters with the legal system and require more education on this topic. Given the frequent contact that emergency physicians have with the medicolegal system, further work is essential to improve trainee preparedness for contact with the legal system. There remains a vast opportunity for this area of resident education to further grow and develop. Medical educators within EM should continue to explore how to best cover these topics within their own programs.

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The Evolution of Board-Certified Emergency Physicians and Staffing of Emergency Departments in Israel

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Introduction: Emergency medicine (EM) was recognized as a specialty in Israel in 1999. Fifty-nine of the 234 (25%) attending physicians working in emergency departments (ED) nationwide in 2002 were board-certified emergency physicians (EP). A 2012 study revealed that 123/270 (45%) of ED attendings were EPs, and that there were 71 EM residents. The EPs primarily worked midweek morning shifts, leaving the EDs mostly staffed by other specialties. Our objective in this study was to re-evaluate the EP workforce in Israeli EDs and their employment status and satisfaction 10 years after the last study, which was conducted in 2012.

Methods: We performed a three-part, prospective cross-sectional study: 1) a survey, sent to all EDs in Israel, to assess the numbers, level of training, and specialties of physicians working in EDs; 2) an anonymous questionnaire, sent to EPs in Israel, to assess their demographics, training, employment, and work satisfaction; and 3) interviews of a convenience sample of EPs analyzed by a thematic approach.

Results: There were 266 board-certified EPs, 141 (53%) of whom were employed in EDs full-time or part-time. Sixty-two non-EPs also worked in EDs. The EPs were present in the EDs primarily during weekday morning shifts. There were 273 EM residents nationwide. A total of 101 questionnaires were completed and revealed that EPs working part-time in the ED worked fewer hours, received higher salaries, and had more years of experience compared to EPs working full time or not working in the ED. Satisfaction correlated only with working part time. Meaningful work, diversity, and rewarding relationships with patients and colleagues were major positive reasons for working in the ED. Feeling undervalued, carrying a heavy caseload, and having complicated relationships with other hospital departments were reasons against working in the ED.

Conclusion: Our study findings showed an increase in the number of trained and in-training EPs, and a decrease in the percentage of board-certified EPs who persevere in the EDs. Emergency medicine in Israel is at a crossroads: more physicians are choosing EM than a decade ago, but retention of board-certified EPs is a major concern, as it is worldwide. We recommend taking measures to maintain trained and experienced EPs working in the ED by allowing part-time ED positions, introducing dedicated academic time, and diversifying EP roles, functioning, and work routine. [West J Emerg Med. 2024;25(4)584–592.]

INTRODUCTION

The Israeli Ministry of Health first recognized emergency medicine (EM) as a subspecialty in 1999. Candidates had to be board certified in either anesthesiology, internal medicine, general surgery, family medicine, or orthopedics. Initially, recognition as specialists in EM was issued to 36 selected physicians with long experience and leadership positions working in emergency departments (ED), and the first EM boards exams were offered in 2002.[1] A national survey conducted in 2002 revealed that only 59 of 234 attending physicians working in EDs nationwide were board certified in EM, and that they were primarily working weekday morning shifts, leaving the ED staffed at other times largely by residents from other specialties. In addition, there were 37 residents in the EM subspecialty residency program.[2]

Emergency medicine was accredited by the Israeli Medical Association Scientific Council as a primary specialty in 2012, and the first residents enrolled in ED training programs. A second national survey conducted during that year showing that 123 of 270 attending physicians employed in EDs nationwide were board-certified emergency physicians (EP). The distribution of the working hours for EPs had remained mostly unchanged compared to the previous decade, with trained EPs primarily working weekday morning shifts. The number of EM subspecialty and specialty residents had risen to 71 in 2012.[3]

In the same year, a labor agreement between the Israel Medical Association, a professional organization representing 95% of Israeli physicians, and the Ministry of Health stipulated the employment mechanism that recognizes the uniqueness of the nature of the work of emergency physicians: a full-time position for EPs was defined as 36 hours per week that may be divided flexibly on weekday mornings and evenings. Additional working hours, as well as night and weekend work, are considered overtime.

Changes in the ED workforce have been seen in recent years in many western countries and have had a major impact on EDs. In the United States, an insufficient number of EPs in the early 2000s seems to have been resolved by the 2020s, at least in urban areas.[4–6] In the United Kingdom (UK), an EM staffing crisis induced the establishment of a taskforce, which was able to greatly improve the situation.[7–10] We believe that our study can shed some light about the EM staffing crisis, not only in Israel but globally.

Our goals in this study were to re-evaluate the characteristics of the EP workforce in Israel, as well as the employment status and work satisfaction of board-certified EPs working both in and out of the ED. We also surveyed the composition of specialist physicians working in the various EDs in Israel to document the number of board-certified EPs and their workplaces and to examine the factors that influence them to persist in their work in EDs or to move to other areas of practice.

Population Health Research Capsule

What do we already know about this issue?
In 2002, 25% of attending physicians working in Israeli EDs were emergency physicians (EP). By 2012, 45% of ED attendings were EPs.

What was the research question?
What is the status in 2022? And what factors affect the retention of EPs?

What was the major finding of the study?
In 2022, 69% of ED attendings were EPs, but only 59% of all EPs worked in EDs. Part-time employment is a factor in predicting EPs' satisfaction (OR 9.8, $P = 0.02$).

How does this improve population health?
A nationwide organizational effort is required to maintain trained and experienced personnel working in Israeli EDs.

METHODS

Study Design and Setting

This was a prospective, cross-sectional study with three components. We conducted a questionnaire-based survey designed to assess the number and percentage of full-time equivalent (FTE), level of training, and specialty (if any) of physicians working in EDs. We enquired about staff member variations at various times during the day as well as during the week (Appendix 1). The survey was adapted from and designed to largely replicate previously published workforce studies of the same population in 2003 and 2012.[2,3] The survey was sent to the administrative staff at all 25 Israeli EDs.

An anonymous questionnaire was sent to all 334 board-certified EPs in Israel to retrieve data on their demographics (age, gender, marital status, and number of children); training (years of practice, hospital, and type of residency); place of employment; and work satisfaction. The questionnaire was emailed to all licensed EPs in Israel with the help of the Israel Medical Association. All respondents were asked if they would be willing to participate in an in-depth interview. Those who agreed—EPs employed in EDs and other various fields of practice—created a convenience sample for the third component of the research: a qualitative analysis of in-depth interviews. The interviews were semi-structured, designed by the research team, conducted telephonically, recorded, and transcribed for analysis. Interviewees were asked about their feelings and opinions

regarding work in the ED, the field of EM, and their motives for career choices. The qualitative analysis of the data obtained during the interviews was based on a thematic approach. Two independent researchers, both with master's degrees in psychology, analyzed the data and followed the six phases suggested by Braun and Clarke's guide for thematic analysis.[11]

Statistical Analysis

We performed data entry and analysis with SPSS Statistics, version 28 (SPSS Inc, Chicago, IL). Questionnaire response rate was calculated based on the American Association of Public Opinion Research guidelines. We described categorical variables by numbers and percentages, and continuous variables by mean ± standard deviation, median, and interquartile range. Normal distribution was assessed using the Shapiro-Wilk test. We assessed differences in continuous variables between two groups with ANOVA for variances with normal distribution and the Kruskal-Wallis test for variances with non-normal distribution. Differences between categorical variables were assessed with the chi-squared or Fisher exact test, as appropriate, and we assessed differences between medians by a Mann-Whitney U test for independent means. Criteria for satisfaction, which were considered important based on a literature review,[7,8,12] were entered into a multivariate model in which odds ratios and 95% confidence intervals (CI) were calculated for factors found to be significant according to a two-tailed *P*-value of <0.05.

RESULTS

National Data and Data from Hospitals

We obtained information from 25/25 Israeli EDs with a survey response rate of 100%, although data on minor points from three EDs was incomplete. There were 266 board-certified EPs of whom 141 (53%) were employed full time or part time in EDs nationwide. Sixty-two non-EP attendings were also employed in the EDs. The average numbers of attendings (both EPs and non-EPs) per ED, stratified by large hospitals (>700 beds), medium hospitals (400–700 beds), and small hospitals (<400 beds), are shown in Table 1.

A FTE is a unit that indicates the workload of an employed person in a way that makes workloads comparable. A FTE of 1.0 is equivalent to a full-time worker, while an FTE of 0.5 represents hours worked that are equivalent to half of those worked by a full-time worker.

The presence of EPs in the ED by shift is shown in Figure 1. The EPs were present in the EDs primarily during weekday morning shifts, and their presence was limited during night and weekend shifts, mainly in large hospitals. The numbers of all active EPs, active EPs working the EDs, non-EP attendings working the ED, and EM residents in Israel are shown in Figure 1 and Table 2.

Table 1. Average number of emergency department (ED) attendings employed in Israeli EDs by hospital size in 2021.

	Emergency physicians			Non-EP attendings		
Hospital size*	Average number of physicians	Years of practice, mean	FTE fraction, mean	Average number of physicians	Years of practice	FTE fraction mean
Large (n = 10)	8.7	9	0.9	3.6	13	0.8
Medium (n = 7)	3.8	15	1.0	2.3	20	1.0
Small (n = 8)	3.9	8	0.8	6.0	6	0.5

ED, emergency department; *EP*, emergency physician; *FTE,* full-time equivalent.
*Large = >700 beds; medium = 400–700 beds; and small = <400 beds.

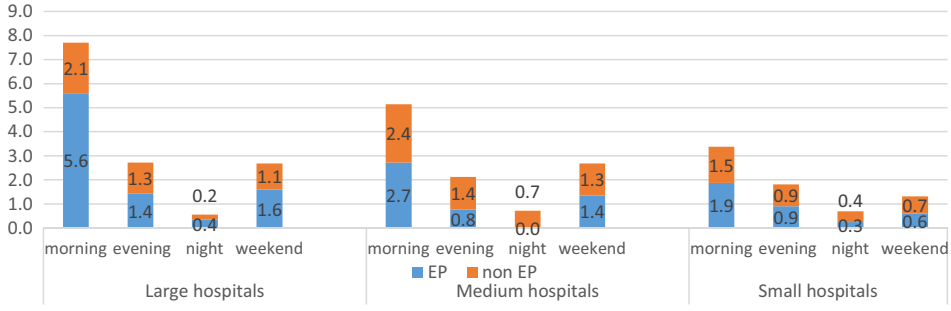


Figure 1. Mean number of emergency department attending physicians by shift.
EP, emergency physicians.

Table 2. Israeli physician workforce in emergency departments nationwide, by year.

Year	Active board-certified EPs	Active board-certified EPs employed in EDs[1]	EM residents	Non-EP attendings employed in EDs	Total number of attendings employed in the EDs	Total number of physicians employed in the EDs
2003	59	59	–	175	234	234
2012	154	110	71	147	257	328
2022	239	141	273	62	203	476

ED, emergency department; *EP*, emergency physician; *EM*, emergency medicine.
[1]Full-time and part-time employment.

Survey Results

Quantitative Analysis

Of 334 questionnaires sent, 106 physicians responded; five responses were excluded due to incomplete replies, for a response rate of 30%. Seventy-nine of the respondents were employed in adults EDs and 22 in pediatric EDs. The mean age of the cohort was 45 ± 10 years, and 65% were males (Table 2). Thirty-five of the 79 EPs in adults EDS (44%) worked full time, 29 (37%) worked part time, and 15 (19%) did not work in any ED. A comparison of age, gender, number of children, residency type, time in practice, and ED weekly hours revealed that they were significantly different between these three groups ($P < 0.05$) (Table 3). Medical experience (in years) was significantly lower among full-time workers compared to both part-timer workers and those who no longer worked in an ED. The mean number of weekly working hours (either in the ED or in another department) was significantly higher for full-timers compared to those who had left the ED. Both total salary and salary per hour were significantly different between the three groups in favor of the group who had left the ED (Table 3).

Work Satisfaction

Sixty-nine of the 83 EP respondents who worked in an ED (83%), completed the work- satisfaction section of the survey. The mean age was 49 years (SD 10), 47 (65%) were male, 59 (82%) were married or in a relationship, and 37 (51%) worked full time. Forty physicians reported not being

Table 3. Demographics of survey participants.

Variable	Full-time (n = 51)	Part-time (n = 32)	None (n = 17)	*P*-value
Age, years	43.3 ± 7.0	55.0 ± 11.3	56.0 ± 14.4	<0.001
Gender, female, n (%)	18 (38.3)	3 (10.0)	4 (28.6)	0.02
Family status				
Married	7 (13.7)	1 (3.1)	2 (11.1)	
Single	43 (84.3)	27 (84.4)	14 (77.8)	0.19
Divorced	1 (2.0)	4 (12.5)	2 (11.1)	
Children				
<18 years of age	2.1 ± 1.4	1.1 ± 1.4	1.0 ± 1.4	0.004
≥18 years of age	0.57 ± 1.1	2.3 ± 2.0	1.6 ± 1.4	<0.001
Residency path, n (%)				
Direct	8 (15.7)	11 (34.4)	1 (5.6)	
Fellowship	37 (72.5)	11 (34.4)	9 (50.0)	<0.001
By license only	1 (2.0)	10 (31.3)	7 (38.9)	
Years in practice	14.0 ± 7.4	25.6 ± 11.8	26.7 ± 14.9	<0.001
Weekly working hours	39.7 ± 8.8	35.4 ± 15.4	30.0 ± 15.8	0.02
Monthly salary (NIS)*	45,400 ± 17,549	73,571 ± 31,530	38,235 ± 17,133	<0.001
Hourly salary (NIS)	248 ± 84	576 ± 570	506 ± 618	0.002

*Average monthly salary in Israel in 2021 – 12,000 NIS.
Values are given mean ±SD unless indicated otherwise.
NIS, New Israeli shekel.

Table 4. Factors predicting emergency physician job satisfaction.

Variable	aOR (95% CI)	*P*-value
Age (years)	0.9 (0.8–1.0)	0.17
Gender	2.7 (0.4–15.7)	0.26
Family status	1.5 (0.02–97.6)	0.97
Number of children	1.2 (0.5–2.8)	0.63
Part-time position (vs full time)	9.8 (1.2–74.9)	0.02
Emergency physician in adult ED (vs pediatric)	7.8 (0.5–107.4)	0.12
Salary (grade)	1.4 (0.8–2.6)	0.17
ED annual visits	1.0 (0.9–1.0)	0.33

aOR, adjusted odds ratio; *ED*, emergency department.

satisfied, and 29 reported that they were satisfied. Table 4 displays a multivariate regression model for ED attending physician satisfaction. Part-time work was the only significant independent predictor of satisfaction, with an adjusted odds ratio of 9.8 (95% CI 1.2–74.9), $P = 0.02$.

Qualitative Analysis

Sixty-six of the 83 EP respondents who worked in an ED (80%) completed the survey section on the ED work environment. Most of them reported that they had a heavy workload and a stressful work environment (93% for each). Only 37% felt properly appreciated, and only 41% felt adequately financially compensated. Most of them (81%) had social satisfaction (ie, enjoyed relationship with colleagues), and 75% had professional satisfaction (for further details on work environment in the ED, see Appendix 2).

Thirty-one of the survey respondents who were EPs currently working in an ED (45%) reported considering leaving the ED for various reasons. We compared their reasons with those stated by physicians who had left the ED and, interestingly, few respondents in each group stated that salary was very influential in considering leaving (11%) or in their decision to leave (7%) the ED, despite the major difference in salaries. Lack of opportunity for professional advancement was more influential in the group that was considering leaving (38%) compared to the group that had left (13%). Good social relationships with co-workers was an important factor for staying in the ED, both for those who had left and for those who considered leaving, 70% and 66% (respectively) stating it as "influential" and "very influential." Work satisfaction was also a significant factor in both groups for staying in the ED (80% and 77%, respectively, stating it as "influential" and "very influential").

We interviewed 19 EPs who ranged in age from 30–75 years; 12 were male. Sixteen worked in adult EDs and three were pediatric EPs; seven worked full time and three worked part time, and nine had left the ED (two for military service, two for a fellowship program abroad, and one who retired). Of those working in EDs, eight worked in large hospitals (five different hospitals), one in a medium-size hospital, and one in a small hospital. Nine worked in a central hospital, and one worked in a peripheral hospital.

The thematic analysis yielded two major axes: axis 1 in favor of working as an EP, and axis 2 against working as an EP. Each axis had three corresponding themes, and each theme had several sub-themes. (See Table 5 for details on the themes). Three main themes were found on both axes: internal motivational factors; external factors; and relationships. Those findings were in line with results from the quantitative analyses. For example, limited career advancement opportunities were found to be significant in both the quantitative and qualitative analyses (axis 2, theme 2). The two safeguarding factors that emerged in both types of analysis were meaningful work (axis 1, theme 1) and a good relationship with the multidisciplinary ED personnel (axis 1, theme 3).

DISCUSSION

The Importance of an Emergency Physician Presence in the ED

It is widely acknowledged that the presence of EPs in the ED is highly beneficial for patient care.[13] Research carried out in 2014 in a large, urban Israeli medical center found an advantage to the presence of EPs in the ED compared to physicians board-certified in other specialties in terms of length of stay in the ED.[14] Shortening the patient's length of stay in an ED reduced ED crowding, a parameter that was found to be associated with reduced mortality.[15] A study in a rural Australian medical center ED showed improvement in patient wait time and access block (the situation where patients who have been assessed in the ED and require admission are boarded in the ED due to a lack of inpatient bed capacity) when EPs were present.[16] Another Australian study showed that patients cared for by EM residents benefitted from the presence of an EP attending.[17] Several UK studies also found clinical benefit in the presence of an EP attending in the ED.[18–20] One study noted that senior

Table 5. Themes of the in-depth interviews with Israeli emergency physicians.

Axis 1	Axis 2
Pros for working as an emergency physician	Cons for working as an emergency physician
1. Internal motivational factors - Meaningful work - Positive previous experience - Personal responsibility - Receiving immediate feedback - Sense of authority - Intellectual satisfaction (learning and teaching opportunities)	1. Internal motivational factors: - Feeling undervalued - Feeling incompatible with role - Effects on one's mental health - Effects on family relationships
2. External factors - Patients and care diversity. - Case-managing - Holistic approach to patient care - Dynamic nature of the field - Suitable compensation for extra hours	2. External factors: - Limited career advancement opportunities - Intense caseload - Verbal and physical abuse from patients and their relatives - Unsuitable baseline wages - Work conditions (staffing, lack of appropriate equipment, lack of sustenance and rest)
3. Relationships - Rewarding patient-doctor relationship - Good relationships with multidisciplinary ED personnel - Good relationships with ED management	3. Relationships - Poor relationships with hospital management - Complicated relationships with consulting experts from other departments - Complicated relationships and tension with other hospital departments

EP, emergency physician; *ED*, emergency department.

doctor input in patient care in the ED added accuracy to disposition decisions, thus impacting patient safety and improving departmental flow.[18] Another study carried out in a pediatric ED showed that the presence of EPs was also cost effective, resulting in fewer admissions, shorter wait time, and fewer patient complaints.[19] These and other studies promoted a recommendation for 24/7 EP presence in EDs in the UK.[20]

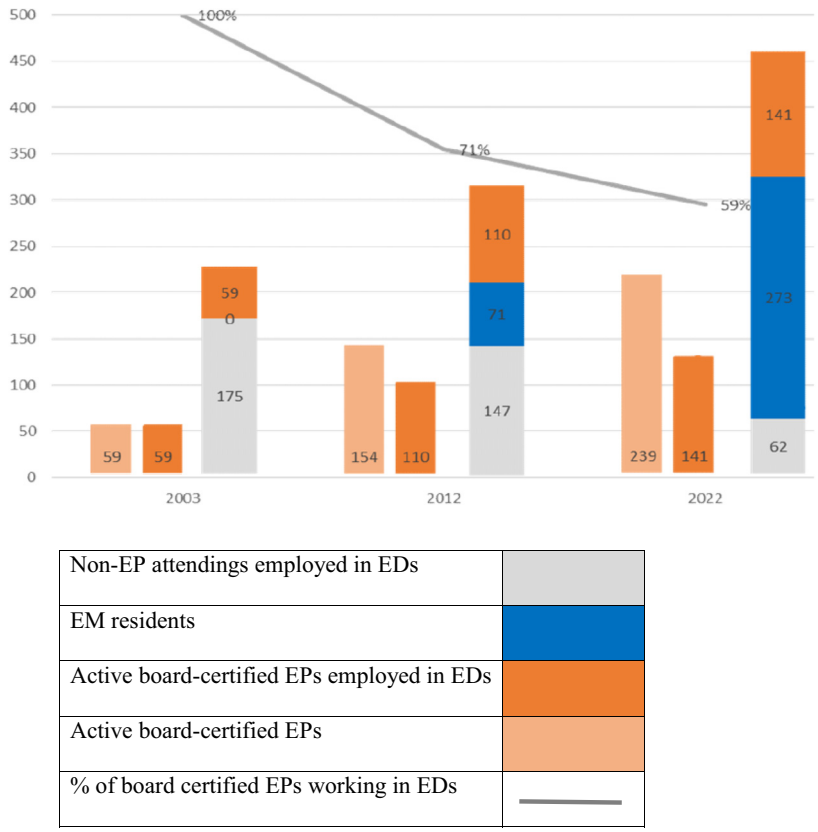
Emergency Department Clinical Workforce

We found a decrease in the number of non-EP attending physicians working in EDs nationwide, and a parallel increase in the number of EM residents. There was an increase in the number of EP attendings working in the EDs, but the percentage of board-certified EPs employed in EDs was decreasing, even after considering the number of retired physicians (Figure 2). The two earlier studies on the Israeli ED workforce in 2003[2] and 2012[3] found that the presence of EPs in the EDs was mostly limited to weekday morning shifts. The 2012 study showed some presence of EPs on weekends, but only in large (>700 beds) hospitals. The findings of the most recent study, conducted in 2022, showed a similar trend, with an increase in the presence of EPs during morning shifts and a smaller increase, if any, in their presence during evening, night, and weekend shifts. (See Appendix 1 for further details.)

Insufficient numbers of EPs working in EDs were evident in the United States (US) in the early 2000s.[4] As part of the effort to rectify this shortage, Camargo et al developed a formula calculating the number of EPs required for the proper function of an ED. The calculation was based upon several assumptions: 1) a board-certified EP was present at all times; 2) an average physician can attend 2.8 patients per hour; and 3) there was a 40-hour work week, with one-third of those hours dedicated to non-clinical work. The formula those authors created is:

$$\text{Number of needed doctors} = \frac{\text{annual number of ED visits}}{3548}.$$

Based upon this model, the authors concluded that only 55% of the current EP demand was being met in the US in 2005.[4] Using data on physicians' workforce and patient volumes, another group found that the 2016 shortage in EPs in the US was decreasing yearly.[6] A follow-up study, conducted in 2020, anticipated that the shortage would be resolved as early as 2021, especially in urban zones. Furthermore, that study predicted that, after extrapolating current trends in residency graduation and accounting for increased patient volumes, the EP workforce could be oversupplied by 20–30% by the year 2030.[5]



EP emergency physicians; ED emergency department; EM emergency medicine

Figure 2. Comparison between workforces in 2003, 2012, and 2022.

The specialty of EM suffered a similar staffing crisis in the UK, which led to the establishment of a taskforce dedicated to finding a solution.[7,8] The British College of Emergency Medicine established a "rule of thumb" for ED staffing that considered sustainability and the need for resident supervision. According to the proposed guideline, 12–16 certified EPs are required for basic coverage for an ED with 100,000 visits per year, assuming the presence of competent residents and physician assistants.[21] Following the recommendations of the taskforce, changes in practice and policy, through innovations as well as recognition of the particular stresses posed by a career in EM, led to rapid growth of EM in the UK in terms of both attending physicians and residents.[9,10] A shortage of EPs in Australia in 2008 caused some policymakers to advocate for the employment of general practitioners in EDs,[22] as had been done earlier in Israel (but to a lesser degree after the establishment of an EM residency). Our current study showed similar findings. We, too, observed a major lack in highly trained personnel in the ED, which should eventually be resolved thanks to the increasing numbers of residents in EM.

Several studies found that burnout played an important role in EP turnover.[10] High burnout rates were also demonstrated in Israeli EPs in a recent study, and that the rate worsened as a result of the COVID-19 pandemic.[23] Low job satisfaction was linked with leaving and intention to leave the ED, according to other reports.[24,25] This issue is a matter of considerable concern: in our current study, 60% of the EPs were found to have low levels of work satisfaction.

The qualitative analysis of our study revealed that the factors contributing to work satisfaction seem to be universal: teamwork; continued training and engaging in academic activities; and work diversity.[26–30] Stress and problematic communication with the administration were also found to be negative factors in EP retention.[26,27,30,31] Our data showed that most EPs find their work to be very stressful. Notably, despite the difference in salaries between EPs who left the ED and those who remained in full- and part-time work and the dissatisfaction with the baseline salaries, salary was rarely the major reason for leaving or considering leaving the ED. This correlates with the finding of our previous study, in which physicians who left reported

lower salaries in the ED but did not state that salary was a major reason for leaving.[28]

To the best of our knowledge, the application of a flexible employment model to increase retention in the ED has rarely been discussed in the literature. Part-time employment was suggested by James et al as a means of motivating veteran physicians to continue working in the ED.[29] In another small, qualitative study, the suitability of EM for flexible working was listed as being a factor influencing the career choice of being an EP.[32]

The concept of part-time work for physicians in general is over two decades old and has been associated with younger and female doctors seeking a better work-life balance. In the late 1990s a series of articles debated the possible impact of flexible and part-time employment on doctors, including its effect on professionalism and career sustainability. The matter of patients' continuity of care was also debated.[33–35] Part-time employment became more common among primary care physicians and pediatricians, but its effect on doctors' wellbeing and patient outcome was rarely researched.[36] Parkerton et al found higher quality performance for primary care physicians working part time, and Panattoni et al found higher patient satisfaction.[37,38]

According to our findings, part-time employment in the ED is an independent predictor for physician satisfaction. Further study is required to determine whether application of this employment model improves work satisfaction and increases retention of EPs. Potentially, a part- time work model could also allow for a larger and more diverse ED workforce.

LIMITATIONS

This study has several limitations that bear mention. First, we relied upon self-reported data for the EDs. Secondly, the questionnaire had a relatively low (30%) response rate and was subject to response bias and under-representation of various groups: our findings showed that while 41% of EPs are not employed in EDs, only 19% of the survey respondents belonged to the group of EPs who had left the ED, rendering that group under-represented in the survey. Other, less easily identified groups may also be under-represented. Additionally, the in-depth interviews were conducted with a small convenience sample and were thus subject to selection bias.

CONCLUSION

Emergency medicine in Israel is at a crossroads. On the one hand, a larger than ever number of young doctors have chosen EM for their residency training. On the other hand, the retention of board-certified EPs is a major concern. It is our view that a nationwide organizational effort is required to maintain trained and experienced clinicians working in our EDs.

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RISE-EM: Resident Instruction in Social Emergency Medicine, a Cohort Study of a Novel Curriculum

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There is recognition in the field of emergency medicine (EM) that social determinants of health (SDoH) are key drivers of patient care outcomes. Leaders in EM are calling for curricula integrating SDoH assessment and intervention, public health, and multidisciplinary approaches to EM care throughout medical school and residency. This intersection of SDoH and the emergency care system is known as social emergency medicine (SEM). Currently, there are few resources available for EM training programs to integrate this content; as a result, few EM trainees receive adequate education in SEM. To address this gap, we developed a four-part training in SEM tailored to EM residency programs and medical schools.

This curriculum, known as RISE-EM (Resident Instruction in Social Emergency Medicine), uses video lectures, case examples, and group discussions to engage trainees and develop competency in providing sound care that is grounded in evidence-based principles of SEM. In the current study, we tested RISE-EM by delivering the video lectures to residents and medical students in two training programs. We administered pre- and post-course knowledge tests and a post-course participant attitudes survey to assess the acceptability and potential efficacy of the program for improving SEM knowledge and attitudes among EM learners.

We found it to be both feasible and acceptable to introduce SEM content in residency conferences, with preliminary data showing statistically significant improvement in knowledge of the content and self-efficacy to apply it to their clinical practice. In summary, RISE-EM has been highly valued by EM learners and viewed as a strong supplement to their existing training, and it has been shown to successfully improve SEM knowledge and attitudes. [West J Emerg Med. 2024;25(4)593–601.]

BACKGROUND

Health is closely intertwined with multiple complex aspects of a person's daily life, an interaction termed social medicine. Several studies have demonstrated that social determinants of health (SDoH), which may include personal, social, economic, and other aspects of well-being, may contribute to 40% or greater of total health outcomes, whereas clinical interventions, both inpatient and outpatient, were estimated to contribute a mere 12–20%.[1] For example, although the clinician may diagnose pneumonia and prescribe antibiotics, the pneumonia will not improve if the patient cannot access the treatment due to cost or other barriers or continues to live in an environment that does not allow or promote healing.[2]

In the 19th century, Virchow stated: "Medicine is a social science, and politics is nothing more than medicine on a large scale."[3] However, only recently has the field of emergency medicine (EM) begun to appropriately emphasize the need for interventions beyond medical care, at both political and societal levels.[4,5] Social medicine, a term that includes

considerations of SDoH, social epidemiology, and social science in the provision of medical care, emphasizes concepts of health equity, advocacy and interdisciplinary approaches to improving patient outcomes and reducing health disparities.[6]

Given the large impact of social determinants on health, it seems natural to emphasize training in social medicine across the stages of medical education. Some undergraduate programs and medical schools have begun implementing new social medicine curricula; however, these modules continue to make up only a small segment of most training programs.[7–9] In response to a growing body of research and interest in social medicine, medical leaders, including the Accreditation Council for Graduate Medical Education and the American College of Emergency PhysiciansACGME and ACEP, are calling for more exposure to social medicine throughout medical school and residency training.[10–12]

Many EM leaders have expressed valid concerns regarding the challenges of addressing SDoH in the ED, often based on lack of resources to effectively implement new services in an already overburdened system. The emergency department (ED) is perceived by many members of the community as a setting where they can seek support for unmet social needs, a pattern that places a substantial burden on care systems not designed for this purpose.[13,14] However, as a system that provides care at all times, regardless of complaint or patient circumstance, the ED is arguably the care setting most critical for integrating principles of social medicine.[15–17]

This reevaluation of the role of EM has occurred in a changing climate of social welfare, where the ED has become part of a critical social safety net.[15] It is becoming clear that it is no longer acceptable to treat the medical etiologies of health problems alone, when SDoH play such a key role in our patients' experience of disease and illness. Given their frontline interaction with SDoH, emergency physicians are in a key position to lead a paradigm shift from merely treating downstream disease to leading change, systemically and collaboratively, in upstream preventative health factors.[4,15,17,18] This intersection of SDoH and the emergency care system is known as social emergency medicine (SEM), a promising approach to responding to the unmet societal demands flooding the ED. Emergency clinicians must embrace an expanded role to guide the healthcare system and policymakers in designing a system that integrates social and medical aspects of care.[15]

Despite these escalating roles and responsibilities of the emergency care system, there has been little inclusion of social medicine in graduate EM education, and many EM education leaders have identified this as an area of need.[13,17–19]At the time this project was started, there were only four social medicine and population health fellowships in EM nationally. This number has grown to 11 by time of publication, reflecting the growing acknowledgment of this field.[20] These residency tracks and fellowships are important in paving the way for the budding field of SEM but are harder to translate to other programs seeking to adopt SEM content.

Population Health Research Capsule

What do we already know about this issue?
The intersection of social determinants of health and emergency medicine is an important area of training for which little open access training material exists.

What was the research question?
Can a social emergency medicine (SEM) curriculum increase resident learners' SEM knowledge and self-efficacy?

What was the major finding of the study?
Our curriculum improved SEM knowledge and self-efficacy in a cohort of 26 students ($P < 0.001$).

How does this improve population health?
Open access education material for SEM can assist in facilitating the development of SEM skills and self-efficacy for residents in their clinical practice.

One way to offer a curriculum or content that is easily adaptable into various programs is Free Open Access Medical Education (FOAMed). This open access education is prominent in EM, and existing online material focuses heavily on standard board exam content, procedural competence, and cutting-edge therapies. Given the paucity of SEM tools available online, projects are currently in the works to offer supplemental blog posts or cases covering SEM material. However, at this time, to the best of our knowledge, a unifying curriculum with objectives, ordered lectures, and supplemental material does not exist in FOAMed form, accessible to the greater EM education community. To address this gap in training resources for EM residents and medical students, we developed a four-part SEM training curriculum to be delivered by video with accompanying case examples and group discussions, known as Resident Instruction in Social Emergency Medicine (RISE-EM).

OBJECTIVES

We describe the design of RISE-EM and findings from piloting the curriculum with three cohorts of EM residents and medical students. Our objective with these pilot cohorts was to test the preliminary feasibility, acceptability, and potential for impact of RISE-EM in facilitating the

development of SEM skills for learners in their clinical practice. The three course objectives are as follows:

1. Expose EM residents and medical students to the concepts of SEM
2. Provide learners with a vocabulary that they can use to proactively address SDoH
3. Teach SEM skills that learners can use in the ED when working with patients

CURRICULAR DESIGN

The RISE-EM curriculum was built upon a core foundation in social medicine principles and curriculum objectives from the Social Medicine Reference Toolkit.[6] The toolkit was validated through an analytical review by 15 social medicine programs worldwide and published by a national organization of physicians and public health scientists known as the Social Medicine Consortium.

The SEM-specific material was developed using diverse published works, including a series from the Inventing Social Emergency Medicine Consensus Conference in 2017, a summit composed of leaders from many organizations, including the Andrew Levitt Center for Social Emergency Medicine and ACEP.[21] We also reviewed the primary literature to identify challenges and successful techniques related to teaching SDoH content. Throughout the modules, difficult concepts were repeated, explained in multiple different ways, and incorporated into clinical scenarios to encourage understanding and depth of processing. "Nudges," a theme throughout RISE-EM, were inspired by nudge theory, a concept in behavioral economics and political theory.[22]

The RISE-EM curriculum is based on video lectures, which allows it to be used asynchronously or synchronously, in one sitting or over multiple sessions. The curriculum consists of four video modules (Figure 1), each approximately 20 minutes in length (Appendix A). The sessions were designed to be short enough to fit into most conferences or to hold the attention of a busy resident outside the hospital. The videos use motifs and engaging discussions carried through each video to encourage depth of processing and to assist with recall. The educational modality was chosen to facilitate easy adoption by EM residency and medical student training programs with teaching guides provided and the ability to fit into various didactic schedules and both in-person and virtual formats.

METHODS

We completed a prospective cohort study designed to test the feasibility, acceptability, and potential efficacy of RISE-EM in improving SEM knowledge and attitudes among EM learners. We tested the curriculum with two groups of EM residents. Group 1 consisted of residents and medical students at a southeastern EM residency conference in October 2020. Group 2 consisted of residents at a northeastern EM residency conference in November 2021. We arranged for participation by sending an introductory email through each residency's email listserv (Appendix B). Participants were given two weeks to complete pre-course material and two weeks to submit post-course material after the intervention. As this was a pilot feasibility study of an educational innovation, the study size was determined by the number of residents and medical students who chose to participate at the two institutions where the

	Module 1	Module 2	Module 3	Module 4
Module title	Introduction to Social Emergency Medicine	How Humans Change the Definition of Illness	Cognitive Framework: Social Factors at the Bedside	We Can't Do This Alone: An Approach that Is Interdisciplinary and Multi-sectoral
Objectives	• Understand the role social determinants of health (SDoH) plays in emergency system patients' health • Be able to state why SDoH are important to the emergency clinician • Be able to identify opportunities to address SDoH in various scenarios	• Understand the ability of society to shape medical definitions • Discuss the composition of high-frequency ED users • Use four lenses to help navigate disposition in socially complex patients	• Discuss and describe how bedside factors impact health equity and health outcomes • Understand challenges of physicians to promote health equity	• Be able to describe examples of innovative programs and pathways to discharge • Become acquainted with local resources and community programs • Apply this knowledge to patient cases

Figure 1. Course modules by individual objectives.

curriculum was tested. This research was conducted with the approval of each institution's institutional review board (IRB).

Learners who wished to participate in the study followed a link in the introductory email, provided their informed consent to participate, and were asked to take a 20-minute pre-test and survey on a secure survey website, with responses collected anonymously. Study participants then watched the four video lectures (delivered differently to Group 1 and Group 2, see below). After watching all the videos, participants engaged in a live group discussion during standard residency didactic time. They were then asked to complete a second 20-minute online survey, comprising the same knowledge test and additional questions about the feasibility and acceptability of the course for future delivery. Reminder emails for completion were automatically sent to individuals every five days after initial pre-course material completion, for a maximum of up to three times as defined in our IRB application. This study protocol is illustrated in Appendix C.

Survey Instruments

The pre-course survey began with basic demographic questions and eight additional questions related to interest and self-efficacy in applying SEM principles in clinical practice (Appendix D). The 19-item pre- and post-knowledge tests were identical, composed of 4–5 multiple-choice questions of content from each RISE-EM lecture, with 19 in total (Appendix E). Each correct response received 1 point for a total score of 0–19. The course content questions were designed to assess baseline and post-course SEM knowledge.

The post-course survey consisted of the same eight items to assess for change in interest and self-efficacy (ie, "Following my completion of this course, I feel confident in assessing and addressing social determinants of health in my clinical encounters"). Feasibility was assessed by recording the number of modules completed by each participant. We also evaluated acceptability and perceptions of course quality with nine questions adapted from the Student Evaluation of Educational Quality (SEEQ) instrument.[23] The post-course survey concluded with open-ended questions regarding 1) specific recommendations for improving the course, 2) content that was most useful, 3) missing content or areas to add, and 4) ways the course changed their perspective on social medicine, if at all (see Appendix F for the full items).

Statistical Analysis

We used descriptive statistics to summarize characteristics of the study sample. We assessed the potential efficacy of the RISE-EM curriculum by comparing participants' pre-and post-curricular scores on knowledge and self-efficacy items using paired samples *t*-tests. Adequate feasibility was defined by a target of at least 80% of participants completing all four course modules and the post-course survey. For the acceptability and course quality questions derived from the SEEQ, we defined adequate acceptability as at least 80% of participants indicating that they fully agreed with the item. It is important to note that these quantitative comparisons are exploratory in nature due to the small sample size in this pilot study.

To analyze participant responses to open-ended questions, we used an applied thematic approach to qualitative analysis.[24] Two study investigators read the responses independently to identify common themes and develop a preliminary codebook. The investigators then came together to discuss these preliminary themes, identify similarities and differences in the codebooks, and combine the themes into a single, cohesive codebook. The team then re-analyzed the qualitative responses onto the final codebook, defined the codes in descriptive memos, and reviewed the codes to identify representative quotations. We randomly selected five participants' (26.3%) responses to be re-coded by a second reviewer and evaluated for inter-coder agreement using a pre-established threshold of 80% agreement.[25] Inter-coder agreement on these responses was 90.5%, which exceeded the desired threshold, and disagreements identified in the re-coding process were reconciled by the two reviewers until consensus was reached.

IMPACT/EFFICACY

Participants

Participants in Group 1 watched the modules in conference over the course of an hour, and then engaged in a 20-minute group discussion. In total, six participants (of 36 total eligible trainees) in Group 1 enrolled in the study. All six enrolled participants completed both the pre- and post-test and survey material. In Group 2, 23 participants (of 30 total eligible trainees) enrolled in the study. Participants watched the video modules on their own and then had a 50-minute group discussion in conference. Two participants in Group 2 (8.3%) did not complete post-course material.

Although both groups had material presented during regularly scheduled educational sessions, Group 2 completed all video modules asynchronously immediately following the pre-course material, possibly explaining the higher rate of participation.

Participants had a mean age of 30 years and a relatively equal gender distribution (Table 1). The majority of participants who identified as White ethnicity (24, 83%) and a relatively even spread between levels of training at about one-third of participants per postgraduate yearPGY year in the combined cohort, plus two fourth-year medical students participating in Group 1. Baseline enthusiasm and interest was very high for SEM. Approximately half of participants reported prior coursework in social medicine, ranging from

Table 1. Participant demographics and other characteristics.

	Group 1 (n = 6) number (%)	Group 2 (n = 23) number (%)	Combined cohort (N = 29) number (%)
Age (years), mean (range)	29 (27–33)	30 (27–37)	30 (27–37)
Female gender	1 (17%)	13 (57%)	14 (48%)
Ethnicity			
White	4 (67%)	20 (87.0%)	24 (83%)
Black	1 (17%)	0 (0%)	1 (3%)
Hispanic or Latino	1 (17%)	0 (0%)	1 (3%)
Asian	0 (0%)	1 (4.3%)	1 (3%)
More than one race/ethnicity	0 (0%)	1 (4.3%)	1 (3%)
Declined to respond	0 (0%)	1 (4.3%)	1 (3%)
Level of training[1]			
MS4	2 (33%)	0 (0%)	2 (7%)
PGY-1	1(17%)	8 (34.8%)	9 (31%)
PGY-2	1 (17%)	9 (39.1%)	10 (35%)
PGY-3	2 (33%)	6 (26.1%)	8 (28%)
Considers SEM important			
"Yes"	6 (100%)	22 (96%)	28 (97%)
"Somewhat"	0 (0%)	1 (4%)	1 (3%)
Interested in learning more about SEM			
"Yes"	6 (100%)	19 (82.6%)	25 (86%)
"Somewhat"	0 (0%)	4 (17%)	4 (14%)
Prior coursework in social medicine	1 (17%)	15 (65.2%)	16 (55%)

MS4, fourth-year medical student; *PGY*, postgraduate year; *SEM*, social emergency medicine.

self-study, single lectures and discussions, or short workshops, to formal courses as a core component of the medical school curriculum.

Improvement in SEM Knowledge and Self-Efficacy

In Group 1, six participants completed pre-and post-course assessments. SEM knowledge significantly improved by 3.2 points on average, from 7.0 to 10.2 ($t(5) = 3.63$, $P = 0.015$), while self-efficacy significantly improved by 4.8 points on average, from 12.3 to 17.1 of 18 possible ($t(5) = 3.24$, $P = 0.023$). In Group 2, pre- and post-course assessments of the 21 participants also showed statistically significant improvement in both knowledge and self-efficacy (Table 2). Knowledge of SEM improved by 2.5 points on

Table 2. Post-course test analysis showing change in \knowledge of social emergency medicine and self-efficacy and completion of modules (n = 27).

	Group 1 (n = 6)	Group 2 (n = 21)	Combined (n = 27)[1]
SEM knowledge	+ 3.2 points ($t(5) = 3.63$, $P = 0.015$)[2]	+ 2.5 points ($t(20) = 4.07$, $P < 0.001$)	+ 2.7 points ($t(26) = 5.00$, $P < 0.001$)
Self-efficacy	+ 4.8 points ($t(5) = 3.24$, $P = 0.023$)	+ 5.8 points ($t(20) = 8.89$, $P < 0.001$)	+ 5.5 points ($t(26) = 9.28$, $P < 0.001$)
Video modules completed by participants (percent completed)	6 (100%)	21 (100%)	27 (100%)

[1]Note: Two participants completed the pre-course survey only.
[2]Paired sample *t*-test: t(degrees of freedom) = t-value, *P*-value.
SEM, social emergency medicine.

average, from 8.2 to 10.7 ($t(20) = 4.07$, $P = 0.001$). Self-efficacy also significantly improved by 5.8 points on average, from 8.0 to 13.8 ($t(20) = 8.89$, $P < 0.001$).

Feasibility and Acceptability

In the two cohorts combined, survey participants completed 100% of the video modules, while 27 of the 29 (93.1%) enrolled participants completed the post-course survey, exceeding our pre-established threshold for feasibility (Table 2). Twenty-five participants who completed the post-course survey (92.6%) felt the course content was important and that they would recommend the course to others, far exceeding our pre-established threshold for acceptability, while two participants (7.3%) agreed with these statements "somewhat."

An overwhelming majority of participants (86%) felt that the course was organized in a manner that facilitated understanding the underlying concepts of SEM and felt the number of sessions (76%) and length of each session (79%) was "just right" (Table 3). Regarding the content of the modules, participants felt overall the modules effectively explained and illustrated the presented concepts (90%), contrasted the implications of various theories (90%), and adequately discussed current developments in the field (90%). See Tables 2 and 3 for complete quantitative results summary.

Qualitative Findings

For the five open-ended questions, 25 participants (five from Group 1 and 20 from Group 2 (86.2%) answered some or all of these questions (see Table 4). Regarding recommendations for course improvement, many responses suggested breaking content into different days or sessions to allow more time to process the content. Many participants also suggested that the instruction should include more examples of how to apply the content, including both case-based and action-focused examples. As one participant shared, it would be helpful to give "more specific examples. The ones provided were very helpful." When asked about missing content, three participants again pointed to the benefit of including more examples, including "more concrete ways to incorporate SEM into my practice in a variety of settings." Other, less common recommendations for improvement included a desire for a short quiz after each module and the suggestion to repeat key information more often across sessions.

In sharing the most helpful content, four participants appreciated the introduction to SDoH, which "was the most generalizable for my ED and included the hardest facts that I was unaware of previously regarding the effects of homelessness." Three participants noted that other helpful content included ways to take action as a clinician toward addressing SDoH. When asked to describe how the course changed their views on social medicine, five participants reported plans to implement a change in their clinical practice, and five indicated that the course reinforced the importance of SDoH. For example, one participant stated that RISE-EM "reinforced [SDoH] importance and has motivated me to consider SDoH in every patient and think more about how this is impacting their health and what my role is in addressing these in the ED."

Table 3. Acceptability and organization responses regarding RISE-EM course (n = 27).

Acceptability questions			
Felt the course was important			
"yes"	6 (100%)	19 (90.5%)	25 (93%)
"somewhat"	0 (0%)	2 (9.5%)	2 (7%)
Would recommend the course to others			
"yes"	6 (100%)	19 (90.5%)	25 (93%)
"somewhat"	0 (0%)	2 (9.5%)	2 (7%)
Course organization questions			
Felt the course was organized in a helpful manner			
"yes"	5 (83%)	20 (95%)	25 (86%)
"somewhat"	1 (17%)	0 (0%)	1 (3%)
No response	0 (0%)	1 (5%)	1 (3%)
Felt the number of sessions was too many, just right, not enough			
"just right"	2 (33%)	20 (95%)	22 (76%)
"too many"	0 (0%)	1 (5%)	1 (3%)
"not enough"	4 (67%)	0 (0%)	4 (14%)
Felt the length of each session was too long, just right, too short			
"just right"	5 (83%)	18 (86%)	23 (79%)
"too long"	1 (17%)	3 (14%)	4 (13.8%)
Module content questions			
Modules effectively explained and illustrated the presented concepts			
"yes"	6 (100%)	20 (95%)	26 (90%)
"somewhat"	0 (0%)	1 (5%)	1 (3%)
Modules contrasted the implications of various theories			
"yes"	5 (83%)	19 (90%)	24 (83%)
"somewhat"	1 (17%)	2 (10%)	3 (10%)
Modules adequately discussed current developments in the field.			
"yes"	5 (83%)	21 (100%)	26 (90%)
"somewhat"	1 (17%)	0 (0%)	1 (3%)
Rate the level of instruction (just right, too basic)			
"just right"	6 (100%)	20 (95%)	26 (90%)
"too basic"	0 (0%)	1 (5%)	1 (3%)

LIMITATIONS

The primary limitation of our research is the small sample size and self-selection of residents who chose to participate in this educational innovation. Participants with high interest in

Table 4. Top themes in qualitative responses, sorted by topic, with exemplar quotes.

Major themes, by question	Exemplar quote
Recommendations to improve, change (questions 1–2)	
Break content into different days, sessions	*"I would have liked to have done one at a time with a discussion between each."*
More examples	*"More specific examples. The ones provided were very helpful."*
Most useful content (question 3)	
Lecture 1 – introduction to SEM	*"Was the most generalizable for my ED and included the most hard facts that I was unaware of previously regarding the effects of homelessness."*
Ways to take action as a clinician toward addressing SDoH	*"I think educating [clinicians] goes a long way, but in order to maximize the change in addressing SEM I think the rest of the ED staff should be included in these educational efforts."*
Missing content (question 4)	
More real-life examples	*"More concrete ways to incorporate SEM into my practice in a variety of settings."*
Nursing consideration and involvement	*"I think educating [clinicians] goes a long way, but in order to maximize the change in addressing SEM I think the rest of the ED staff should be included in these educational efforts."*
Perspective change (question 5)	
Plans to implement a change in their clinical practice	*"Reinforced [SDoH] importance and has motivated me to consider SDoH in every patient and think more about how this is impacting their health and what my role is in addressing these in the ED."*
The course reinforced the importance of SDoH	*"This course does a great job of raising awareness of the need for SEM, emphasizing the importance and feasibility of addressing it."*

SEM, social emergency medicine; *ED*, emergency department; *SDoH*, social determinants of health.

SEM material may have self-selected into the study, leading to higher ratings for acceptability. Given the importance we placed on ensuring that residents did not feel inappropriately compelled to participate, this was an anticipated result. Future testing of the intervention should incorporate larger and more diverse samples and may include testing in programs where completion of these modules is a mandatory component of training. Additionally, participants took the same test twice, which may have contributed to a practice effect that falsely elevated improvement. Future studies may incorporate a control group to compare improvement of those who receive the training as compared to those who complete the assessments only.

Another consideration is that Group 1 participants watched the videos in conference, in a single hour-long sitting, whereas the material was designed to be spaced out over four sessions. This format was chosen as it best met the needs and time available of the residency program at the time. Group 2 watched the videos asynchronously; so the time spent between video lectures was undefined. These differences in course delivery (conference vs home) and ability to space lectures out over time may have led to unmeasured differences in results based on training format.

CONCLUSION

Leaders in emergency medicine and social medicine combined forces to create a new field of study, education, and interventions: social emergency medicine, the interaction between social factors and the emergency care system.[26] Just as the field was in its early stages of development, COVID-19 struck, putting into the public eye social disparities and the growing burden on the emergency care system.[27–29] The resulting wave of demand for addressing social medicine in the ED has trickled into resident education, as evidenced by the increased number of related fellowships and ACGME recommendations.[30] Now, with growing awareness of the importance of addressing social determinants of health in EM, our video modules offer flexible, FOAMed resources to the program or clerkship director. Over 90% of participants felt the course content was important and would recommend the course to others. Furthermore, RISE-EM showed potential efficacy in improving SEM knowledge and growth in interest and self-efficacy in applying SEM competencies.

We identified a need for an easily implementable and educationally sound curriculum to improve knowledge of social determinants of health in EM training programs for both residents and medical students. We created a didactic video series with core content that can be integrated into existing EM training. The RISE-EM curriculum is a feasible, acceptable form of free open access medical education to assist in facilitating the development of SEM skills and self-efficacy for residents in their clinical practice. Residents demonstrated improved knowledge of SEM concepts and improved comfort in applying SEM to their practice. Given

the participants in the study were recruited from two separate EM residencies, we feel that this curriculum is adaptable to other EM programs. In future studies we aim to include a larger sample size to allow for greater statistical power and more advanced statistical analysis, including assessing different delivery formats and evaluating differences in RISE-EM impact and outcomes based on various learner characteristics.

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Rural and Ethnic Disparities in Out-of-hospital Care and Transport Pathways After Road Traffic Trauma in New Zealand

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Introduction: The out-of-hospital emergency medical service (EMS) care responses and the transport pathways to hospital play a vital role in patient survival following injury and are the first component of a well-functioning, optimised system of trauma care. Despite longstanding challenges in delivering equitable healthcare services in the health system of Aotearoa-New Zealand (NZ), little is known about inequities in EMS-delivered care and transport pathways to hospital-level care.

Methods: This population-level cohort study on out-of-hospital care, based on national EMS data, included trauma patients <85 years in age who were injured in a road traffic crash (RTC). In this study we examined the combined relationship between ethnicity and geographical location of injury in EMS out-of-hospital care and transport pathways following RTCs in Aotearoa-NZ. Analyses were stratified by geographical location of injury (rural and urban) and combined ethnicity-geographical location (rural Māori, rural non-Māori, urban Māori, and urban non-Māori).

Results: In a two-year period, there were 746 eligible patients; of these, 692 were transported to hospital. Indigenous Māori comprised 28% (196) of vehicle occupants attended by EMS, while 47% (324) of patients' injuries occurred in a rural location. The EMS transport pathways to hospital for rural patients were slower to reach first hospital (total in slowest tertile of time 44% vs 7%, $P \geq 0.001$) and longer to reach definitive care (direct transport, 77% vs 87%, $P = 0.001$) compared to urban patients. Māori patients injured in a rural location were comparatively less likely than rural non-Māori to be triaged to priority transport pathways (fastest dispatch triage, 92% vs 97%, respectively, $P = 0.05$); slower to reach first hospital (total in slowest tertile of time, 55% vs 41%, $P = 0.02$); and had less access to specialist trauma care (reached tertiary trauma hospital, 51% vs 73%, $P = 0.02$).

Conclusion: Among RTC patients attended and transported by EMS in NZ, there was variability in out-of-hospital EMS transport pathways through to specialist trauma care, strongly patterned by location of incident and ethnicity. These findings, mirroring other health disparities for Māori, provide an equity-focused evidence base to guide clinical and policy decision makers to optimize the delivery of EMS care and reduce disparities associated with out-of-hospital EMS care. [West J Emerg Med. 2024;25(4)602–613.]

INTRODUCTION

Recent decades have seen the evolution of out-of-hospital emergency medical services (EMS) from transportation of patients to emergency departments (ED) through to clinicians of advanced out-of-hospital healthcare and delivery of major trauma patients directly to appropriate care via a range of transportation means and destination pathways.[1] These EMS responses and the transport pathways to hospital play a key role in patient survival and are the first component of a well-functioning, optimised system of trauma care. Internationally there is growing recognition of the critical need to eliminate inequities in healthcare. Poorer outcomes following major injury for residents of rural communities and for indigenous and minoritized ethnic groups are well documented,[2] with evidence of longer times to reach definitive care for rurally located injured patients[3–6] and lower standards of EMS care and transport for racial and ethnic minorities.[7] However, little is known about differential access to or delivery of out-of-hospital EMS care for rural and ethnic sub-groups, in particular whether disparities in trauma outcomes can be reduced by more equitable access to EMS care and designated transport pathways.

Population-level data on EMS-delivered out-of-hospital care and transport pathways to hospital can help inform the optimisation of national EMS systems, address inequities, and improve patient outcomes following major trauma, yet major knowledge gaps remain in these areas. The national healthcare system of Aotearoa New Zealand (NZ) has had longstanding challenges in delivering equitable levels of access to healthcare services to indigenous Māori and to rural communities.[8–10] Māori, as indigenous people of Aotearoa, are partners to the health equity commitments under Te Tiriti – Treaty of Waitangi with the Crown, yet they experience pervasive inequities.[11] Previous research has identified longer theoretical access times to out-of-hospital EMS care for Māori, which are hypothesized to reflect, in part, the higher proportion of Māori residing in rural regions with limited timely access to healthcare services.[12,13] Improvements in trauma outcomes, therefore, require investigation of inter-related inequities based on both geography and ethnicity. This major gap in knowledge is reflected in the national EMS systems of other nations with comparable health system contexts and similarly situated rural remote and indigenous populations, thereby further motivating the need for investigation.

The actual out-of-hospital EMS care responses and transport pathways to hospital experienced by under-served rural and Māori populations and the interconnected and overlapping geographic and ethnic disparities remain unexplored at a national level. Deeper understanding of sources of disparities in EMS care and transport pathways to hospital are the first step in guiding quality improvements and planning for equitable out-of-hospital EMS services.

Population Health Research Capsule

What do we already know about this issue?
Poorer injury outcomes in rural, indigenous, and minority communities are well documented.

What was the research question?
What are the rural and ethnic inequities in out-of-hospital care and transport pathways following traffic crashes in New Zealand?

What was the major finding of the study?
Disparities were most evident in rural Māori: less likely to first be transported to (33 vs 56%, $p < 0.001$), or ever reach a tertiary care hospital (51 vs 73%, $p < 0.001$).

How does this improve population health?
More equity-focused planning and investment in rural EMS services to reduce documented disparities in EMS care would benefit both rural and indigenous populations.

Our objective in this analysis was to describe potential geographic, and intersectional geographic and ethnic inequities, in out-of-hospital care and the transport pathways to hospital delivered by NZ EMS professionals following major trauma due to road traffic crashes (RTC).

METHODS

Study Design and Setting

In this observational study we used a retrospective cohort based on two years (2016–2018) of clinical and EMS utilisation data from NZ's two road ambulance services: Hone Hato St John, servicing 97% of NZ's geographical area; and Wellington Free Ambulance, servicing the remaining greater Wellington and Wairarapa. Data is routinely collected in a prescribed format by ambulance staff to create a collective electronic administrative resource comprised of individual electronic patient report forms (ePRF); this objective data was used for analysis. The full study protocol has been published elsewhere.[14,15]

Out-of-hospital EMS are predominantly based on the provision of emergency road ambulance services. Road services are predominantly dispatched in the first instance. Air services, operating helicopters on a regional basis, are dispatched on an as-needed basis to provide additional

clinical care to access remote sites or facilitate timely transport of seriously injured patients. Emergency medical serrvices are readily accessible via a single, national emergency telephone number (111) with two national ambulance control centres triaging and dispatching appropriate EMS. Funding for EMS services provided within 24 hours of an injury incident is covered by NZ's universal no-fault injury provider, the Accident Compensation Corporation.[16]

New Zealand's trauma system, covering the two main islands of 265,000 km^2 and approximately five million people, is designed around four regional nodes of trauma care with 22 trauma-receiving hospitals.[17,18] Each node has at least one metropolitan, tertiary trauma hospital service providing intensive care, advanced resources, and services around the clock, generally similar to Level 1 American College of Surgeons-verified trauma centres.[19] Regional trauma hospitals are capable of initial resuscitation, stabilisation, intensive care and, in some instances, definitive management of injured patients. Small rural hospitals are capable of basic non-specialist trauma services with limited trauma specialisation and resources.[18,20]

The New Zealand Major Trauma Destination Policy, which is applied in out-of-hospital trauma responses, was introduced in 2017 to improve survival from major trauma.[21] The policy outlines the eligibility criteria to be assessed by EMS professionals at the scene for direct transfer to a major trauma centre.[20]

Selection of Participants

To obtain a dataset of EMS-attended major trauma patients, we undertook linkage between electronic records of EMS attendance and the New Zealand Trauma Registry (NZTR), a registry of all hospitalised major trauma patients.

Study participants were individuals aged 0–84 years who had suffered a major trauma as defined by the NZTR (Injury Severity Score, [ISS] >12, or died in or out-of-hospital) and had been attended by a road EMS professional between 1 December 2016–30 November 2018. Attendance by air EMS professionals was captured in the records of attendance taken by road EMS professionals. We excluded patients with incomplete clinical records. For this analysis study participants were restricted to motor vehicle occupants who sustained injuries during a RTC to allow for any inequities in EMS care to be identified irrespective of differences in injury mechanism. To focus on those patients with the most to benefit from timely EMS care and transport, analyses were conducted on patients assessed by ambulance staff as having an on-scene EMS triage condition of status 1 (critical, immediate threat to life) or status 2 (serious, potential threat to life). Analyses describe all non-transported (ie, died on scene, refused transport) and transported patients, and then focus on EMS pathways by restricting analyses to those transported from the scene by EMS.

Measurements

We obtained sociodemographic characteristics of age, gender, and ethnicity from the Ministry of Health's National Health Index database. Ethnicity is collected in national health data using established data collection protocols and allows for people to self-identify up to three separate ethnic affiliations. In accordance with Te Tiriti principles and ethnicity data protocols in NZ,[22] ethnicity was categorised as Māori and non-Māori, prioritising Māori if any of the Ministry of Health-recorded ethnicity fields were Māori.

The geographic location of injury incident was determined by applying the 2018 Geographical Classification for Health (GCH) to EMS-recorded co-ordinates of the patient's location; the two major- level GCH classifications of rural or urban was used.[23] We determined the "rurality" of the injury incident by applying the 2018 GCH to EMS-recorded co-ordinates of the patient's location; the two major-level GCH classifications of rural or urban (includes suburban) were used.[23] We used population, drive-time thresholds, and stakeholder workshops to classify small areas into GCH categories, which were then validated quantitatively. Injury characteristics included dominant injury type (blunt or penetrating) and presence of traumatic brain injury as assessed on scene by EMS staff. The NZTR provided data on ISS, which is automatically coded using Abbreviated Injury Scale codes entered at hospital discharge. We classified ISS values into two groups: survivable (ISS $\leq$ 25) and reduced survivability (ISS > 25).

We determined on-scene patient status and vital signs from EMS staff data. The Glasgow Coma Scale (GCS) indicates the degree of patient consciousness ranging from entirely unresponsive (scored 3) to normal response (scored 15): categorised $\leq$10 and >10. Pulse rate was grouped into one of two categories: 60-130 beats per minute or "<60 or >130." Systolic blood pressure was dichotomised: <90 and $\geq$90 millimeters of mercury. Life-threatening events that could jeopardise patient survival were defined using the methodology of Gomes et al (2010).[24] We identified these events using EMS clinical impressions captured on scene and grouped them into airway (A), breathing (B), circulation (C), and neurological disability (N) based on the commonly used 'Airway Breathing Circulation' approach for identifying and treating life-threatening events following trauma (Figure 1).[25,26]

Outcome Measures

Outcome measures of EMS care and transport used in this study were predominantly captured in emergency road ambulance staff data, which we categorised as follows.

Measures of EMS infrastructure and practice level at incident included the highest practice level of crew attending the incident categorised into three categories reflecting the increasing level of skill of EMS staff on scene: emergency medical technician (EMT), paramedic, and intensive care

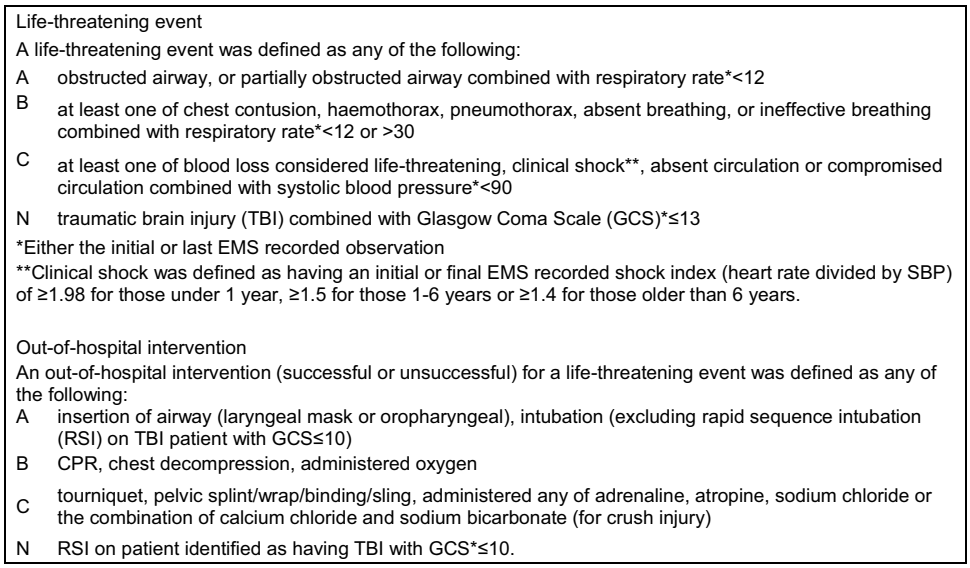

Figure 1. Definition of life-threatening event and out-of-hospital interventions (consistent with Gomes et al, 2010).[24] *EMS*, emergency mdical servics; *CPR*, cardiopulmonary resuscitation.

paramedic (ICP). A variable indicating whether a single vehicle crew attended the incident was generated from EMS vehicle attendance count.

EMS transport pathways to trauma care included measures of final computer-aided dispatch triage status as assigned by the EMS professional, direct transport to highest level of hospital care during the care episode, and whether transport involved air ambulance. We also included the level of trauma care of the first receiving hospital (level 1 [L1] being the highest level in NZ), and whether the patient reached a tertiary trauma hospital (L1) during the episode of care. Total time to reach hospital was grouped according to the overall distribution of this variable, with the slowest tertile (ie, slowest third) corresponding to total times ≥113 minutes. We calculated theoretical access time to hospital-level care (categorised into <60 minutes, ≥60 minutes); this measure captures the estimated shortest time taken to travel from the road ambulance base location to the locations of the incident, and then to the hospital location.[27]

EMS interventions delivered to address life-threatening events identified in the patient on scene were identified and classified using a modified version of classification from Gomes et al (2010)[24] (Figure 1).

We created aggregate measures of 'any life-threatening event' and 'any out-of-hospital intervention received'. Unmet need was measured by identifying those with a life-threatening event who received no out-of-hospital intervention on scene.

Primary Data Analysis

Analyses describe the transport status for the total cohort and the patterns of EMS care received and transport pathways for the transported sub-cohort receiving EMS care, using frequencies and proportions. We used chi-squared tests to compare proportions, with *t*-tests used to compare means between those injured in different geographical locations (rural/urban) and between those in combined ethnicity-geographical locations (rural Māori/rural non-Māori and urban Māori/urban non-Māori). Following the advice of Rothman,[28,29] no adjustment was made for multiple comparisons. Instead, *P* values have been provided to sufficient precision, so that readers can apply a threshold for significance if they wish.[30] Statistical analyses were performed using Stata SE, version 17 (StataCorp, College Station, TX).[31]

RESULTS

Characteristics of Study Subjects

The study population was comprised of 3,333 patients attended by an out-of-hospital EMS professional; of these, 748 met the inclusion criteria (Figure 2). A total of 56 patients in this cohort were not transported: one who declined transport and 55 patients who died on scene (Table 1). There was no evidence of differences in the distribution of on-scene deaths by location of incident or ethnicity. However, when compared to the overall proportion of Māori in the NZ population (17% of the NZ population aged ≤85 years[17]), Māori were disproportionately represented amongst on-scene fatalities due to RTC (19/55, 36% of on-scene RTC fatalities, $\chi^2 = 4.82$ $P = 0.03$). Of those meeting the criteria, 692 (93%) were transported to a hospital by an EMS professional and are described further.

The transported cohort had a mean age of 42 years and was predominantly male (59%) (Table 2). Indigenous Māori comprised 28% (196 patients) of status 1 and 2 vehicle

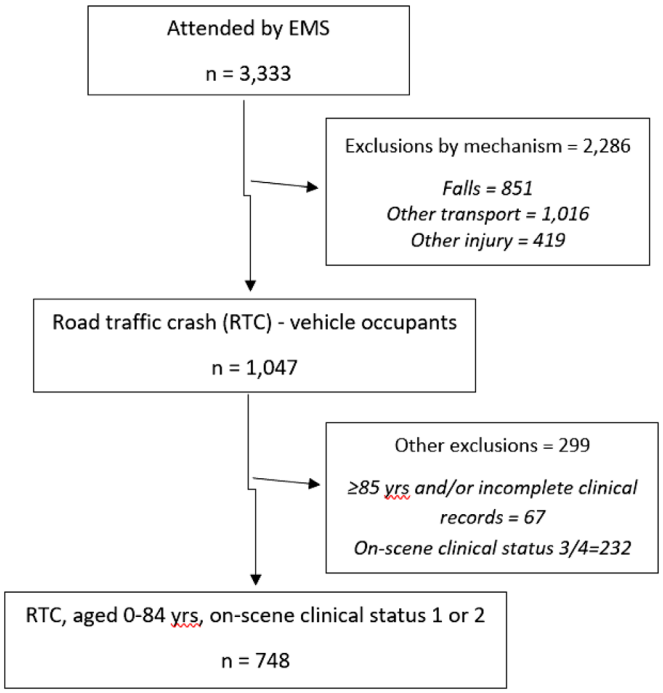

Figure 2. Flow diagram of vehicle occupant cohort selection.

occupants attended by EMS, while 47% (324) of patients' injuries occurred in a rural location. All injuries sustained by vehicle occupants were classified as blunt injuries. Differences in patient demographics and on-scene clinical status in the cohort were evident for Māori (Table 2). Rural Māori were on average four years younger while urban Māori were 11 years younger compared to their non-Māori counterparts. Despite similar average ISS scores and proportions of very severe ISS scores (ISS ≥ 25), on-scene EMS clinical triaging assessments differed markedly. However, ISS is calculated post event and is not available on scene to inform clinical triaging assessments by ambulance staff. A higher proportion of rural non-Māori patients were clinically assessed as having "potentially life-threatening" injuries (79% vs 68% of rural Māori, $P = 0.03$) while the opposite was observed in the urban setting (73% of urban non-Māori vs 84% of Māori, $P = 0.01$). The incidence of an assessment of GCS ≤ 13, indicating moderate to severe brain injury, was higher in urban Māori patients (16% vs 9% in urban non-Māori, $P = 0.05$).

Main Results

Table 3 examines differences in EMS infrastructure and transport pathways by incident location alone. Overall, most of the transported cohort (94%) were triaged into the fastest dispatch response ("purple-red"), were transported directly to their highest level of care achieved during the care episode (82%), and were attended, on scene, by the highest practice level of ICP (74%) (Table 3). Single-vehicle crew attendance was uncommon, occurring in 12% of attended patients. Overall, a lower proportion of patients injured rurally were directly transported to the highest level of care achieved in the care episode (77% vs 87% of urban patients) (Table 3). Patients in rural areas took longer to reach in-hospital care (44% vs 7%, out-of-hospital time ≥ 113 minutes, $P < 0.001$). Rural patients had significantly lower theoretical access to healthcare with 60 minutes (2% vs 40%, $P < 0.001$) and a higher level of air transport (51% vs 4% of urban patients, $P < 0.001$).

Table 4 examines the intersectional differences between incident location and ethnicity. Ethnic differences in EMS transport pathways to hospital-level care were most evident for rural Māori patients. Compared to rural non-Māori a lower proportion of rural Māori received the fastest triaged dispatch (92% Māori vs 97% non-Māori, $P = 0.05$), first attended a tertiary trauma hospital (33% vs 56%, $P < 0.001$), or reached a tertiary trauma hospital (51% vs. 73%, $P < 0.001$). The total out-of-hospital time to reach the first hospital was, on average, slower for rural Māori with 55% in the slowest tertile of total transport times (ie taking at least 113 minutes, or longer) to reach first hospital, compared with 41% of rural non-Māori patients ($P = 0.02$). There was no evidence of differences in theoretical access <60 minutes ($P = 0.2$) or use of air

Table 1. Emergency medical services transport status of road-traffic crash vehicle occupant cohort, by incident location and ethnicity (n = 748).

		Incident location			Combined incident location and ethnicity					
					Rural			Urban		
	Total (n = 748) n (%)	Rural (n = 345) n (%)	Urban (n = 397) n (%)	*P*-value	Māori (n = 93) n (%)	non-Māori (n = 250) n (%)	*P*-value	Māori (n = 120) n (%)	non-Māori (n = 270) n (%)	*P*-value
Transported	692 (92.6)	324 (93.9)	364 (91.7)		85 (91.4)	239 (95.6)		109 (90.8)	253 (93.7)	
Died on scene	55 (7.3)	21 (6.1)	33 (8.1)	0.3	8 (8.6)	11 (4.4)	0.1	11 (9.2)	17 (6.3)	0.3
Declined transport	1 (0.1)									

Missing items: Of those transported, 4 patients are missing incident location, and 8 patients are additionally missing ethnicity. Of those who died on scene, 1 patient is missing incident location, and 7 patients are additionally missing ethnicity.

Table 2. Patient demographics, injury characteristics and patient status on scene, by incident location and ethnicity (n = 692).

		Incident location			Combined incident location and ethnicity					
					Rural			Urban		
	Total (692) Mean	Rural (324) Mean	Urban (364) Mean	*P*-value	Māori (85) Mean	non-Māori (239) Mean	*P*-value	Māori (109) Mean	non-Māori (253) Mean	*P*-value
Mean age	42.42	41.59	43.17	0.8	38.41	42.8	0.03	35.08	46.49	<0.001
Mean ISS	19.47	19.48	19.49	0.5	19.18	19.59	0.3	19.96	19.27	0.8
	n (%)	n (%)	n (%)		n (%)	n (%)		n (%)	n (%)	
Male	409 (59)	190 (59)	217 (60)	0.7	54 (63)	136 (57)	0.2	69 (69)	147 (58)	0.3
Māori	196 (28)	85 (26)	109 (30)	0.2			–			–
Rural	324 (47)			–			–			–
TBI	50 (7)	19 (6)	31 (8)	0.1	6 (7)	13 (5)	0.5	9 (8)	22 (84)	0.8
ISS >25	128 (18)	61 (19)	67 (18)	0.9	16 (19)	45 (19)	0.9	24 (22)	42 (17)	0.2
Immediate threat to life	530 (77)	248 (76)	278 (76)	1	58 (68)	190 (79)	0.03	92 (84)	186 (74)	0.01
Systolic blood pressure (<90 mm Hg)	23 (3)	13 (4)	9 (2)	0.2	5 (6)	8 (3)	0.3	3 (3)	6 (2)	0.8
GCS (≤13)	82 (12)	40 (12)	42 (11)	0.7	10 (12)	30 (13)	0.8	18 (16)	24 (9)	0.05
Pulse (<60 or >130 bpm)	43 (6)	25 (8)	18 (5)	0.1	10 (12)	15 (6)	0.1	10 (9)	8 (3)	0.2

Missing data: 4 cases missing location, 2 cases were additionally missing ethnicity. There was a small amount of missing data: 4 missing rurality; 2 missing ethnicity indicator; 15 missing systolic blood pressure; 2 missing pulse.
GCS, Glasgow Coma Score; *ISS*, Injury Severity Score; *bpm*, beats per minute; *mm Hg*, millimetres of mercury.

Table 3. Emergency medical services infrastructure and transport pathways, total and by incident location (n = 692).

		Incident location		
	Total (692)* n (%)	Rural (324) n (%)	Urban (364) n (%)	*P*-value
EMS infrastructure and practice level				
Intensive care paramedic	513 (74.1)	240 (74.1)	269 (73.9)	1
Single crew attendance	87 (12.5)	38 (12.5)	49 (14.5)	0.4
EMS transport pathways				
Fastest dispatch response	654 (94.5)	310 (95.7)	340 (93.5)	0.2
Direct transport to definitive care*	572 (82.6)	251 (77.5)	318 (87.4)	0.001
Transport involved air ambulance	183 (26.4)	166 (51.2)	16 (4.4)	<0.001
First attended L1 hospital	385 (55.6)	163 (50.3)	220 (60.4)	0.009
L1 definitive care* hospital	469 (67.8)	217 (66.9)	249 (68.4)	0.6
Theoretical access < 60 minutes	162 (23.4)	16 (1.9)	146 (40.1)	<0.001
Total time to reach hospital (slowest tertile)	173 (25.0)	145 (44.8)	28 (7.7)	<0.001

Missing data: 4 cases missing location.
*Highest level of hospital care achieved during the care episode; ^ slowest tertile of times, lower boundary 113 minutes; all percentages are calculated as column percentages.
EMS, emergency medical services; *L1*, Level 1.

transportation ($P = 0.7$) by ethnicity for rural patients. Additionally, there was no evidence of substantive significant differences in EMS transport pathways between Māori and non-Māori patients injured in urban locations.

As presented in Table 5, some differences in receipt of life-saving EMS interventions were observed by incident location: a greater proportion of rural patients received an EMS intervention (54% rural vs 44% urban, $P = 0.01$).

Table 4. Emergency medical services infrastructure and transport pathways, by combined incident location and ethnicity (n = 692).

	Combined incident location and ethnicity					
	Rural			Urban		
	Māori (85) n (%)	Non-Māori (239) n (%)	*P*-value	Māori (109) n (%)	Non-Māori (253) n (%)	*P*-value
EMS infrastructure and practice level						
Intensive care paramedic	61 (71.8)	179 (74.9)	0.5	87 (79.8)	180 (71.2)	0.09
Single crew attendance	14 (17.9)	24 (10.6)	0.09	10 (9.6)	39 (16.8)	0.08
EMS transport pathways						
Fastest dispatch response	78 (91.8)	232 (97.0)	0.05	102 (93.6)	236 (93.3)	1
Direct transport to definitive care*	62 (72.9)	189 (79.1)	0.2	93 (85.3)	224 (88.5)	0.3
Transport involved air ambulance	45 (52.9)	121 (50.6)	0.7	2 (1.8)	14 (5.5)	0.1
First attended hospital L1	28 (32.9)	135 (56.5)	<0.0001	62 (56.9)	157 (62.1)	0.4
L1 definitive care* hospital	43 (50.6)	174 (72.8)	<0.0001	71 (65.1)	176 (69.6)	0.4
Theoretical access <60 minutes	2 (2.4)	14 (5.8)	0.2	48 (44.0)	98 (38.7)	0.3
Total time to reach hospital (slowest tertile)	47 (55.3)	98 (41.0)	0.02	7 (6.4)	21 (8.3)	0.5

Missing data: 4 cases missing location, 2 cases missing ethnicity.
*Highest level of hospital care achieved during the care episode; ^ slowest tertile of times, lower boundary 113 minutes; all percentages are calculated as column percentages.
EMS, emergency medical services; *L1*, Level 1.

Table 5. Life-threatening problems and potentially life-saving EMS interventions, by incident location and ethnicity (n = 692).

		Incident location		
	Total n (%) n = 692	Rural n (%) n = 324	Urban n (%) n = 364	*P*-value
Any life-threatening events experienced	115 (16.6)	45 (13.8)	69 (18.9)	0.07
Any potentially life-saving EMS intervention received	338 (48.8)	176 (54.3)	160 (43.9)	0.01
Presence of life-threating event, no EMS intervention	47 (6.8)	15 (4.6)	32 (8.8)	0.03
Life-threatening event	n = 115	n = 45	n = 69	
Airway (A) problem	0 (0.0)	0 (0.0)	0 (0.0)	–
Breathing (B) problem	90 (78.3)	30 (66.7)	59 (85.5)	0.4
Of those with (B), received treatment	46 (51.1)	18 (60.0)	27 (45.8)	0.2
Circulation (C) problem	16 (13.9)	11 (24.4)	4 (5.8)	0.004
Of those with (C), received treatment	8 (50.0)	5 (45.5)	2 (50.0)	0.8
Neurotrauma (N) problem	11 (9.6)	5 (11.1)	6 (8.7)	0.7
Of those with (N), received treatment	1 (<0.0)	1 (<0.0)	0 (0.0)	0.3

Missing data: 4 cases missing location, 2 cases missing ethnicity.
EMS, emergency medical services.

Additionally of those presenting with a life-threatening event, a greater proportion of urban patients received no recorded EMS intervention (5% rural vs. 9% urban, $P = 0.03$). While small percentages they likely reflect the closer proximity of hospital-level care in urban settings. There was no strong evidence of differences in percentages that identified with life-threatening events or that received EMS interventions between Māori and non-Māori in either rural or urban locations.

For those experiencing life-threatening events the majority experienced breathing problems (78%), with just over half these patients receiving one of the potentially life-saving EMS interventions in (outlined in Figure 1) to address these concerns while out of hospital. Similarly, only half of

those with life-threatening circulatory problems (8 of 16) received an identifiable EMS intervention (outlined in Figure 1). There were few substantive differences when examined by incident location (Table 5); however, rural patients were more likely to have a recorded circulatory problem than urban patients ($P = 0.004$). Similarly, there were few intersectional differences by location and ethnicity (results not shown in Table 5) with the exception of life-threatening events, which were more prevalent in urban non-Māori compared to rural non-Māori (13% rural vs 20% urban non-Māori, chi2 = 4.45, $P = 0.03$).

DISCUSSION

Disparities in EMS transport times in rural located patients are common, and longer EMS transport times are thought to play an important role in survival following major traumatic injury events.[3–6] The examination of disparities has largely been limited to rural differences in transport times, however, and there is little known about differential transportation pathways or EMS care received, despite well-known rural and ethnic disparities in major trauma outcomes.[2] Our study identified considerable differences in EMS response and transport pathways, with these differences patterned by the inter-relationship between the geographical location of the incident and ethnicity. Similar to previous studies, we identified a lower proportion of those injured in rural locations who were directly transported to the highest level of care achieved during the care episode. Similarly, those injured in rural (compared to urban) locations were more likely to take longer to reach first hospital and were more likely to involve air ambulance transportation.[3,4,6]

In examining the intersection of geographic location of injury and ethnicity we found overlapping disparities that would not have been identified by examining these sources of disparities individually. Comparisons of rurally located indigenous Māori patients to rural non-Māori patients revealed that despite similar on-scene ISS presentation, rural Māori were triaged to slower dispatch and on-scene response pathways and took longer to reach first hospital. Rural Māori were less likely to reach high-level specialist trauma care and facilities, both as a first hospital or at any time during the episode of care. The opposite was observed for Māori patients injured in an urban location, which were more likely to be prioritised; this may have been due to higher incidence of concussive symptoms identified on scene using the GCS. In combination, these findings suggest that there are additional challenges associated with providing equitable out-of-hospital care for Māori injured in rural locations, potentially set in place by out-of-hospital triaging processes.

To the best of our knowledge this is the first study to describe the inter-relationship between rural and ethnic disparities for out-of-hospital EMS care and transport pathways to hospital-level care following RTC trauma in a national context. Rurally located patients, particularly rurally located Māori patients, were identified as being particularly underserved by out-of-hospital EMS following an RTC, despite similar on-scene presentation. Delays along pathways of care and differences in quality of care resulting in excess Māori mortality have also been identified for rural Māori in other areas of healthcare in NZ, including cancer care.[32–34] More specifically, ethnically patterned delays in care have been found for out-of-hospital cardiac arrest (OHCA) in NZ. Māori patients had few EMS-witnessed OHCA and a higher level of bystander intervention, suggesting EMS assistance arrives later or help is not sought immediately, resulting in poorer 30-day survival for Māori patients.[35] Recent examination of ED processes in NZ also identified delays in care experienced, although a higher proportion of Māori ED presentations are self-presentations (unattended by out-of-hospital EMS) and were triaged to be seen within a longer time frame.[36]

This situation is not unique to NZ. Our study expands upon existing literature regarding health inequities in other countries, especially rural indigenous disparities in Australia, Canada, and the United States. While not specific to EMS many studies of healthcare access and utilisation have found rural location to be a barrier to healthcare that disproportionately affects remote, rural indigenous populations.[37] Factors presenting as barriers to healthcare for indigenous communities include rural location, communication, cultural differences, and poor access to the positive social determinants of health.[37,38] With regard to the provision of emergency trauma care, rural locations present challenges such as long distances and travel times, limited trauma care resources and skilled staff.[39] Higher mortality rates following traumatic injuries in rural areas have been attributed to longer incident-discovery times, longer out-of-hospital time, limited access to major trauma in-hospital care, and delays in receiving definitive in-hospital care.[3,5] Mixed evidence for an intersectional relationship between 'race'/ethnicity and insurance status has been reported at the level of trauma hospital care in the US healthcare system but has not been examined in the out-of-hospital setting.[2]

Understanding the complex intersectional relationship between the geographic location of injury and ethnicity is important to optimising the planning and targeting of healthcare delivery. The barriers generated by geographical location, such as longer distances and times to travel to centralised tertiary hospital-level care, invariably located in metropolitan centres, are exacerbated by ethnicity. For example, in NZ, Māori are more likely to live in rural and more remote places.[32] The interweaving of complex systemic and structural factors, including institutional and interpersonal racism, differential distribution of the social determinants of health, less access to specialist care, and longer and slower pathways through health systems, all underpinned by the process of colonisation, are well

recognised to generate health inequities.[11,40] National healthcare reforms currently underway in NZ are strongly focused on addressing inequities for quality improvements in the healthcare system.[41] Our findings suggest that addressing the overlap between rural and ethnic disparities through strong, equity-focussed planning and prioritisation and through increased investment in rural services has the potential to improve the delivery of rural EMS for both indigenous and non-indigenous populations.

Achieving equitable healthcare is a persistent challenge for healthcare systems worldwide. Our findings suggest the need for better resourcing of rural EMS service with particular attention to inequities experienced by rural Māori communities. Greater recruitment and training of Māori EMS professionals would address Māori under-representation amongst professional EMS staff and reduce hesitancy in accessing unrepresentative services, as well as reduce patient experiences of institutional and interpersonal racism in NZ healthcare.[42–44] Qualitative analyses with EMS professionals are also required to understand ethnic and rural differences in coverage of EMS services, infrastructure, staffing, training, experience, skill levels, and deployment for rural communities. It is important that this includes the perspectives of Māori and rural EMS staff and patient voices. To understand ethnic barriers to accessing care following trauma further research should also include a Māori-led investigation of the continuum of trauma care from out-of-hospital EMS dispatch triage through to access to post-hospital rehabilitation services, including any differences between rural and urban care.

Our study found EMS triaging processes (especially for prioritisation of EMS transport from the scene to a L1 hospital) was comparatively slower for rural Māori patients compared to rural non-Māori. Triaging policy is a further mechanism to address disparities in EMS transport pathways and access to tertiary-level trauma care by potentially providing opportunities to prioritise based on location of incident and ethnicity, alongside life-threatening presentations. Further examination of the reasons for differences in triaging and selection of destination hospital are needed given that cultural differences in communication and interpretations of presenting symptoms have been found to influence access to healthcare in indigenous populations.

Patient/family proximity requests are common reasons for hospital selection in other contexts.[4,37] Whānau (family) support for patients in hospital is critical for Māori to mitigate against consistently reported negative hospital experiences.[45] Recent examination of hospitalisations for Māori identified the difficulties for the provision of whānau support during a hospital transfer, or an away-from-home hospital admission, and it is possible this may influence decisions on destination hospital in situations where a choice exists.[46] Adherence to New Zealand's 2017 Out-of-Hospital Major Trauma Triage Policy is being examined in more detail to identify unwarranted clinical variations in transporting EMS patients in this cohort.[47]

The question remains whether the difference in EMS transport and access to tertiary-level trauma care and facilities leads to poorer mortality outcomes following an RTC, requiring further examination. Analysis of the wider cohort including non-transported patients identified that when compared with the non-indigenous NZ population Māori were disproportionately represented amongst on-scene fatalities due to RTC. This finding suggests that along with improved EMS healthcare response following trauma there must be a corresponding effort strengthening primary prevention policies and actions focused on addressing upstream risk factors for RTC, including the social and economic determinants of health.

This study has many strengths beyond examining the intersection between geography and ethnicity relevant to healthcare delivery. The use of a consistent mechanism of injury (in this case vehicle occupants in RTCs), allowed for the examination of rural and ethnic differences within a cohort with a more consistent case mix and injury circumstance between sub-groups. Additionally, this study utilised the rurality of the location of injury incident, which is more closely aligned to EMS need than patient residence. The provision of many health services is planned on the distribution of the usually resident population, which misses the highly mobile nature of a population and the occurrence of injury in locations away from domicile, especially RTC.[48] Road EMS resourcing in NZ is based on the use of retrospective data to model predicted demand according to dispatch response category, number of incidents in a geographic area, and specified response times using specialist modelling software.

Future EMS placement should also include rurality, ethnicity, and deprivation in order to optimise service coverage. Rural community health needs, including access to health services, are often overlooked, especially for rural Māori and for isolated communities, and this study can inform Priority 3 (focused on placing health services closer to rural communities) of the NZ Rural Health Strategy acknowledging the need to consider placement of EMS services in relation to where rural communities live as well as locations with high occurrence of RTC.[49] The utilisation of an urban/rural geographic classification specifically developed for use in health policy and research, reduces the likelihood of geographic misclassification.[23] Finally, the universal free-of-cost access to EMS for trauma care in NZ minimises any selection biases caused by economic factors.

LIMITATIONS

There are several limitations to this study. We analysed data corresponding to EMS care delivered in NZ between

2016–2018, which therefore may not reflect current EMS practice or destination policies[50] or be directly generalisable to other countries. The findings are limited to Road and Air EMS captured in ePRF data potentially underestimating EMS use when Air EMS service utilisation is not captured by ePRF data. Reasons for Air EMS activation or non-activation are not available in ePRF data. Previously self-presentation to EDs (ie, walk-ins) has been reported to be more common in Māori patients (63% compared with 57% of non-Māori presentations) thus this study that analysed patients attended by EMS may not be representative of ethnic difference in the incidence of major trauma.[37] Misclassification of ethnicity occurs for Māori, estimated at a 16% undercount using ethnicity reported by the National Health Index, potentially underestimating differences for Māori.[51]

Analyses are limited to those injured as vehicle occupants in RTCs, and patterns of EMS care and pathways to transport may differ for other injury contexts. Analyses examining differences in EMS interventions delivered involved small numbers of patients limiting the ability to make inferences about observed differences. Results highlight comparisons with $P < 0.01$ or smaller, allaying concerns about false positives with multiple comparisons. The adapted measure of life-threatening events identifies airway, breathing, circulatory, or neurotrauma problems and will, therefore, not capture all critical events; one such example is a ruptured spleen or severe head injury, such as haemorrhage, not immediately indicated by on-scene measurements.

CONCLUSION

This study identified several disparities in EMS transport pathways that are strongly intertwined with rurality and ethnicity. These findings provide an evidence base to help guide clinical and policy decision-makers in identifying opportunities to optimise the delivery of EMS care and to reduce overlapping disparities associated with EMS care, nationally and internationally. Greater equity-focused planning and investment in rural EMS services to reduce documented disparities in EMS triage, transport. and access to high quality specialist trauma care is clearly warranted and would benefit both indigenous and non-indigenous populations.

DECLARATIONS

Ethics Approval and Consent to Participate

The Health and Disability Ethics Committee (reference 18NTB142) provides ethics approval. Access approvals to study datasets was obtained from the New Zealand Trauma Registry (NZTR) Data Governance Group; Ministry of Health for extracts from the National Health Index database; and from St John and Wellington Free Ambulance for EMS data.

Availability of Data and Materials

The raw data that supports the findings of this study are available from Hone Hato St John, Wellington Free Ambulance and the NZTR. Restrictions apply to the availability of this data. Derived data is available from the corresponding author on request.

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Acceptance of Automated Social Risk Scoring in the Emergency Department: Clinician, Staff, and Patient Perspectives

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Introduction: Healthcare organizations are under increasing pressure from policymakers, payers, and advocates to screen for and address patients' health-related social needs (HRSN). The emergency department (ED) presents several challenges to HRSN screening, and patients are frequently not screened for HRSNs. Predictive modeling using machine learning and artificial intelligence, approaches may address some pragmatic HRSN screening challenges in the ED. Because predictive modeling represents a substantial change from current approaches, in this study we explored the acceptability of HRSN predictive modeling in the ED.

Methods: Emergency clinicians, ED staff, and patient perspectives on the acceptability and usage of predictive modeling for HRSNs in the ED were obtained through in-depth semi-structured interviews (eight per group, total 24). All participants practiced at or had received care from an urban, Midwest, safety-net hospital system. We analyzed interview transcripts using a modified thematic analysis approach with consensus coding.

Results: Emergency clinicians, ED staff, and patients agreed that HRSN predictive modeling must lead to actionable responses and positive patient outcomes. Opinions about using predictive modeling results to initiate automatic referrals to HRSN services were mixed. Emergency clinicians and staff wanted transparency on data inputs and usage, demanded high performance, and expressed concern for unforeseen consequences. While accepting, patients were concerned that prediction models can miss individuals who required services and might perpetuate biases.

Conclusion: Emergency clinicians, ED staff, and patients expressed mostly positive views about using predictive modeling for HRSNs. Yet, clinicians, staff, and patients listed several contingent factors impacting the acceptance and implementation of HRSN prediction models in the ED. [West J Emerg Med. 2024;25(4)614–623.]

INTRODUCTION

Screening for, and addressing, patients' health-related social needs (HRSN) is an increasingly common aspect of patient care[1,2] that is supported by numerous professional organizations[3] and policy makers.[4,5] Patients' HRSNs encompass a variety of nonclinical, socioeconomic, and contextual factors that are essential drivers of morbidity, mortality, utilization, disparities, and costs.[6,7] The emergency department (ED) is a potentially appropriate setting for HRSN screening, as a high proportion of ED patients report HRSNs,[8–11] patients with HRSN often have difficulty accessing primary care services,[12] and EDs frequently are the source of care for underserved and vulnerable populations.[13,14]

The ED presents several challenges to HRSN screening, and patients are frequently not screened for HRSNs.[1,15,16] For example, ED workflows are sometimes unclear about which care team members should screen for or intervene on patients' HRSNs.[1,10,15,17] Also, a recent Society for Academic Emergency Medicine panel noted that, given the resources required, it is debatable whether EDs should engage in targeted or universal HRSN screening.[18] Ideally, HRSN screening should also help identify a course of action for addressing patients' HRSNs.[19–21] Yet clinicians experienced with screening efforts report having insufficient information to refer patients to appropriate services.[22,23] As further complication, some patients may decline to share HRSNs they deem stigmatizing or unrelated to their clinical needs.[24,25]

Predictive modeling using machine learning and artificial intelligence (ML/AI) approaches may address some pragmatic HRSN screening challenges in the ED. Predictive modeling involves applying statistical or computer science methods to healthcare data to prospectively classify patients according to underlying risks.[26] Predictive models in clinical information systems have demonstrated promise in identifying patients with HRSNs.[27–29] Because predictive modeling is automated, it can eliminate some pragmatic challenges, including time constraints, workflow challenges, or staff availability. Also, automated predictive modeling operates as a universal screening program. Thus, it is less susceptible to biases that lead to selectively administered screening questionnaires,[21] missing data due to patient nonresponse, or omissions in clinical text because clinicians failed to record needs or patients did not disclose them.[30–32] Furthermore, predictive modeling can capitalize on the growing volume of data in electronic health records (EHR), health information exchange, and data from non-healthcare organizations that reflect patients' social circumstances and factors.[33,34] This data can provide a longitudinal and comprehensive patient overview and is not dependent on a single healthcare organization for data collection. Finally, the risk scores created by predictive modeling can be the inputs to clinical decision support systems that refer patients to needed services.[29]

Implementing HRSN predictive modeling in ED settings represents a substantial change from current approaches of questionnaire-based screening or collecting HRSN data during patient examinations.[1] Such changes can elicit mixed reactions from relevant parties, despite their potential advantages. For example, physicians, non-physician clinicians, and healthcare administrators favor explainable predictive models with clear rules; thus, they may be less receptive to advanced prediction models that are less interpretable.[35] In this study, we explored the acceptability of HRSN predictive modeling by conducting in-depth, semi-structured interviews with emergency clinicians, ED staff, and patients. This study increases understanding of clinician, staff, and patient perceptions of predictive modeling for HSRNs and how predictive modeling could be implemented in ED encounters.

Population Health Research Capsule

What do we already know about this issue?
The emergency department (ED) has challenges in screening patients for health-related social needs (HRSN). Artificial intelligence based predictive modeling, to determine which patients need social resouces, may address some HRSN screening challenges.

What was the research question?
Our goal was to explore the perspective of emergency clinicians, ED staff, and patients on the acceptability and usage of HRSN predictive modeling in the ED.

What was the major finding of the study?
Emergency clinicians, ED staff, and patients agreed that artificial intelligence-based predictive modeling, to screen patients for the need for social services, must lead to actions and positive patient outcomes.

How does this improve population health?
Prediction models for HRSNs can potentially improve screening and contribute to addressing the HRSN needs of patients in the ED.

METHODS

To explore the perceptions of emergency clinicians, ED staff, and patients, we adopted a modified thematic analysis approach[36] and reported our methods following the Standards for Reporting Qualitative Research (SRQR) recommendations.[37] The research team had expertise in health informatics, clinical decision support systems, HRSNs, health disparities, and clinical care.

Context and Sampling Strategy

We recruited emergency clinicians, ED staff, and patients who practiced at or had received care from an urban, Midwest, safety-net teaching hospital system. All research team members have prior or ongoing research collaborations with this healthcare organization. Eligible emergency clinicians included physicians, residents, fellows, and nurse practitioners and were recruited through presentations to faculty groups and emails. Eligible ED staff included social workers, case managers, and registered nurses and were recruited through email in cooperation with organizational

leadership. The recruitment presentations and emails provided guidance on how eligible individuals could contact the research team to express their interest in participating in our study. Lastly, we recruited adult (≥18 years old) patients by phone calls to patient representatives identified by the organization's Community Relations Department and by emails to recent ED patients who had consented to be contacted for research opportunities.

Data Collection Instruments

Our interview guide included questions to gather perspectives on collecting and using HRSN information through traditional means (eg, survey and discussions with patients). Additionally, the guide asked about the acceptability and usage of predictive modeling for HRSNs in the ED. Because predictive modeling for HRSN would likely be implemented in information technology-based decision support, the interview questions were informed by concepts from two relevant frameworks: the five rights of clinical decision support[38] framework and the contextual information model.[39]

In our interviews with clinicians and staff, we referenced clinical examples of sepsis risk scoring or opioid use scores. These references were designed to facilitate understanding by drawing parallels to clinical risks often estimated via the application of statistical or computational methods. Like predictive modeling, such scoring approaches leverage multiple patient data elements to arrive at an overall measure of risk. In contrast, we could not assume patients would have the training in, or the direct application of, computational methods to aggregate data to support decisions. Therefore, in our interviews with patients, we referenced online streaming service recommendations or targeted marketing (eg, advertisements or coupons) that draw on prior data collection on consumers to illustrate the application of predictive modeling in everyday experiences.

We piloted the interview guides for length and content with the four members of our study's advisory panel: a nurse practitioner; a social worker; and two patients. These pilots were not included in the final analytical data. The advisory panel also assists the research team in interpreting the findings in the context of their diverse perspectives and lived experiences. This study is part of a larger project to improve the collection and use of patient health-related social needs in the ED.

Data Collection Methods

All interviews were conducted using an online meeting platform from December 2022–May 2023. One team member led the interviews of clinicians (physicians and nurse practitioners). A second team member led the interviews of staff (nurses, social workers, and care managers), and the third team member led the interviews of patients. All interviewers were supported by at least one additional team member for notetaking. Interviews lasted, on average, 33 minutes. We met repeatedly during the data collection process to assess the emergence of new information. Saturation was determined when the research team agreed no new themes were being identified. We recorded all interviews with consent for transcription purposes. Before each interview, participants reported age, gender, and race/ethnicity using a web-based survey. Clinicians and staff also reported their credentials and years in practice. We monitored recruitment progress to ensure participant diversity.

Ethical Issues

All participants provided written consent before data collection. The study was approved by the Indiana University Institutional Review Board.

Analyses

We analyzed interview transcripts using a modified thematic analysis approach.[36] Clinician and staff transcripts were analyzed independently from patient transcripts. This decision was based on two considerations: first, clinicians and staff had day-to-day experience with HRSN data collection and applications and, therefore, broader experiences than patients; and second, the results of HRSN screening approaches are predominately clinician-facing; ie, questionnaire results, prediction models, or even interviews during examination are meant to drive decisions and actions of clinicians, not patients. We began with the clinician and staff transcripts. We conducted preliminary screenings of three interview transcripts through a line by line reading process to identify initial themes and confirm that interview questions yielded responses informing our study questions. Once all interviews were completed, we screened all interview transcripts to create an initial codebook. We then tested the codebook reliability by independently applying the codes to three transcripts. We then met and discussed the accuracy and consistency of the codebook and made necessary adjustments. Upon completing the codebook development, three team members consensus coded each transcript. Next, two coders independently coded the same transcripts and then met to adjudicate any differences through discussion to reach consensus.[40] We agreed on a final set of overarching themes and representative quotes. The above process was repeated on the patient transcripts.

Once all transcripts were consensus coded, we undertook axial coding to identify common, overarching themes. We then met to resolve differences and arrive at a final set of themes. Throughout this process, we employed established procedures in the qualitative methods literature to ensure the rigor and validity of our findings.[41–43] These procedures included practicing reflexivity (continually questioning interpretations, seeking answers in the data to verify or challenge interpretations, becoming aware of one's

preconceptions and biases), depth of description (seeking out the rich details of participants' words), and searching for alternative explanations or interpretations. We used co-occurrence and stratification to compare views about predictive modeling and traditional methods of HRSN information collection. We conducted the entire analysis using Dedoose qualitative analysis software, version 8.2 (SocioCultural Research Consultants, Los Angeles, CA). As a further check on our interpretation, we reviewed a summary of our findings with our advisory panel members.

RESULTS

Participants included eight emergency clinicians, eight ED staff, and eight patients (Table 1). Participants were mostly female (66.7%) from diverse racial and ethnic backgrounds. The mean age was 42.1 years. Clinician, staff, and patient views of predictive modeling for HRSNs during ED encounters encompassed three broad themes: *impact*; *performance requirements*; and *barriers and facilitators to implementation* (Table 2).

Impact

Emergency clinicians, staff, and patients agreed that HRSN predictive modeling should be designed to enable actionable responses and to result in positive patient outcomes. Furthermore, clinician and staff acceptance of predictive modeling tools was contingent on the expectation that routine use of these tools would lead to tangible improvements in patient outcomes. For clinicians and staff, the preference was that predictive modeling would lead to referrals, prompts to collect additional information, and the initiation of connections to services that would change the patient's health status. As one staff member pointed out:

> *"I think it would help … if a score was like generated and…if we had like a dropdown box that had resources…That we can either educate the patient on or give directly to the patient, or coworkers in the hospital like social work, or financial advice that we can send the patient to before they leave the [ED], to kind of get them … on the right track. I feel like we know patients have these issues, but we don't know how to go about it and … help them." (#10)*

While clinicians and staff preferred the predictive modeling to support actions, they had mixed opinions about the predictive modeling results being used to initiate automatic referrals to HRSN services. Some participants preferred automatic orders. For example, a physician stated:

> "*Whatever you can automate would be ideal.* [EHR] *automatically generates a discharge packet that prints the food voucher and that prints all of the discharge paperwork and then the patient gets it, and they get the referral to primary care, they get the referral to social work, and then it all kind of works out" … (#8)*

Others preferred receiving recommendations they could discard after consulting with the patient, such as described by one nurse:

> "*I think having automatic referrals and appointment scheduled would be great, but I also think that it takes a conscious and mindful person when they're speaking to the patient about everything to go back in and cancel the appointments or change them based off of the patient's schedule, because some of them they might, might feel offended that, 'Oh, you're already making a plan for me. I can take care of myself. I'm grown.'" (#9)*

Table 1. Demographics of participants.

	Emergency clinicians (n = 8)	ED staff (n = 8)	ED patients (n = 8)	Total (n = 24)
Gender				
Female	50.0	87.5	62.5	66.7
Male	50.0	12.5	25.0	29.2
Transgender	0.0	0.0	12.5	4.2
Race/ethnicity				
Asian	12.5	0.0	0.0	4.2
Black	0.0	37.5	25.0	20.8
Hispanic	0.0	12.5	25.0	12.5
Multiple/other	25.0	12.5	0.0	12.5
White	62.5	37.5	50.0	50.0
Age (mean, SD)	37.8 (7.2)	41.4 (10.9)	47.3 (14.3)	42.1 (11.4)
Work experience (mean years, SD)	7.6 (8.2)	6.1 (5.2)	n/a	n/a

ED, emergency department.

Table 2. Themes and illustrative quotes from clinicians, staff, and patients on the potential use of risk prediction approaches to health-related social needs in the emergency department setting.

Theme	Description & representative quotes
Impact	*Predictive modeling for HRSNs leads to actionable responses to create positive patient outcomes*
Emergency clinician	I think what will solidify it for me is starting to see some positive impact of using that. (#4)
	Knowing the services that are being provided because of this decision. We're going to increase the number of homeless people off the street and get them into shelters. We're going to provide this number of patients with food or if we see the value added of that tool, it will get used. If it's 'let's use this tool for the sake of using the tool,' but we actually don't see improvement or it actually addresses the unmet need then there will be some hesitation. (#6)
ED staff	Having the algorithm that flags our social work would be more beneficial. Because they could take the time with the patient to set up the resources. Whereas kind of on the medical end, a nurse's time is thin already. (#15)
Patient	In an ideal world they would connect you with a social worker who would be able to assist you with those things with resources. (#18)
	Stuff that we've identified is that this, this, this, and this and we just wanna reach out and see if there's anything we can do to help you, connect you with resources . . . It's gonna get addressed. (#19)
	But I also think that that it could really aid in helping. [Clinicians] see a lot of people, and they have to make a lot of guesses and a lot of judgments on what somebody might need. If it's my doctor who I've been seeing for years, then their guesses are going to be a lot better than somebody seeing somebody in the emergency room for the first time, who has absolutely no record. But, you know, ultimately having some more statistical information to be able to sort through the noise . . . (#21)
Performance requirements	*Details about the functioning of predictive modeling for HRSNs required for acceptance*
Emergency clinician	How up to date is it? How representative of our population is it? How does it keep updating itself over time? If it does all of that very well, then in real-time, it would be updating itself with date, new data every day, and relearning and then reprocessing and then showing up on the EHR. (#1)
ED staff	I would want to know who's gathering the information. What determines a score? (#13)
	I would probably guarantee that over 50% of patients we see is going to ping this algorithm. (#15)
Patient	I would hope that [risk prediction] wouldn't discriminate against anyone based on their financial status or anything like that. (#18)
	I think I have the right to know that you're doing that, you know? I don't think that you should do it in some secretive fashion and then come to me with these questions when it would be so much easier if you just told me, "Look, you know, we identify certain patterns and – However they say it, at least let the person know. (#19)
	I just don't want the computer system just assuming, 'Oh. She said that she needs public transportation. Oh, that must mean that she has a housing issue'– It doesn't mean any of that. It's just, it is what it is. Don't make apples out of oranges or vice-versa. Just leave it where it is. (#24)
Barriers and facilitators of implementation	*Contexts and conditions that would improve adoption and usage*
Emergency clinician	Honestly, being in a teaching hospital, getting the residents onboard first sometimes is easier, 'cause you can get a little bit of upward teaching. If the residents start using it, it kind of forces our attendings to start using it, too. (#2)
ED staff	There's a lot of creatures of habit that don't like change. (#12)
Patient	If you have a nurse or a doctor or the medical team or a program or a tablet or anything, . . . it will be approached in a trusting environment. Because the whole purpose is to help the social need. We really need to make sure is that the approach is friendly and that whoever does it is trained to truly get to the social need, not just to fill out the form, but to make sure and invite the patient, 'Hey, we want to understand you in our community and we want to help you in every need that you have.' (#20)

HRSN, health-related social needs; *ED*, emergency department; *EHR*, electronic health record.

One physician was strongly against it due to the unknown legal risks: "*When the machine messes up, who, who are we gonna sue? The hospital? The person who coded? The clinician? All of'em? We don't have rules for that, yet."* (#1)

Relatedly, some patients hesitated about automatic referrals to address their HRSNs; rather, they preferred to be consulted on their post-ED care options. This is how one patient described it: *"I don't want somebody just to automatically take action on it. I want them to just say 'Here's what we can offer you.' Some people feel better about having a shuttle versus taking public transportation . . . because depending upon the day is depending upon which kind of help I would want." (#24)*

Additionally, patients reported that results from HRSN prediction models would have the additional benefit of helping initiate conversations about their needs or that assistance would not solely depend upon patients having to disclose sensitive information. This is how a patient described the potential benefits of prediction models:

> "*If a person could come due to this algorithm and bring up things that I might not have brought up myself or were reluctant to bring up. Maybe I don't want to tell people I'm poor. Maybe I don't want to tell people that we're struggling at home. Maybe I don't want to tell people that I just lost my car, because I couldn't make the payment so I have transportation issues. You know, whatever it is. Everybody's embarrassment level is different, but yeah, if a nurse could come in and say, you know, "Hey, let me talk to you about this. We have this program. I don't know if it pertains to you or not, but we have this program and if you are interested, I could probably do something and maybe see if we can get you into it." (#17)*

Performance Requirements

Emergency clinicians and staff wanted additional detailed information about HRSN predictive modeling to determine the potential for accepting it in their clinical practice. This additional information included transparency, performance, and concerns for unforeseen consequences. Regarding transparency, emergency clinicians and staff wanted to know the data's nature, timing, and quality underlying a prediction model. They also wanted to know how often prediction models would be updated based on changes in a patient's life. As one ED nurse practitioner described it:

> "*Is it going to change with new information? Where's that new information coming from? Six months ago someone may not have had a job and no car, or were living in* [shelter]*, and then now they have a job, they have a subsidized living apartment, they know how to utilize public transport to get around, things like that. Our population is somewhat transient, but you have changes that happen to people that come pretty regularly. And sometimes, it's positive changes." (#3)*

A nurse had a similar opinion: "*I would need to know where we got the information from . . . is it something they filled out on their own?" (#12)*

Like clinicians and staff, ED patients also wanted transparency in how an HRSN prediction model would operate and be used in their care. As one patient put it: "*It would be okay that they're pulling the information, but I would want to know what that computer system is doing with that information. Are they selling my information? Is it kept in privacy? That would be a big concern." (#18)*

Clinicians and staff underscored a need for a high-performing prediction model. However, they acknowledged the complexity of HRSN data, as one physician pointed out that "*with anything social, there can be a lot of a gray area."* (#3) Thus, several clinicians and staff judged prediction model performance in terms of face validity instead of specific performance metrics. This is how one emergency physician explained it:

> "*I see something like a risk score* [ie, the product of predictive modeling] *here as a trigger for me to start asking some questions. So, if I go into the room, and I ask a patient about some things, and I'm getting a very confirmatory response there, I think that would probably make me lean more onto a model like that." (#4)*

Similar to that idea of a "*confirmatory response,*" one physician would check to see whether predictive modeling results "*matches your gestalt."* (#6) Likewise, a nurse said that she wanted to see that the prediction model "*kind of tracks"* with what she could observe. (#10)

Patients vs clinicians and staff had different perspectives on the negative consequences of poor-performing HRSN predictive modeling. Patients were concerned that prediction models might miss individuals who required services. This is how one patient described it: "*Because that computerized program could pick people up that don't need to be picked up that really need to be and dismissing people that really need it out." (#23)*

Furthermore, some patients expressed reservations about potential biases inherent in, or resulting from, predictive modeling. For example, one patient noted the threats if predictive modeling did not account for potential differences in patient background demographics, "*because in that case it doesn't help. It just becomes an extension of an already biased system*." (#22) Other patients noted that results from the prediction models should not be used to make other assumptions about patients' needs or to treat patients differently. In contrast, emergency clinicians and staff

expressed concerns with potential over-identification and the wasting of resources. One physician stated: "*If I started seeing a trend of my social worker is coming to me, frustrated, because 'Hey, I've doubled my volume of consults, and I'm seeing all these patients, and I can't do anything for any of them.' That would be more concerning." (#4)*

Barriers and Facilitators to Predictive Modeling Implementation

Participants acknowledged that predictive modeling is a potentially useful method for measuring and acting upon HRSNs. Given their familiarity with clinical risk scores, the emergency clinicians and staff were generally favorable toward the predictive modeling concept. Nevertheless, they did identify several factors and requirements that would facilitate the adoption of HRSN predictive modeling. For example, emergency clinicians noted the value of clinical champions and specific training. A physician noted: "[The] *majority of people who work in our department have a desire to work with underserved populations, and then those people might be open to trying something. Probably having like, a position champion in the department is a good idea." (#5)* In addition, ED staff indicated that visible positive impact on their patients can facilitate adoption, but that competing demands for time and attention, as well as general inertia, could inhibit it. A nurse described it thusly:

> "*Because people get caught up in their everyday life and no one wants to stop what they're doing to have to learn something else because it feels like, 'I don't have time to do that and that's just gonna slow me down.'" (#16)*

Several patients described the need for health professionals to be trained to be better communicators when asking about HRSNs, in general, or in response to a prediction model being used. This view may have been rooted in prior experiences of feeling like "*just a number*" (#23) to the healthcare system.

DISCUSSION

Emergency clinicians, ED staff, and patients were mostly positive about using predictive modeling for HRSNs. Their view that predictive modeling is compatible with the healthcare environment was based on their past experiences delivering (other clinical scores) and receiving (consumer experiences) care. Nevertheless, clinicians, staff, and patients raised several key issues that dampened their acceptance of HRSN prediction models in the ED.

First, participants noted that predictive modeling can support increased awareness of HRSNs. But this alone is insufficient to address HRSNs. For maximum impact, it must be complemented by a straightforward course of action for patient care. For example, predictive modeling connected with a decision support system or referral system could help clinicians direct patients to relevant resources more efficiently and effectively.[44] This theme from the current interviews aligns with prior work in which clinicians emphasized the need for HRSN screening efforts to directly inform clinical decisions, referral pathways, and interventions.[22,23] Also consistent with prior literature on HRSN screening,[45] we found that patients expect beneficial actions resulting from healthcare organizations' using HRSN risk predictive modeling. Notably, our participants suggested predictive modeling could be an avenue to initiate further HRSN data collection or investigation and serve as a conversation starter, leading to more comprehensive clinical encounters.

Second, participants envisioned predictive modeling as a complement to, rather than a replacement of, the human-to-human component of HRSNs screening efforts. Emergency clinicians and staff wanted to check prediction model recommendations for consistency with clinical expertise, with the option to override automated orders triggered by a patient HSRN when necessary. Similarly, patients stressed that outcomes or recommendations from any prediction models needed to respect and prioritize their autonomy, specifically their preference to decline or tailor services. Ample evidence suggests that even if patients have identified HRSNs, large percentages may not want any services or actions taken on their behalf.[46] We note that this theme is somewhat in tension with the preceding theme. That is, while pairing predictive modeling with automated referrals or default orders would have efficiencies of scope and scale, it runs the risk of not respecting patient preferences.

It is possible to ease these tensions through processes that ensure human input. For example, predictive modeling could trigger automated messages to patient portals asking about the desirability of services or prompt inquiries from case managers or patient navigators. Such processes would respect patient preferences and clinical expert knowledge and could enhance the safety and acceptability of predictive models.[47,48] Still, while incorporating human input could have benefits, it could also introduce other implicit (or explicit) biases into addressing HRSN. Additionally, incorporating clinical expertise into the process increases the workflow redesign and integration burden. Thus, future implementers of HSRN predictive modeling should carefully evaluate both the model outputs and the human use of these outputs for their roles in introducing or mitigating biases.

Relatedly, participants wanted transparency in prediction models. The artificial intelligence and machine learning (AI/ML) communities have made substantial methodological advances in fostering model explainability, often to illustrate the importance of different model inputs or performance under differing circumstances.[49] While valuable, this is not the type of transparency the healthcare professionals described to foster acceptance and trust. Participants in this

study applied expert judgments to both the data sources and the predictions' perceived reliability. Such expert judgments on inputs and results are a key component to trusting a prediction model in the clinical medicine field.[48]

Whether expert opinion about data inputs and confirmation with clinical experience is just as applicable to HRSNs is not as clear. The HRSNs are not a primary focus in physician and nurse training, which likely contributes to the fact that HRSNs are seldomly and inconsistently documented.[50] Another potential contributor is that individuals have implicit biases that may cause them to overlook or overemphasize certain patient characteristics.[51] Thus, trust in the underlying data should not be dismissed. Still, for implementers of more advanced analytic interventions for HRSNs, eventual end-user acceptance may be more realized through actual performance and changes in patient outcomes.

LIMITATIONS

First, the study responses and discussions may be influenced by the characteristics of participants who agreed to be interviewed for this study. Second, emergency clinicians and staff were all part of a single healthcare system. Thus, our findings may only generalize to similar settings. Third, we used common examples to make predictive modeling salient to our participants. These examples were identified by our advisory panel members during the piloting of the interview guide. Nevertheless, use of different examples could affect perceptions and responses. Relatedly, the AI field is undergoing rapid evolution. As a result, perspectives on ML and other AI-based tools may swiftly transform as individuals accumulate experience with these technologies and engage in ongoing dialogue about them.

CONCLUSION

Emergency clinicians, ED staff, and patients expressed mostly positive views about using predictive modeling for health-related socal needs. Nevertheless, clinicians, staff, and patients noted several contingent factors impacting the acceptance and implementation of HRSN prediction models in the ED.

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"Let's Chat!" Improving Emergency Department Staff Satisfaction with the Medication Reconciliation Process

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Introduction: Patients who stay in the emergency department (ED) for prolonged periods of time require verification of home medications, a process known as medication reconciliation. The complex nature of medication reconciliation can lead to adverse events and staff dissatisfaction. A multidisciplinary team was formed to improve accuracy, timing, and staff satisfaction with the medication reconciliation process.

Methods: Between November 2021–January 2022, stakeholders were surveyed to identify gaps in the medication reconciliation process. This project implemented education on role-specific tasks, as well as a "Let's chat!" huddle, bringing together the entire care team to perform medication reconciliation. We used real-time evaluations by frontline staff to evaluate effectiveness during plan- do-study-act cycles and obtain feedback. Following the implementation period, stakeholders completed the post-intervention survey between June-July 2022, using a 4-point Likert scale (0 = very dissatisfied to 3 = very satisfied). We calculated the change in staff satisfaction from pre-intervention to post-intervention. Differences in proportions and 95% confidence intervals are reported. This study adhered to the Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0) and followed the Lean Six Sigma rapid cycle process improvement (define-measure-analyze-improve-control).

Results: A total of 111 front-line ED staff (physicians, nurse practitioners, physician assistants, pharmacists, nurses) completed the pre-intervention survey (of 350 ED staff, corresponding to a 31.7% response rate), and 89 stakeholders completed the post-intervention survey (a 25.4% response rate). Subjective feedback from staff identifying causes of low satisfaction with the initial process included the following: complexity of process; unclear delineation of staff roles; time burden to completion; high patient volume; and lack of standardized communication of task completion. Overall satisfaction improved after the intervention. The greatest improvement was seen in the correct medication (difference 20.7%, confidence interval [CI] 6.3–33.9%, $P < 0.01$), correct dose (25.6%, CI 11.4–38.6%, $P < 0.001$) and time last taken (24.5%, CI 11.4–37.0%, $P < 0.001$).

Conclusion: There is a steep learning curve to educate multidisciplinary staff on a new process and implement the associated changes. With goals to impact the safety of our patients and reduce negative outcomes, engagement and awareness of the team involved in the medication reconciliation process is critical to improve staff satisfaction. [West J Emerg Med. 2024;25(4)624–633.]

INTRODUCTION

Problem Description

There is a shortage of inpatient beds in our nation's hospitals. This shortage results in the frequent practice of retaining to-be-admitted patients in the ED until their inpatient bed becomes available. This practice is known as "ED boarding."[1] Patients subjected to ED boarding sustain a prolonged ED length of stay (LOS). In many instances, the ED LOS becomes so lengthy that these patients' usual, or "home," medications must be correctly administered while they remain in the ED,[2] rather than being administered only after the patient arrives to their inpatient bed. To enable accurate administration of these "home" medications, the process of "medication reconciliation" must occur within the ED.

"Medication reconciliation" is the process of verification of the names of the patient's usual medications, as well as their dosages and times of administration. Medication reconciliation for "boarded" patient at our institution has become the responsibility of the ED staff, who also must correctly obtain and administer medications newly ordered by the emergency physician. The ED medication history and reconciliation process is complex and error prone,[3] particularly in the setting of competing, urgent priorities in the ED, and results in a high risk of adverse patient outcomes.[4] We identified a staff satisfaction gap in the process of medication reconciliation in our ED and sought to improve this process.

Population Health Research Capsule

What do we already know about this issue?
Medication reconciliation for boarding ED patients is complex and can lead to adverse events and staff dissatisfaction.

What was the research question?
How can we improve the process of medication reconciliation for boarding patients?

What was the major finding of the study?
After implementation of the medication reconciliation improvement project, staff satisfaction score improved an average of 20–25.6% for correct medication, dose, and time last taken.

How does this improve population health?
Having a streamlined process for medication reconciliation and ordering ensures that all patients accurately receive their home medications while boarding in the ED.

Available Knowledge

All patients admitted to the hospital require a medication reconciliation, defined by the Joint Commission as the process of reviewing and confirming medications that a patient is currently taking to the medications that are ordered for the patient.[5,6] To avoid errors, the Joint Commission National Patient Safety Goal requires that a good faith effort be made to obtain complete medication information from the patient. Despite this effort, errors still occur.[7] A medication discrepancy, defined as inconsistencies between two or more medication lists, impacts nearly all patients admitted to the hospital, increasing potential harm to patients.[8] Adverse drug events (ADE) due to unintentional discrepancies in the admission medication list have been cited as the most common cause of preventable drug events.[9] If not recognized early, medication discrepancies can lead to an increased risk of readmissions, ED visits, and prolonged hospital stays.[9]

Allocating a member of the pharmacist team to handle this specific task, as is done with patients admitted to inpatient beds, could ensure safe and timely medication reconciliation, subsequently improving patient care.[10] In the state of Minnesota, however, the law precludes pharmacy technicians from obtaining medication histories and taking responsibility for medication reconciliation.[11] Using pharmacists to obtain medication histories and perform medication reconciliation is an option in some EDs but not in ours. This limitation is not unique to our facility, because in Minnesota pharmacy technicians are not allowed to obtain or review a patient's medication list. Further, given that there is a national pharmacist shortage[12] and that practice advisories arising from the American College of Emergency Physicians (ACEP) and other organizations have long stated that it is preferable to have pharmacists focus their clinical efforts on bedside patient care,[13] we determined that non-pharmacist emergency clinicians must become involved in the process of medication reconciliation at our facility.

Rationale

At our institution, there is low staff satisfaction with the current medication history, reconciliation and home medication ordering process for patients with extended LOS in our ED observation unit (EDOU) and behavioral health (BH) area. Standard processes for performing medication histories and ordering home medications as used in the inpatient setting are difficult in the ED given other priorities and urgent tasks in this environment, the time required, multiple interruptions, and the lack of a dedicated role to perform the task.[14] Dissatisfaction with the process may contribute to delays, inaccuracies, and safety events.

Interprofessional training modules for taking medication histories and medication reconciliation in the ED have been shown to improve employee communication, behavior, knowledge, and attitude.[15] Despite previous educational initiatives, safety events related to medication histories reconciliation persist. Thus, we sought to newly assess our current ED staff satisfaction to further improve the process for EDOU and BH patients.[15]

Specific Aims

In this project we aimed to assess and improve ED staff satisfaction with the medication reconciliation process for patients with prolonged ED stay, including EDOU and BH boarding patients, by 20%.

METHODS

This quality improvement (QI) initiative was a before-and-after study and considered to be exempt from institutional review board review. We followed the Standards for Quality Improvement Reporting Excellence: (SQUIRE 2.0) standardized methodological guidelines. We used the Lean Six Sigma rapid cycle process improvement to overcome barriers to protocol use and fidelity with the define-measure-analyze-improve- control) framework.[16] In this study we used voluntarily provided, anonymous staff survey information. Our pre-intervention survey was sent out in November 2021, and our post-intervention survey was completed in July 2022.

Context

Stakeholders included ED front-line staff (ie, attending physicians, emergency medicine [EM] residents, nurse practitioners [NP], physician assistants [PA], pharmacists, registered nurses [RN], care team assistants [CTA], ED psychiatry consult team [psychiatry-specific physician, resident, and NP or PA]), ED quality staff, and patients and their families. The CTAs are ED employees who facilitate moving patients on the electronic health record (EHR) track board, communicating with consulting services, scheduling outpatient appointments, and in general having overall awareness of patient flow throughout the department. Our study team included representative members of the various stakeholder groups, all of whom volunteered their time to this project.

Our institution is an academic medical center embedded within a larger healthcare system in the Midwest. We have a volume of 78,000 visits per year and are a Level I trauma and stroke center. Of the 70 beds in the ED, four are dedicated for BH patients and nine are used for ED observation. We have a three-year EM residency training program with nine residents per year as well as an NP/PA EM fellowship. Various resident programs rotate through the ED. We have 12 ED-specific NPs or PAs. Our pharmacists provide 24/7 coverage to our department, and we have a pharmacy residency program with one fellow per year.

The medication history and reconciliation process used in our ED at the time this study was initiated lacked a clear delineation of each clinician's role in the process. A need existed for each patient's medication list to be verified, but our procedures did not define which ED frontline staff must perform this task. All patients who will be admitted and are EDOU or BH boarding require a medication reconciliation.

Interventions

Figure 1 illustrates the timeline and summary of our project and the multiple plan-do-study-act (PDSA) cycles.

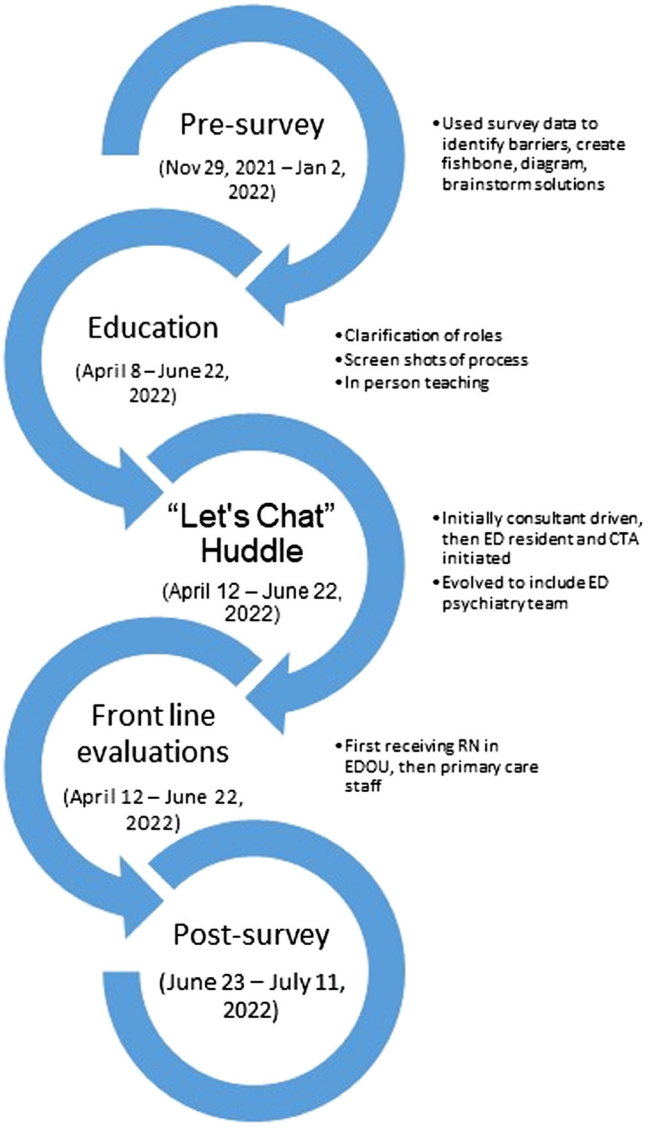

Figure 1. Plan, do, study, act (PDSA) cycles.
EDOU, emergency department observation unit.

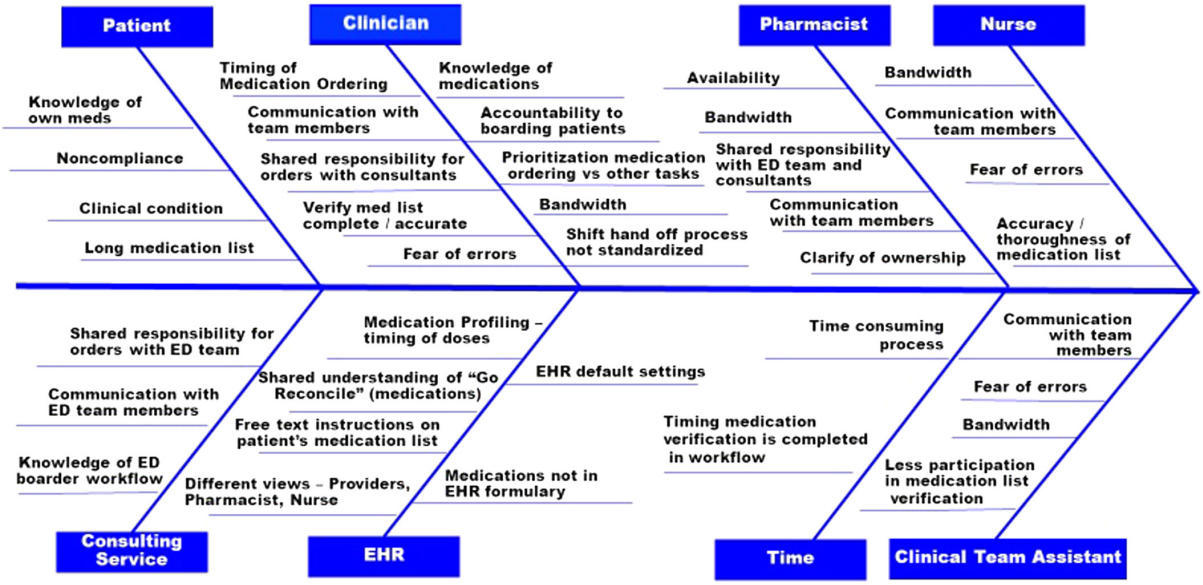

Figure 2. Fishbone diagram: stakeholder dissatisfaction with components of the medication reconciliation process for patients boarding in the emergency department.
ED, emergency department; *EHR*, electronic health record.

Pre-intervention survey

In the first quarter of 2022, ED staff (emergency physicians and residents, NPs, PAs, pharmacists, and CTAs) received anonymous electronic surveys (Supplement 1). The survey was designed specifically to gauge satisfaction with initial medication history and medication reconciliation when the patient changes status to ED observation/BH boarding and to identify barriers to the process. Staff members in the ED rated satisfaction on a 4-point Likert scale (very dissatisfied = 0 to very satisfied = 3). From this survey, we identified potential gap (s) and their root causes, from the stakeholders' viewpoints (Figure 2). We then focused on determining which key causes were amenable to improvement. Communication with care team members was identified as the underlying contributing factor that was most amenable to a process improvement.

The survey and its associated data were generated using Qualtrics software, version November 2021 (Qualtrics International Inc, Provo, UT).[17]

Electronic Health Record Alert

With knowledge gained from the baseline survey, the first proposed step to ameliorate the gap in care was an alert within the EHR to the patient care team. This pop-up would notify the associated ED team members to perform a medication reconciliation once the patient's status was changed from "in process" to ED observation/BH boarding. This proposal was initially declined given limited availability of EHR programming resources during the pandemic.

Front-line Staff Education

In the pre-intervention survey, staff members noted a lack of clear delineation of roles for the medication history and reconciliation process. For the PDSA cycle starting on April 8, 2022, educational materials were created for staff members to delineate role-specific tasks (Figure 3) as well as identify a linear timeline of how the process of medication history and reconciliation should be completed to allow for time-efficient and safe patient flow in the ED (Figure 4). This new process included role-specific tasks for each ED team member that were optimized for their job-specific responsibilities and was designed so that medication orders for EDOU and BH boarding patients could be verified by a pharmacist and errors minimized.

The optimal flow was the CTA starts a "Let's Chat" huddle, the bedside nurse completes the medication history, the primary clinician orders the medications based on the completed medication history, and the pharmacist then verifies the medication orders against the completed medication history. This medication reconciliation process was an additional responsibility given to ED team members who were already working; thus, our project did not require any additional hiring or full-time equivalennts. These materials were distributed to staff in the form of emails and handouts that were displayed throughout the ED for the duration of the initial intervention (April–July 2022). Education also included instructions on how to initiate a "virtual" multidisciplinary chat with active ED care team members—a "Let's Chat!" huddle—within the EHR (Supplement 2). Staff also had the ability to have a huddle in person, if they preferred.

Primary clinician (physician, nurse practitioner or physician assistant)
1) Initiate (or delegate to CTA) to initiate multidisciplinary chat in the EHR when patient identified as boarder. Include in the chat:
   a) Primary clinician
   b) Registered nurse (RN)/team lead
   c) Pharmacist
   d) CTA
2) Order pertinent home medications after medication reconciliation is complete

Care team assistant (CTA)
1) Initiate multidisciplinary chat in the EHR if requested to include:
   a) Primary clinician (physician, nurse practitioner or physician assistant)
   b) RN/team lead
   c) Pharmacist
   d) CTA
2) Place evaluation form in patient's packet (to be completed by RN)
3) Collect completed evaluation forms

Registered nurse (RN)
1) When you receive the chat in the HER, verify the patient home medication list ensuring it is an accurate list and that the time last taken is marked for each medication
2) Respond back to the chat when the medication list is completed
3) Receiving RN: Complete the evaluation form that will be placed in the patient's packet and leave in packet to be collected

Pharmacists
1) Collaborate with RN to ensure medication verification is complete
2) After the physician, nurse practitioner or physician assistant orders the medications, double-check, and verify the appropriateness

Figure 3. Educational document outlining role-specific tasks.
EHR, electronic health record.

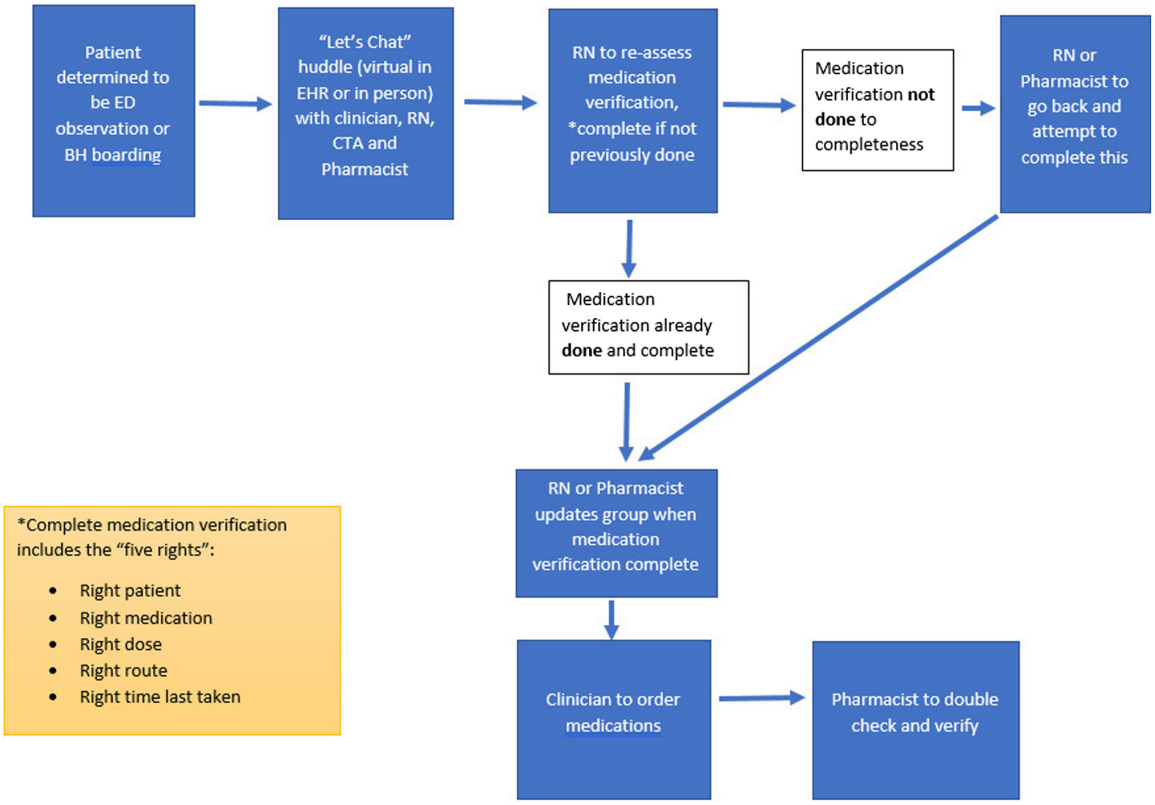

Figure 4. Flow diagram.
ED, emergency department; *EHR*, electronic health record; *RN*, registered nurse; *CTA*, care team assistant.

Attending physician-led "Let's Chat!" Huddle

The ED attending physician is in charge of the patient's care and has the most responsibility. Additionally, the attending physician is most familiar with medications and the plan of care for the patient's ED course. The first intervention of the "Let's Chat!" huddle required the attending physician to send the invitation to the care team. The investigators sent reminder emails, presented at the department meeting, and had in-person discussions with staff to encourage participation. This was met with resistance, as attendings were already taking on a large workload managing care for several patients while supervising and teaching. These factors led in many cases to the "Let's Chat!" huddle not taking place and the medication reconciliation not being performed optimally. Regardless, our team felt that it was important to have the attending physician comfortable and familiar with this process as the team leader in the first iteration before we transitioned this responsibility to others.

Resident/NP/PA-initiated "Let's Chat!" Huddle

In the next PDSA cycle, started on June 8, 2022, the resident physician, NP, or PA (whoever was caring for the patient), was tasked with initiating the "Let's Chat!" huddle. These team members have similar knowledge of the patient's medical history and treatment plans but oversee fewer patients at a time compared to the attending physician, which theoretically would allow the NP/PA/resident physician more time to initiate a multidisciplinary "Let's Chat!" huddle Our department is a teaching institution and regularly has off-service residents rotating through the department. Often, these residents do not have the time to educate themselves on the medication history and reconciliation process during their brief time in the ED. For this reason, off-service residents were not expected to initiate the "Let's Chat!" huddle; instead, ED residents and attending physicians helped them complete this process.

Care Team Assistant-initiated "Let's Chat!" Huddle

In the final cycle (June 2022), CTAs initiated the "Let's Chat" huddle. Our ED CTAs have overall awareness of the entire department and facilitate communication among team members, making them excellent at facilitating this process. With great response, CTAs were able to start the huddle promptly after noting the patient's status change to ED observation or BH boarding in the EHR. This combined approach of a CTA-initiated electronic "Let's Chat!" huddle to alert the nurse, clinician(s), and pharmacist to complete the medication history and reconciliation, and the subsequent roles each team member assumed allowed for designated multidisciplinary roles in the medication reconciliation process.

Emergency Department Psychiatry Consult Team Involvement

During our final cycle (June 2022), the ED psychiatry consult team also became involved in the "Let's Chat" huddle for patients changing to BH boarding status. They were instructed to participate in the virtual or in-person huddle with the rest of the care team members. They were expected to weigh in on the psychiatric medications ordered for the patient. The ED psychiatry team showed enthusiastic participation in this process.

Study of the Interventions

During each PDSA cycle, we used real-time evaluations by front-line ED staff (attending physicians, residents, NP/PAs, RNs, and pharmacists) to evaluate the effectiveness of each intervention cycle, obtain feedback on the process, and to determine how accurately medications were ordered (Supplement 3). This was initially done by the receiving nurse in the EDOU (whether BH boarding or ED observation patient) but was expanded to include all front-line ED staff. We used this information informally to adjust each PDSA cycle. This served a dual purpose as it was also a reminder to staff to do the "Let's Chat!" huddle.

Measures

We initially looked at hundreds of charts to identify quantitative indicators of errors or adjustments of medication reconciliation. Despite significant time dedicated to this data extraction, ultimately no useful quantitative data was obtained. Most of these errors are identified and corrected in real time through phone calls and in-person discussions, making it difficult to capture errors or adverse events using a retrospective health record review.

Our team reviewed the literature to see how others had obtained this data in similar projects, but there is a paucity of information regarding medication reconciliation in the ED. In studies of the medication reconciliation in inpatient units, review is frequently done by a pharmacist or pharmacy technician. Due to the limitations based on state law we were unable to use a pharmacy technician in the ED. Additionally, inpatient units lend themselves to better retrospective communication as the teams are more consistent day to day, allowing the pharmacist to ask the team about decisions made the day previously, whereas in the ED our teams are highly variable from shift to shift.

We also considered doing a quantitative review of reported medication errors or patient safety events during the time before and after our intervention. This was felt to be inaccurate as not every event gets reported. Due to our inability to identify a reliable quantitative measure of errors or safety events, we decided to focus on ED staff satisfaction. The thought was that if staff are satisfied and engaged in the process, there will be fewer errors. Front-line ED staff as stakeholders completed real-time evaluations to

evaluate effectiveness during the PDSA cycles, provide feedback on the process, and completed the pre- and post-intervention surveys.

Analysis

The same 4-point Likert scale was used for the post-intervention survey. Survey participants were asked their role in the ED, but this was de-identified from the rest of the responses for each survey. Responses were combined for analysis, no matter the role in the ED, to reflect the multidisciplinary nature of the impact of this study. We report averages of scores and overall satisfaction with the medication reconciliation process. Additionally, stakeholders were asked to provide free-text input about potential root causes of the gap in satisfaction. Each survey item was summarized with frequency counts and percentages for each response, as well as the overall mean response. We compared responses between the pre- and post-intervention surveys using two-sided Wilcoxon rank-sum tests and presented them as differences in proportions with 95% confidence intervals (CI). For each component of the medication history and reconciliation process, we used the average of the sum of "satisfied" or "very satisfied" responses to quantify the overall percentage staff satisfaction pre- and post-intervention.

RESULTS

In April 2022, our team initiated the "Let's Chat!" huddle to improve staff satisfaction with the medication history and reconciliation process. We administered a pre-intervention survey that was completed by 111 of 350 (31.7%) front-line ED staff across disciplines. (One staff member did not identify their role). In June 2022, we administered post-intervention surveys that were completed by 89 (25.4%) front-line staff. Completion rates are summarized in Table 1.

Pre-intervention Surveys

The pre-intervention survey identified a gap in ED staff satisfaction with the medication history and reconciliation process. In large part, staff were very dissatisfied with the medication reconciliation process for boarding patients. We looked specifically at each part of the "five rights" of medication administration: right patient; right medication; right dosage; right route; and right time.[18] We found that 70.6% were dissatisfied or very dissatisfied with the right dosage, and 82.7% with the right time (time medication last taken).

Post-intervention Surveys

After multiple interventions (see PDSA cycles above), the same survey was distributed to the same ED staff. Survey responses for each item are summarized in Table 2. Some respondents failed to answer each aspect of the survey, causing the individual totals of each question at times to add up to less than our total number of respondents. Respondents reported higher satisfaction with the medication reconciliation process after the intervention with regard to getting the right medication (1.69 vs 1.30; $P = 0.004$), right dosage (1.51 vs 1.03; $P < 0.001$), and time medication was last taken (1.29 vs 0.81; $P < 0.001$). Survey respondents were more satisfied with the medication history and reconciliation process getting the right patient prior to the intervention (average response 2.31 vs 2.16; $P = 0.02$), likely attributed to high satisfaction at baseline. There was no difference in satisfaction with the medication reconciliation process getting the right route for medication between the two surveys ($P = 0.94$).

When we combined the percentage of respondents choosing "satisfied" or "very satisfied" and compared pre- to post-intervention satisfaction with the medication history and reconciliation process, we also saw an overall improvement in satisfaction (as shown in Table 3). Three of the "five rights" of the components of medication reconciliation had improvement in staff satisfaction over our stated goal of 20%. Overall, we saw a 17.9% improvement in ED staff satisfaction (64.7% vs 46.8%).

In free-text responses in the post-intervention survey, many staff members noted that increased use of the "Let's Chat!" huddle was felt to be an additional venue through which all team members, knowing their roles in the process, can assist one another to ensure that medication reconciliation is complete and accurate.

Table 1. Pre- and post-intervention survey completion rates of front-line staff.

Pre-intervention survey (number and percentage of front-line staff members responding)	Post-intervention survey (number and percentage of front-line staff members responding)
Physician (37/77 [48.1%])	Physician (39/77 [50.7%])
NP/PA (9/12 [75%])	NP/PA (8/12 [66%])
RN (54/150 [36%])	RN (33/150 [22%])
Pharmacist (10/10 [100%])	Pharmacist (9/10 [90%])

Note: Based on 110 respondents who identified their role.
NP, nurse practitioner; *PA*, physician assistant; *RN*, registered nurse.

Table 2. Summary of survey results.

	Very dissatisfied (0)	Dissatisfied (1)	Satisfied (2)	Very satisfied (3)	Average response	*P*-value
Right patient						
Pre-intervention	13 (11.7%)	9 (8.1%)	20 (18.0%)	69 (62.2%)	2.31	0.02
Post-intervention	5 (6.2%)	6 (7.4%)	41 (50.6%)	29 (35.8%)	2.16	
Right medication						
Pre-intervention	24 (21.8%)	40 (36.4%)	35 (31.8%)	11 (10.0%)	1.30	0.004
Post-intervention	8 (10.0%)	22 (27.5%)	37 (46.3%)	13 (16.3%)	1.69	
Right dosage						
Pre-intervention	35 (32.1%)	42 (38.5%)	26 (23.9%)	6 (5.5%)	1.03	<0.001
Post-intervention	9 (11.3%)	27 (33.8%)	38 (47.5%)	6 (7.5%)	1.51	
Right route						
Pre-intervention	21 (19.1%)	17 (15.5%)	36 (32.7%)	36 (32.7%)	1.79	0.94
Post-intervention	6 (7.5%)	12 (15.0%)	47 (58.8%)	15 (18.8%)	1.89	
Time medication was last taken						
Pre-intervention	45 (40.9%)	46 (41.8%)	14 (12.7%)	5 (4.5%)	0.81	<0.001
Post-intervention	13 (16.5%)	33 (41.8%)	30 (38.0%)	3 (3.8%)	1.29	

Note: Based on 111 responses received for the pre-intervention survey and 89 responses received for the post-intervention survey.

Table 3. Staff satisfaction with each component of the "5 rights".

Survey question	Pre (percentage responding satisfied or very satisfied)	Post (percentage responding satisfied or very satisfied)	Change in percentage meeting satisfaction criteria	>20% threshold met
Satisfaction with medication reconciliation when the patient's status changes to ED observation/BH boarding	Right patient (80.2%)	Right patient (86.4%)	6.2%	No
	Right medication (41.8%)	Right medication (62.6%)	20.7%	Yes
	Right dose (29.4%)	Right dose (55%)	25.6%	Yes
	Right route (65.4%)	Right route (77.5%)	12.1%	No
	Time last taken (17.3%)	Time last taken (41.8%)	24.5%	Yes
Overall percent satisfaction	46.8%	64.7%	17.9%	No

DISCUSSION

Summary

Patients are experiencing increasing LOS in the ED.[2] During these prolonged stays, patients require medication history reconciliation[1]; unfortunately this process is complicated and challenging, leading to ADE.[8] Delineation of roles and the electronic chat function in the EHR ("Let's Chat!" huddle) were novel interventions that led to measurably increased satisfaction with the medication history and reconciliation process for EDOU and BH boarding patients. Using validated frameworks like the Lean Six Sigma, this project increased the understanding of how to improve the quality of ED care for BH boarding and EDOU patients.[19]

A chat function within the EHR allowed for alternative means of communication and increased the flexibility and buy-in of ED staff members. Evident in the low return of responses to the post-intervention surveys, there is a steep learning curve to get a large number of multidisciplinary staff educated on this new process in a busy work environment to implement the change.

Interpretation

Looking at this system as a whole, the "Let's Chat!" huddle improved front-line staff satisfaction with the medication reconciliation process, which should correlate with improved patient safety, decreased LOS, and positive patient outcomes.[20] Measuring satisfaction in specific aspects of this process taps into the multidisciplinary nature of medication history and reconciliation and covers many bases that could be missed with a solitary unit of measurement

(eg, LOS, ADEs). Measurement of staff satisfaction allows the stakeholders to apply their judgment as to whether the process was a success or failure, serving as a "stamp of approval" with the process.

This novel study is difficult to compare to other research, given the lack of published QI work covering this topic. Availability of pharmacy technicians is a focal point of prior studies; however, due to state statutes we were unable to use this group in our ED.[9] In attempting to facilitate a change, the efforts of the "Let's Chat!" huddle found that a collaborative multidisciplinary approach is necessary to have impact in this process. Carpenter et al demonstrated that knowledge alone is necessary but insufficient to improve healthcare outcomes; thus, adapting behaviors of clinicians, patients, and stakeholders to new standards of evidence-based clinical practice is often significantly delayed.[21]

Future directions for research include working on an implementation study with evidence-based interventions, determining how to measure patient-oriented health outcomes, testing the effectiveness of the implementation strategy, and including cost analysis, fidelity of the intervention, and evaluation of unintended effects in groups, among other steps as recommended by the Standards for Reporting Implementation Studies statement.[22]

The "Let's Chat!" medication reconciliation process was approved as a practice at this institution going forward. After the proven success of the project, the EHR alert has been implemented, alerting CTAs to initiate a "Let's Chat!" huddle when patients are placed on boarding status. This automated process could potentially be applied for discharging patients as well, which would broaden its impact and further decrease ED LOS.

The engagement and awareness of the team involved in the medication history and reconciliation process is critical to the safety of our patients, staff satisfaction, and optimal outcomes. Attention to the medication history and reconciliation continues to be an important part of the patient's ED visit. Continued reinforcement of the interventions, communication with staff, and monitoring for safety events is needed in the future to determine whether actual improvement is recognized by staff.

LIMITATIONS

Because this was a single-center study it may not be inherently generalizable to other institutions with fewer ED staff resources. Second, staff satisfaction is impacted by many factors that are not possible to measure or control. There were low response rates (from 25.4–31.4%) with the lowest completion rate among nurses who are our largest and most heterogeneous group of ED staff. We should also acknowledge that staff in the email list were not all working clinically during the four-week period that the survey was open.

Third, the sampling population was limited, as the survey was elective. This may have contributed to participation bias from individuals with strongly weighted feelings toward this process to skew the results. Additionally, overall satisfaction with this process is difficult to conclude, as an improved ED medication reconciliation extends beyond the front-line ED staff to the inpatient and consulting psychiatry teams, hospitalists, and patients who were not surveyed for their satisfaction and potential feedback. A wider net could be cast in the future iterations of this project to avoid survivorship bias.

Fourth, by using staff satisfaction instead of measurable quantitative information about errors or safety events related to medications reconciliation, the data is subject to the responders' interpretation of the question. Quantitative data is difficult to sway in this fashion and is a limitation of using satisfaction. Fifth, resistance and intermittent failure of ED staff to perform "Let's Chat" huddles during the physician-led huddle cycle due to lack of familiarity with roles could mean that the two-month window for staff to be familiarized with the intervention may have been insufficient for them to comfortably use the new process before answering the post-intervention survey. Historically, other implementation strategies have demonstrated an initial enthusiasm by staff that swiftly wanes. Use of a washout period between interventions could prevent this attrition and allow for more time for staff to passively review information while not having to use it. Further experience and use of the "Let's Chat!" huddles, if sustained, will allow staff to become more comfortable with the process.

Sixth, the method of staff education (email and printed materials) was selected based on availability of resources and not the most effective method backed by research for distributing information and educating a team. Further work should include evaluation of the sustainability of the "Let's Chat!" virtual huddle tool, duration of the effectiveness of education strategies used, and application to other patient groups dismissed from the ED.

CONCLUSION

The "Let's Chat!" huddle facilitates communication and increases satisfaction among ED team members related to the medication reconciliation process. The increased use of the "Let's Chat!" huddle was felt to be an additional and effective venue through which all team members, knowing their roles in the process, can assist one another to ensure the medication reconciliation is complete and accurate. Ongoing work is needed to continue to improve and build on the culture change for enhancing the medication history and reconciliation process.

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Pediatric Burns – Who Requires Follow-up? A Study of Urban Pediatric Emergency Department Patients

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Introduction: Hundreds of children suffer burn injuries each day, yet care guidelines regarding the need for acute inpatient treatment vs outpatient follow-up vs no required follow-up remain nebulous. This gap in the literature is particularly salient for the emergency clinician, who must be able to rapidly determine appropriate disposition.

Methods: This was a retrospective review of patients presenting to a Level II pediatric trauma center, January 1, 2017–December 31, 2019, and discharged with an International Classification of Diseases, Rev 10, burn diagnosis. We obtained and analyzed demographics, burn characteristics, and follow-up data using univariate and bivariate analysis as well as logistic regression modeling. Patients were stratified into three outcome groups: group 1—patients who underwent emergent evaluation at a burn center or were admitted at their first follow-up appointment; group 2—patients who followed up at a burn center (as an outpatient) or at the emergency department (and were discharged home); and group 3—patients with no known follow-up.

Results: A total of 572 patients were included in this study; 58.9% of patients were 1–5 years of age. Sixty-five patients met group 1 criteria, 189 patients met group 2 criteria, and 318 patients met group 3 criteria. Sixty-five percent of patients met at least one American Burn Association criteria, and 79% of all burns were second-degree burns. Flame and scald burns were associated with increased odds (odds ratio [OR] 1.21, OR 1.12) of group 1 vs group 2 + group 3 ($P = 0.02$, $P < 0.001$). Second/third-degree burns and concern for non-accidental trauma were also associated with increased odds of group 1 vs 2 or 3 (OR = 1.11, 1.35, $P \leq 0.001$, 0.001, respectively). Scald burns were associated with increased odds of group 2 compared to group 3 (OR 1.11, $P = 0.04$). Second/third degree burns were also associated with increased odds of group 2 vs 3 (OR 1.19, $P \leq 0.001$).

Conclusion: There were few statistically significant variables strongly associated with group 1 (emergent treatment/admission) vs group 2 (follow-up/outpatient treatment) vs group 3 (no follow- up). However, one notable finding in this study was the association of scald burns with treatment (admission or follow-up) suggesting that the presence of a scald burn in a child may signify to clinicians that a burn center consult is warranted. [West J Emerg Med. 2024;25(4)634–644.]

INTRODUCTION

Approximately one US child presents to the emergency department (ED) for a burn injury every six minutes; 10,000 are hospitalized over the course of a year.[1,2] Burn injuries, especially in children, carry significant risk of physical and psychological sequelae.[2–5] In 2017 alone, ED costs relating to pediatric burns amounted to over $700 million and total hospitalization to over $1.5 billion.[6] Advances in burn therapy have led to an overall trend toward outpatient management, reducing the risk associated with hospitalization and allowing for more efficient treatment and resource allocation.[7,8] However, the process of identifying which patients may be best served by inpatient care vs follow-up outpatient treatment vs discharge home without set follow-up is not well delineated.

The American Burn Association (ABA) has published guidelines regarding transfer/referral to regional burn centers; however, understanding and implementation of these guidelines has varied. Some clinicians have perceived these guidelines as absolute transfer criteria and others as consult/referral criteria.[9] It is, therefore, unsurprising that transfer/consult/referral practices differ widely, with frequent reports of patients being both under- and over-referred.[10,11] Interestingly, Anderson et al found that although most pediatric patients presenting to their institution with burn injuries were low acuity, a majority were admitted, and social factors and transfer status were more strongly associated with admission than burn size or mechanism.[12] In light of these factors, the documented inconsistency of non-burn center clinician's evaluation of burns, and the lack of randomized control studies, an expert panel devised updated guidelines in 2020.[13–16] Perhaps the most important message from this update is the reframing of the ABA criteria as "consultation guidelines." There do not otherwise appear to be substantive changes regarding more specific disposition recommendations for pediatric patients.

It is notable that emergency physicians—the clinicians most often tasked with the initial evaluation and decision to contact burn centers—were not included until the third stage of the eDelphi process. The 2020 update also includes recommendations regarding telemedicine. While telemedicine certainly has the potential to transform many aspects of patient care, its use in all patients with potentially deep burns may be prohibitive from a time, technological, legal, and insurance perspective. Clearer standards regarding which patients might benefit most from this process, which ones may be transferred without telemedicine consultation, and which may be discharged home with or without follow-up would likely facilitate ED flow and burn center processes.

Our objective in this study was to describe characteristics of pediatric burn patients directly transferred/admitted to a burn center, patients who followed up, and those who did not follow up. We aimed to identify patient and burn characteristics associated with these three groups to better inform clinician disposition decisions. This three-tiered approach was chosen with the emergency clinician in mind as they must be able to determine which patients require immediate transfer, which may benefit from follow-up, and which patients may be discharged home without need for further evaluation. Our secondary objective was to examine the distribution of patients meeting ABA criteria among these three groups.

Population Health Research Capsule

What do we already know about this issue?
Hundreds of children suffer burn injuries each day, but care guidelines for inpatient admission vs outpatient follow-up or no follow-up remain nebulous.

What was the research question?
Are there variables associated with how emergency clinicians refer pediatric burn patients for follow-up?

What was the major finding of the study?
Flame and scald burns (OR 1.21), and non-accidental trauma (OR 1.11) had higher odds of evaluation at a burn center ($P < 0.001$).

How does this improve population health?
Referral decisions for pediatric burns is challenging; scald burns often require treatment and should almost always warrant treatment at a burn center.

METHODS

This retrospective chart review included patients 0–21 years presenting to the ED of a pediatric Level II trauma center January 1, 2017–December 31, 2019 who were discharged with an International Classification of Diseases, Rev 10 (ICD-10) burn diagnosis (ICD-10 codes may be found in the supplementary materials). We collected data regarding demographics, burn mechanism, burn site, degree of burn, total burn surface area (TBSA), ABA criteria, concern for non-accidental trauma (NAT), and manner of arrival. Concern for NAT was considered to be present if documented in the emergency physician's or social worker's note. We collected follow-up data from this institution's ED as well as the two burn centers serving the surrounding

region. Data was abstracted by three trained data abstractors (BL, AT, BV) using a standard operating procedure manual. We collected and managed study data using REDCap electronic data capture tools hosted at Children's Hospital of Orange County. The REDCap data collection form may be found in the supplementary materials. Charts were identified via a query using ICD-10 diagnosis code (ICD-10 codes T20–31) and ED visit date (January 1, 2017–December 31, 2019) as inclusion parameters. A post-hoc inter-rater reliability (IRR) process was completed wherein a newly trained abstractor used the same standard operating procedure manual to review charts at the main study site. The IRR was analyzed using the Cohen kappa, and all data variables were confirmed as having a Cohen kappa coefficient ranging from 0.870–1.000; 67% of variables reviewed resulted in a Cohen kappa coefficient of 1.000. This study was approved by all study institutions' institutional review boards. As this was a retrospective chart review subjects were not asked to consent to participate in this study.

We stratified patients into three outcome groups for analysis: group 1 patients representing those likely to require interventions or care best provided by a specialized burn center (as opposed to what may be available at a referring institution or in the outpatient setting); group 2 patients representing those whose wounds likely required further follow-up; and group 3 representing those at lowest risk (ie, those who likely did not need any follow-up). Group 1 included patients who were transferred from the presenting ED directly to one of the two regional burn centers (or their respective EDs) or patients who were admitted at their first follow-up visit. Group 2 included patients who followed up at one of the two regional burn centers (in the ED or clinic) or the presenting ED (for a burn-related visit). Group 3 included patients who were not known to follow up (ie, they did not follow up at either burn center's clinic or ED or the presenting ED and were not initially transferred to a burn center). Outcomes were defined by disposition, (ie, inclusion in group 1, group 2, or group 3).

Univariate and Bivariate Statistical Analysis

We measured differences in the distribution of continuous and categorical variables reporting frequency and proportions of categorical variables and mean/standard deviation of continuous variables across outcome groups. The bivariate inferential statistics of the Wilcoxon rank-sum test were used to test the difference in distribution of continuous variables of age and total burn surface area. We used the chi-square test of proportions to test the difference in distribution of categorical variables across groups. These bivariate inferential tests were applied to patients meeting the criteria of in either outcome group 1 or outcome group 2 or lower risk outcome group 3. We conducted missingness analysis on those variables with >10% missing data. The Little test was conducted on all variables meeting this missingness threshold.

Logistic Regression Models

We used logistic regression models to test the association between demographics/observed clinical variables with the probability of treatment group 1, 2, or 3. Variables that were found to have high correlation or variance inflation using R variance inflation factor measurements (R 4.03) were pruned from the model depending upon a variable's utility as determined by the study team. As these were full models, we did not apply methods related to backward, forward, or stepwise variable selection.

RESULTS

Descriptive Analysis

A total of 572 patients were included in this study; 8.04% of patients were <1 year; 58.9% of patients were 1–5 years; 18% were 5–10 years; 8.74% were 11–15 years; and 6.29% were >15 years. Of all study patients, 48.7% were male, 63.4% were Hispanic, and 73.2% had public insurance (or opted for self-pay). Sixty-five patients were directly transferred to a burn center or admitted at their first follow-up visit (group 1), 189 patients attended at least one follow-up visit (group 2), and 318 patients did not follow up at any of the study institutions (group 3). A total of 372 patients (65%) met at least one ABA criteria. The distribution of characteristics by outcome group is shown in Table 1.

There was a significant difference associated with gender distribution among groups 1, 2, and 3, with a higher percentage of males in groups 1 and 3 as compared to females, and a higher percentage of females in group 2, $P = 0.01$. There was also a significant difference associated with burn mechanism, with a higher percentage of scald and contact burns than other burn mechanisms in all three groups; scald burns were the predominant burn type in groups 1 and 2 (73.8% and 49.2%, respectively), $P < 0.001$. The location of the burn was also associated with a significant difference between groups 1, 2, and 3, with a predominance of wrist/hand/palmar burns in groups 2 and 3 (39.6% and 32.3%, respectively) compared to lower extremity burns in group 1 (26.1%), $P \leq 0.001$ (Table 1).

The majority of all burns were second-degree burns (79%). There was a significant difference associated with meeting at least one ABA criteria, with 86.1% of those in group 1 meeting the criteria compared to 67.7% in group 2 and 59.1% in group 3, $P = 0.01$. Concern for NAT was also associated with a significant difference, with 23% of those in group 1 with concern for NAT compared to 8.99% and 6.28% in groups 2 and 3, respectively ($P \leq 0.001$) (Table 1).

Table 1. Distribution of sociodemographic and clinical variables across burn treatment outcome groups.

Patient characteristics	Total n = 572	Group 1, n = 65 (direct transfer to burn center or admitted at first follow-up)	Group 2, n = 189 (patient followed up)	Group 3, n = 318 (patient did not follow up)	*P*-value
Age					0.1
<1	46 (8.04%)	10 (15.3%)	16 (8.46%)	20 (6.28%)	
1–5 years	337 (58.9%)	38 (58.4%)	100 (52.9%)	199 (62.5%)	
5–10 years	103 (18.0%)	9 (13.8%)	44 (23.2%)	50 (15.7%)	
11–15 years	50 (8.74%)	5 (7.69%)	15 (7.93%)	30 (9.43%)	
>15	36 (6.29%)	3 (4.61%)	14 (7.40%)	19 (5.97%)	
Gender					0.01
Male	279 (48.7%)	39 (60.9%)	89 (47.0%)	178 (55.9%)	
Female*	292 (51.0%)	25 (38.4%)	100 (52.9%)	140 (44.0%)	
Race					0.38
White	345 (60.3%)	36 (55.3%)	121 (64.0%)	188 (59.1%)	
Non-White	227 (39.6%)	29 (44.6%)	68 (35.9%)	130 (40.8%)	
Ethnicity					0.28
Hispanic	363 (63.4%)	47 (72.3%)	119 (62.9%)	197 (61.9%)	
Non-Hispanic	209 (36.5%)	18 (27.6%)	70 (37.0%)	121 (38.0%)	
Insurance					0.74
Private	153 (26.7%)	10 (15.3%)	152 (80.4%)	257 (80.8%)	
Public/self-pay	419 (73.2%)	55 (84.6%)	37 (19.5%)	61 (19.1%)	
Burn mechanism					<.001
Flame	15 (2.62%)	3 (4.06%)	3 (1.58%)	9 (2.83%)	
Scald	261 (45.6%)	48 (73.8%)	93 (49.2%)	120 (37.7%)	
Steam	6 (1.04%)	0 (0%)	1 (0.52%)	5 (1.57%)	
Chemical	40 (6.99%)	2 (3.07%)	6 (3.17%)	32 (10.0%)	
Electrical	5 (0.87%)	0 (0%)	3 (1.58%)	2 (0.62%)	
Contact	215 (37.5%)	10 (15.3%)	78 (41.2%)	127 (39.9%)	
Other	30 (5.24%)	2 (3.07%)	5 (2.6%)	23 (7.23%)	
Burn site					<.001
Head/neck/face	65 (11.3%)	7 (10.7%)	12 (6.34%)	46 (14.4%)	
Lower limb (Including knees, ankle, foot, sole)	137 (23.9%)	17 (26.1%)	56 (29.6%)	64 (20.1%)	
Perineum/ genitalia	9 (1.57%)	2 (3.07%)	4 (2.11%)	3 (0.94%)	
Trunk/back	87 (15.2%)	15 (23.0%)	20 (10.5%)	52 (16.3%)	
Upper limb (excluding wrist and hand)	82 (14.3%)	13 (20%)	21 (11.1%)	48 (15.0%)	
Wrist/hand/palm	189 (33.0%)	11 (16.9%)	75 (39.6%)	103 (32.3%)	
Missing site	3 (0.52%)	0 (0%)	1 (0.52%)	2 (0.62%)	
Degree of burn					<.001
1st	114 (19.9%)	4 (6.15%)	23 (12.1%)	87 (27.3%)	
2nd	452 (79.0%)	59 (90.7%)	163 (86.2%)	230 (72.3%)	

(*Continued on next page*)

Table 1. Continued.

Patient characteristics	Total n = 572	Group 1, n = 65 (direct transfer to burn center or admitted at first follow-up)	Group 2, n = 189 (patient followed up)	Group 3, n = 318 (patient did not follow up)	*P*-value
3rd	6 (1.04%)	2 (3.07%)	3 (1.58%)	1 (0.31%)	
Total burn surface area (TBSA)**					<.001
<1%	153 (26.7%)	5 (7.69%)	36 (19.0%)	112 (35.2%)	
1 to 1.9%	20 (3.49%)	0 (0%)	11 (5.82%)	9 (2.83%)	
2 to 4.9%	117 (20.4%)	15 (23.0%)	47 (24.8%)	55 (17.2%)	
5 to 9.9%	42 (7.34%)	21 (32.3%)	11 (5.82%)	10 (3.14%)	
10 to 15%	10 (1.74%)	9 (13.8%)	1 (0.52%)	0 (0%)	
>15%	5 (0.87%)	4 (6.15%)	0 (0%)	1 (0.31%)	
Not stated	225 (39.3%)	11 (16.9%)	83 (43.9%)	131 (41.1%)	
Was ABA referral criteria met?					<.001
Yes	372 (65.0%)	56 (86.1%)	128 (67.7%)	188 (59.1%)	
No	193 (33.7%)	9 (13.8%)	58 (30.6%)	126 (39.6%)	
Not stated	7 (1.22%)	0 (0%)	3 (1.58%)	4 (1.25%)	
Was there concern for non-accidental trauma?					<.001
Yes	52 (9.09%)	15 (23.0%)	17 (8.99%)	20 (6.28%)	
No	520 (90.9%)	50 (76.9%)	172 (91.0%)	298 (93.7%)	

*Gender was recorded as undetermined for one patient.
**Missing TBSA values were significantly associated with outcome group.
ABA, American Burn Association.

Logistic Regression Analysis - Group 1 vs 2

Age 5–10 years was associated with decreased odds (odds ratio [OR] 0.86) of direct transfer/admission at first follow-up (group 1), compared to attending at least one follow-up visit (group 2), $P = 0.04$. Flame and scald burns were associated with increased odds (OR 1.52, OR 1.17, respectively) of a group 1 vs 2 outcome, as was concern for NAT (OR 1.48), $P = 0.02$, $P = 0.02$, $P = 0.02$. Head/neck/facial burns, burns to the trunk, and burns to the upper limb (excluding the wrist/hand/palm) were also associated with increased odds of group 1 vs group 2 outcomes (OR 1.26, 1.22, and 1.21, respectively, $P = 0.04$, $P = 0.04$, $P = 0.04$) (Table 2).

Group 1 vs Group 3

Male gender was associated with decreased odds of direct transfer/admission at first follow-up (group 1) compared to not following up (group 3) (OR 0.92, $P = 0.02$). Scald burns were associated with increased odds (OR 1.23, of group 1 vs group 3 outcomes, $P < 0.001$). Second/third degree burns and concern for NAT were also associated with increased odds of group 1 vs group 3 outcomes (OR 1.21 and 1.49, respectively, $P < 0.001$, $P = 0.003$) (Table 3).

Group 2 vs Group 3

Scald burns were associated with increased odds of follow-up (group 2) compared to no follow-up (group 3) (OR 1.11, $P = 0.04$). Second/third degree burns were also associated with increased odds of group 2 vs group 3 outcomes (OR 1.19, $P \leq .0001$). Burns to the trunk were associated with decreased odds of group 2 vs group 3 outcomes (OR 0.81, $P \leq .0001$) (Table 4).

Group 1 or 2 vs Group 3

Male gender was associated with decreased odds of direct transfer/admission at first follow-up (group 1), or any follow-up (group 2) compared to not following up (group 3) (OR 0.904, $P = 0.01$.) Scald burns and second/third degree burns were associated with group 1 or 2 outcomes vs group 3 outcomes (OR 1.18 and 1.261, respectively, $P \leq 0.001$, $P < 0.001$). Burns to the trunk were associated with decreased odds (OR 0.857, of group 1 or 2 outcomes compared to group 3, $P = 0.03$) (Table 5).

Group 1 vs 2 or 3

Flame and scald burns were associated with increased odds of direct transfer/admission at first follow-up (group 1)

Table 2. Logistic regression model: estimated odds ratios of group 1 vs group 2.

Patient characteristic	Odds ratio	95% Confidence interval		*P*-value
Age (reference: 1–5 years)				
<1	1.05	0.87	1.26	0.62
5–10 years	0.86	0.75	0.99	0.04
11–15 years	0.93	0.76	1.15	0.52
>15	0.94	0.75	1.18	0.61
Race (reference: non-White)				
White	0.95	0.85	1.07	0.42
Gender (reference: female)				
Male	0.94	0.85	1.05	0.29
Ethnicity (reference: non-Hispanic)				
Hispanic	1.04	0.93	1.17	0.50
Insurance (reference: public insurance)				
Commercial insurance	1.02	0.89	1.18	0.78
Burn mechanism (reference: contact)				
Chemical	1.13	0.81	1.57	0.47
Electrical	0.91	0.56	1.49	0.70
Flame	1.52	1.06	2.19	0.02
Other	1.09	0.78	1.52	0.61
Scald	1.17	1.03	1.33	0.02
Steam	0.74	0.32	1.71	0.48
Degree of burn (reference: 1st degree)				
2nd degree or 3rd degree	1.12	0.93	1.35	0.22
Burn site (reference: wrist/hand/palm)				
Head/neck/face	1.26	1.02	1.56	0.04
Lower limb (knees, ankle, foot, sole)	1.05	0.91	1.21	0.51
Perineum/genitalia	1.17	0.81	1.67	0.40
Trunk	1.22	1.01	1.47	0.04
Upper limb	1.21	1.01	1.45	0.04
Was there concern for non-accidental trauma? (Reference: No)				
Yes	1.48	1.07	2.06	0.03

vs following up at least once (group 2) or not following up (group 3) (OR 1.21 and 1.12, $P = 0.02$, $P < 0.001$). Second/third degree burns and concern for NAT were also associated with increased odds of group 1 vs 2 or 3 outcomes (OR 1.11, 1.35, respectively, $P \leq 0.001$, 0.001) (Table 6).

DISCUSSION

In this retrospective study we attempted to describe the population of pediatric patients presenting to our ED with burn injuries as well as investigate whether there may be patient or burn characteristics associated with particular outcomes. Our study population reflected national statistics with regard to burn mechanism with a predominance of scald (45.6%) and contact burns (37.5%).[17] This appears similar to an Australian study by Abeyasundara et al in which the majority of burns were scald, followed by contact.[18] It is, however, slightly different from work by Abramowicz et al who examined pediatric visits to the ED (using the Nationwide Emergency Department Sample database) for burn-related injuries and reported that a majority of burns were due to electrical appliances, followed by scald injuries.[6] Scald burns were generally associated with need for treatment, both in our study (increased ORs of group 1 or group 2 outcomes) and in analysis by Mitchell et al, which demonstrated an almost three-fold increase in likelihood of admission for patients with scald burns compared to other

Table 3. Logistic regression model: estimated odds ratios group 1 vs group 3.

Patient characteristics	Odds ratio	95% Confidence interval		*P*-value
Age (reference: 1–5 years)				
<1	1.10	0.96	1.27	0.18
5–10 years	0.96	0.86	1.07	0.46
11–15 years	1.04	0.91	1.19	0.58
>15	1.03	0.88	1.20	0.75
Race (reference: non-White)				
White	1.00	0.93	1.08	0.90
Gender (reference: female)				
Male	0.92	0.85	0.98	0.02
Ethnicity (reference: non-Hispanic)				
Hispanic	1.06	0.98	1.15	0.13
Insurance (reference: public insurance)				
Commercial insurance	0.99	0.91	1.09	0.91
Burn mechanism (reference: contact)				
Chemical	1.05	0.88	1.26	0.57
Electrical	1.04	0.64	1.71	0.86
Flame	1.23	0.99	1.53	0.07
Other	0.94	0.81	1.10	0.44
Scald	1.23	1.13	1.35	<.001
Steam	0.88	0.63	1.21	0.43
Degree of burn (reference: 1st degree)				
2nd degree or 3rd degree	1.21	1.10	1.34	<.001
Burn site (reference: wrist/hand/palm)				
Head/neck/face	1.11	0.96	1.28	0.16
Lower limb (knees, ankle, foot, sole)	1.02	0.92	1.13	0.75
Perineum/genitalia	1.23	0.89	1.71	0.22
Trunk	1.01	0.89	1.13	0.91
Upper limb	1.07	0.96	1.21	0.22
Was there concern for non-accidental trauma? (Reference: No)				
Yes	1.49	1.15	1.93	<0.001

burn mechanisms.[1] These population findings are especially important when considering local injury prevention and education efforts.

The majority of patients in our study (58.9%) were between the ages of 1–5. This data is similar to that reported by Abeyasundara et al who found that children between the ages of 1–5 years of age accounted for 59.3% of all children (0–16 years of age) in their study.[18] This is likely reflective of developmental abilities achieved (and lacking) during this period. In addition, the large percentage of patients 1–5 years in group 3 (62.5%) is perhaps indicative of the increased mobility of these children coupled with increased parental concern for burns in younger children.

Interestingly, and in contrast to other studies, 51% of patients in our study were female, whereas Mitchell et al who analyzed the US National Electronic Injury Surveillance system from 1990–2014 and Abramowicz et al who examined the Nationwide Emergency Department Sample from 2008–2013, found a majority of patients were male (58.4% and 56%, respectively).[1,6] Of note, however, the majority of patients in group 1 (likely representing the most serious burns) and group 3 (those who didn't follow up) were male compared to group 2 in which the majority were female. One possible explanation for this discrepancy is increased parental concern in our population for burn injuries in females as compared to males.

Table 4. Logistic regression model results: estimated odds ratios of group 2 vs group 3.

Patient characteristics	Odds ratio	95% Confidence interval		*P*-value
Age (reference: 1–5 years)				
<1	1.06	0.90	1.26	0.48
5–10 years	1.10	0.98	1.24	0.09
11–15 years	1.02	0.87	1.20	0.82
>15	1.09	0.91	1.30	0.36
Race (reference: non-White)				
White	1.07	0.98	1.17	0.14
Gender (reference: female)				
Male	0.93	0.85	1.01	0.09
Ethnicity (reference: non-Hispanic)				
Hispanic	1.00	0.92	1.10	0.95
Insurance (reference: public insurance)				
Commercial insurance	1.03	0.92	1.14	0.66
Burn mechanism (reference: contact)				
Chemical	0.98	0.78	1.22	0.83
Electrical	1.19	0.78	1.81	0.43
Flame	0.95	0.71	1.27	0.72
Other	0.86	0.71	1.04	0.12
Scald	1.11	1.00	1.23	0.04
Steam	0.89	0.59	1.32	0.55
Degree of burn (reference: 1st degree)				
2nd degree or 3rd degree	1.19	1.06	1.33	<0.001
Burn site (reference: wrist/hand/palm)				
Head/neck/face	0.90	0.75	1.07	0.23
Lower limb (knees, ankle, foot, sole)	0.98	0.87	1.11	0.76
Perineum/genitalia	1.13	0.78	1.62	0.52
Trunk	0.81	0.70	0.94	<0.001
Upper limb	0.88	0.77	1.01	0.08
Was there concern for non-accidental trauma? (Reference: No)				
Yes	1.10	0.79	1.54	0.57

In this study we examined rates of transfer to a burn center and admission at the first follow-up visit (group 1). Eleven percent of patients in this study fell into this category, similar to admission rates reported by Mitchell et al and Abramowicz et al.[1,6] In addition, we analyzed transfer/admission rates and follow-up by ABA criteria. Among those in group 1, 86.1% met ABA criteria; however, 67.7% of those in group 2 met criteria, and 59.1% of those in group 3 even met ABA criteria. Although the ABA guidelines are meant to assist in building an appropriate referral system and not meant to be definitive care recommendations, our data suggests that adaptations to the ABA criteria may be valuable as many children, including those who don't seem to require follow-up care, meet current ABA guidelines. Further research regarding this low-risk population would likely benefit both EDs and burn referral centers.

Several studies have shown there is confusion and differing policies regarding ABA guidelines and the need for referral vs transfer vs specialist consult.[10] For example, Johnson et al reported that only 8.2% of pediatric burn patients meeting ABA transfer guidelines were transferred from low-volume hospitals, Doud et al reported an under-referral rate of 55%, and Van Yperen et al found that according to the referral criteria of the Australian Emergency Management of Severe Burns course, just over 25% of patients (adult and pediatric) were under-transferred.[19–21] However, Rose et al examined the referral patterns of children presenting to an ED in the United Kingdom (UK)

Table 5. Logistic regression model: estimated odds ratios of group 1 or 2 vs group 3.

Patient characteristics	Odds ratio	95% Confidence interval		*P*-value
Age (Reference: 1–5 years)				
<1	1.091	0.935	1.272	0.27
5–10 years	1.062	0.951	1.186	0.29
11–15 years	1.025	0.881	1.193	0.75
>15	1.094	0.923	1.297	0.30
Race (reference: non-White)				
White	1.056	0.972	1.148	0.20
Gender (reference: female)				
Male	0.904	0.833	0.980	0.01
Ethnicity (reference: non-Hispanic)				
Hispanic	1.024	0.939	1.117	0.59
Insurance (reference: public insurance)				
Commercial insurance	1.022	0.920	1.136	0.68
Burn mechanism (reference: contact)				
Chemical	0.985	0.801	1.211	0.88
Electrical	1.169	0.763	1.790	0.47
Flame	1.064	0.818	1.383	0.64
Other	0.839	0.695	1.014	0.07
Scald	1.180	1.070	1.302	<0.001
Steam	0.820	0.549	1.223	0.33
Degree of burn (reference: 1st degree)				
2nd degree or 3rd degree	1.261	1.127	1.411	<0.001
Burn site (reference: wrist/hand/palm)				
Head/neck/face	0.949	0.805	1.118	0.53
Lower limb (knees, ankle, foot, sole)	0.986	0.881	1.104	0.81
Perineum/genitalia	1.183	0.853	1.640	0.32
Trunk	0.857	0.748	0.982	0.03
Upper limb	0.932	0.818	1.062	0.29
Was there concern for non-accidental trauma? (Reference: No)				
Yes	1.277	0.961	1.698	0.09

for burn injuries and reported that although 74% were under-referred only 3.2% of these patients subsequently required referral to a burn unit and none required specialist intervention, suggesting that complete adherence to the UK's burn referral criteria (National Burn Care Review) might not be necessary and in fact might necessarily increase the workload of regional burn units.[22] Notably, Garcia et al examined admission practices at 34 pediatric burn centers across the US and found significant variation in admission decisions regarding patients with minor burns (<10% TBSA) vs ED-initiated outpatient management.[11] In this setting of significant practice variation in multiple countries, and lack of definitive guidance regarding best practices, we attempted to identify which characteristics were most associated with admission/transfer or follow-up alone.

Burns to the head/neck/face, trunk, and upper limb were all associated with statistically significantly increased odds of direct transfer/admission at first follow-up compared to attending at least one follow-up visit. Few variables were associated with statistically significant odds of group 2 vs group 3 outcomes. Notably, scald was associated with increased odds of group 2 vs group 3 outcomes. It is not surprising that the presence of second/third degree burns was almost always associated with significantly increased odds of admission or follow-up compared to no follow-up. Concern for NAT was found to be associated with increased odds of group 1 vs 2 or 3 outcomes; however, given the additional

Table 6. Logistic regression model - estimated odds ratios of group 1 vs Group 2 or 3.

Patient characteristic	Odds ratio	95% Confidence interval		*P*-value
Age (reference: 1–5 years)				
<1	1.06	0.96	1.17	0.22
5–10 years	0.95	0.88	1.02	0.15
11–15 years	1.00	0.91	1.10	0.97
>15	1.01	0.90	1.12	0.90
Race (reference: non-White)				
White	0.98	0.93	1.04	0.56
Gender (reference: female)				
Male	0.95	0.90	1.00	0.05
Ethnicity (reference: non-Hispanic)				
Hispanic	1.04	0.98	1.10	0.19
Insurance (reference: public insurance)				
Commercial insurance	1.00	0.94	1.07	0.94
Burn mechanism (reference: contact)				
Chemical	1.02	0.90	1.17	0.73
Electrical	0.97	0.74	1.27	0.82
Flame	1.21	1.03	1.44	0.02
Other	0.96	0.85	1.08	0.51
Scald	1.12	1.06	1.20	<0.001
Steam	0.90	0.70	1.16	0.41
Degree of burn (reference: 1st degree)				
2nd degree or 3rd degree	1.11	1.04	1.20	<0.001
Burn site (reference: wrist/hand/palm)				
Head/neck/face	1.09	0.98	1.21	0.10
Lower limb (knees, ankle, foot, sole)	1.01	0.94	1.09	0.79
Perineum/genitalia	1.12	0.91	1.38	0.28
Trunk	1.05	0.96	1.15	0.27
Upper limb	1.08	0.99	1.17	0.07
Was there concern for non-accidental trauma? (Reference: No)				
Yes	1.35	1.12	1.62	<0.001

considerations necessary when there is concern for NAT, it is difficult to disentangle the social vs clinical considerations behind the ramifications of this finding.

LIMITATIONS

Limitations of this study include its relatively small sample size and, therefore, limited power and limited generalizability. It is important to note that in this study we used the outcome of admission or follow-up as a proxy for requirement of admission and/or follow-up. In addition, investigator knowledge of follow-up was limited to patients returning either to the ED of initial presentation or to the two regional burn centers. It is possible that some patients in group 3 followed up at outside institutions or primary care clinics. However, the pediatric ED involved in the study is the only pediatric-specific ED in the study county, and the two regional burn centers are the only burn specialty centers in the study county. We did not include length of stay for patients who were directly transferred in this analysis, and it is possible that patients who were directly transferred but discharged from the burn center ED were incorrectly apportioned to group 1. This may have led to characteristics incorrectly associated with need for direct transfer.

CONCLUSION

This study demonstrates the importance of individual institution/regional population data as it may differ from national estimations, and these statistics may inform injury

prevention education and outreach regarding pediatric burns. The limited statistically significant data associated with transfer/admission vs follow-up vs no follow-up was surprising yet illuminates potential causes for the diverse transfer/admission practices demonstrated in previous studies. These results highlight the potential role of telemedicine for expert guidance; however, future studies are necessary to determine which patients may be best suited to telemedicine consults. One notable finding in this study was the association of scald burns with treatment (admission or follow-up), suggesting that the presence of a scald burn in a child may signify to clinicians that a burn center consult is warranted. Future research could expand on this work by analyzing larger patient populations and expanding burn and patient variables to capture further significant data points that may help improve clinician disposition decisions.

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Perceived Versus Actual Time of Prehospital Intubation by Paramedics

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Introduction: Situational awareness is essential during emergent procedures such as endotracheal intubation. Previous studies suggest that time distortion can occur during intubation. However, only in-hospital intubations performed by physicians have been studied. We aimed to determine whether time distortion affected paramedics performing intubation by examining the perceived vs actual total laryngoscopy time, defined as time elapsed from the laryngoscope blade entering the mouth until the endotracheal tube balloon passes the vocal cords.

Methods: For this retrospective study we collected prehospital intubation data from a suburban, fire department-based emergency medical services (EMS) system from January 5, 2021–May 21, 2022. The perceived total laryngoscopy time was queried as a part of the electronic health record. Video laryngoscopy recordings were reviewed by a panel of experts to determine the actual time. Patients >18 years old who underwent intubation by paramedics with video laryngoscopy were included for analysis. The primary outcome was the difference between actual and perceived total laryngoscopy time. Secondary analysis examined the relationship between high time distortion, defined as the highest quartile of the primary outcome, and patient age, paramedic years of experience, perceived presence of difficult anatomy, excess secretions, use of rapid sequence intubation, and multiple intubation attempts. We conducted descriptive analysis followed by logistic regression analysis, chi-square tests, and Fisher exact tests when appropriate.

Results: A total of 122 intubations were collected for analysis, and 10 were excluded due to lack of video recording. Final analysis included 112 intubations. Mean actual laryngoscopy time was 50.0 seconds (s) (95% confidence interval [CI] 43.7–56.3). Mean perceived laryngoscopy time was 27.8 s (95% CI 24.7–31.0). The median difference between actual and perceived time was 18 s (interquartile range 6–30). We calculated high time distortion as having a difference greater than 30 s between actual and perceived laryngoscopy time. None of the secondary variables had statistically significant associations with high time distortion. Overall, we show that the paramedic's perception of total laryngoscopy time is significantly underestimated even when accounting for paramedic experience and perceived airway difficulty.

Conclusion: This study suggests that time distortion may lead to an unrecognized prolonged procedure time. Limitations include use of a convenience sample, small sample size, and potential uncollected confounding variables. [West J Emerg Med. 2024;25(4)645–650.]

INTRODUCTION

Effective airway management is a critical prehospital intervention, and endotracheal intubation (ETI) has long been considered an essential paramedic skill to manage a patient with an unstable airway or ineffective breathing. While ETI is potentially lifesaving, the procedure can quickly become harmful if hypoxia develops during laryngoscopy.[1] Although preoxygenated healthy patients may have a safe apnea time up to 10 minutes, the most likely patient to require prehospital ETI is a patient in extremis or cardiac arrest for which there is minimal literature regarding safe procedure time.[2] The moribund patient likely already has abnormal oxygenation and ventilation, which further complicates intubation, as any amount of apnea time could worsen the patient's condition. First-pass success and a short procedure time is the key to minimizing adverse events during intubation; however, the ability of paramedics to maintain awareness of the elapsed time during intubation is unknown.[3,4]

Anesthesia literature and high-profile events demonstrate that even expert clinicians can suffer from cognitive errors during intubation that cause an unrecognized prolonged procedure time and a poor patient outcome from hypoxia.[5,6] Studies of healthcare workers suggest that stressful situations, such as those during an intubation or resuscitation, diminish the ability to accurately identify the passage of time.[7,8] A study of emergency physicians found that the estimated time to intubation was significantly less than the actual procedure time.[9] However, the generalizability of these studies to clinicians operating outside the hospital environment is unknown. To date, there has been a paucity of studies examining the ability of emergency medical services (EMS) professionals to estimate time during stressful situations in the prehospital environment.

We sought to examine the perceived vs actual total laryngoscopy time (TLT) during prehospital intubation performed by paramedics in a countywide EMS system. This information can be used to inform future best practices for prehospital intubation.

Population Health Research Capsule

What do we already know about this issue?
Elevated stress and an increased cognitive load during intubations can reduce the ability of clinicians to accurately determine the passage of time.

What was the research question?
Among paramedics, is there a difference between perceived vs actual total laryngoscopy time (TLT)?

What was the major finding of the study?
Perceived TLT (26.8 seconds, 95% CI 23.7–29.8) was significantly lower than actual TLT (44.6 seconds, 95% CI 41.2–48.1).

How does this improve population health?
The identified time differences offer guidance for educational and procedural interventions with the goal of improving clinical outcomes for patients.

METHODS

We performed a retrospective review comparing actual TLT vs perceived TLT among a convenience sample of all patients intubated with video laryngoscopy in the prehospital setting from January 5, 2021–May 21, 2022 at a single, combined fire and EMS department. Total laryngoscopy time was defined as time elapsed from the laryngoscope blade entering the mouth until the endotracheal tube balloon passed the vocal cords.

Patients were intubated by firefighter paramedics from Howard County Department of Fire & Rescue Services (HCDFRS). All firefighter paramedics are licensed in the state of Maryland and maintain active certification with the National Registry of Emergency Medical Technicians. The HCDFRS is a combined career-volunteer department with over 900 career and volunteer personnel. The department receives over 30,000 EMS calls per year and serves about 325,000 residents in Howard County, MD. The department is comprised of 14 stations, all of which are staffed with career personnel and six are supplemented by volunteer crews. The department operates both Basic Life Support and Advanced Life Support (ALS) transport units staffed with a minimum of two EMT-B personnel and at least one paramedic, respectively. Three paramedic duty officers (MDO) operating in fly cars provide daily operational supervision of EMS operations, incident command, and additional ALS support to crews dispatched on high-complexity calls.

Each ALS unit carries medical equipment that is standardized across the department. For intubations, the department provides video laryngoscopes (UE Scope 2, UE Medical Devices, Inc, Newton, MA) in addition to a standard complement of conventional, non-video laryngoscopes and rescue airway devices such as a bougie and supraglottic airway device (i-gel, Intersurgical, Ltd, Rugby, United Kingdom). Airway management procedures and protocols are outlined in a departmental general order. The general order recommends the use of video laryngoscopy as the preferred method of laryngoscopy. If video

laryngoscope equipment is not available or if the clinical circumstances dictate, the intubation may be performed with direct laryngoscopy. Immediately following a call during which video laryngoscopy was performed, the MDO will immediately conduct a debriefing of the procedure with the responding crew and download the video for internal departmental quality assurance. In situations where oxygenation and ventilation cannot be adequately performed, an emergency needle cricothyroidotomy may be performed.

Paramedic intubation competency is assessed during yearly continuing education, which includes a one-hour airway lecture led by an EMS physician followed by a skills assessment. Paramedics who are internally credentialed to perform rapid sequence intubation (RSI) are required to attend at least one cadaver lab every year, as well as monthly RSI debriefs led by an EMS physician. The cadaver lab and debriefs are optional for non-RSI credentialed paramedics.

We conducted our retrospective chart review, data collection, and analysis following best practice methodologic standards for health record review.[10] Following each intubation, the intubator must complete an "airway form," which includes a question asking the paramedic to estimate the intubation procedure time. If the paramedic conducted multiple intubation attempts to successfully intubate the patient, the paramedic was asked to estimate the procedure time for each intubation attempt. The perceived TLT was then retrieved from the electronic health record. Actual TLT was determined by consensus from a trained panel of experts blinded to the study objectives who reviewed prehospital video laryngoscopy recordings obtained from the video laryngoscope. The expert panel consisted of two board-certified emergency physicians with subspecialty certification in EMS, an EMS fellow, two paramedic fire officers, one paramedic field supervisor, a quality improvement officer, and two field paramedics. If the patient was successfully intubated multiple times by the paramedic, only the first intubation was included in the dataset. The panel also collected information and came to a consensus on several variables that may have affected the airway procedure time. We then compiled all data into a dataset. Patients in which data was incomplete were excluded from the dataset prior to analysis.

Inclusion criteria consisted of all patients ≥18 years who were intubated by a paramedic with video laryngoscopy. The primary outcome was the difference between actual TLT and perceived TLT. Secondary analysis examined the relationship between high time distortion and secondary variables including patient age, paramedic years of experience, perceived presence of difficult anatomy, excess secretions, and the use of RSI. We used the highest quartile of the primary outcome as the cut-off point to define cases with high time distortion. We calculated the mean, median, and interquartile range (IQR) to provide initial descriptive analysis of the data. Outliers were defined as values that were greater than 150% of the IQR. We used the paired *t*-test to compare the difference between actual and perceived TLT, excluding any identified outliers. Logistic regression analysis, chi-square tests, and Fisher exact tests were used when appropriate to examine the relationship between high time distortion and secondary variables. We conducted all data analysis using STATA version 17, (StataCorp LLC, College Station, TX).

This study was approved by the Johns Hopkins Medicine Institutional Review Board (reference number IRB00319716).

RESULTS

During the defined study period, a total of 122 intubations were conducted by the department, and all attempts involved the use of video laryngoscopy. No attempts used backup airway methods. Among these attempts, 112 met inclusion criteria. Ten intubations were excluded due to lack of available video recording. Table 1 demonstrates call location and ultimate disposition of the patient at the end of the call.

Patients were intubated due to cardiac arrest in 84% (94/112) of cases. Rapid sequence intubation occurred in 15% (17/112) of patients. Time range of attempts was 19–300 seconds (s), with 83% (93/112) taking 60 s or less. First-pass success was 83% (93/112) with an average time of 47.5 s (19–300). Of the attempts that took longer than a minute, the average TLT was 100.4 s. Unsuccessful attempts took an average of 62.5 s (24–120) (Table 2). Paramedics intubating had an average of 10.7 years of experience in the department and average 2–3 intubations per year.

The mean actual TLT was 50.0 s (95% confidence interval [CI] 43.7–56.3),and the mean perceived TLT was 27.8 s (95% CI 24.6–31.0). After excluding nine identified outliers the mean actual TLT was 44.6 s (95% CI 41.2–48.1), and the mean perceived TLT was 26.8 s (95% CI 23.7–29.8). The differences in means and medians between actual and

Table 1. Demographics and characteristics of patients intubated.

Characteristics	Overall (n = 112)
Age, mean (years)	61.9
Male gender (%)	62 (55%)
Call location	
Home/other residence (%)	77 (69%)
Public (%)	21 (19%)
Healthcare facility (%)	11 (10%)
Other (%)	3 (2%)
Patient disposition	
Transferred to hospital care (%)	95 (85%)
Pronounced deceased on scene (%)	17 (15%)

Table 2. Actual intubation average time and range broken down by different groups.

Intubation sample	Average (seconds)	Range (seconds)
Overall intubation time (n = 112)	50.0	19–300
First pass – successful intubation time (n = 93)	47.5	19–300
First pass – unsuccessful intubation time (n = 19)	62.5	24–120
Total laryngoscopy time for attempts ≤60 seconds (n = 93)	39.7	19–60
Total laryngoscopy time for attempts >60 seconds (n = 19)	100.4	61–300
Rapid sequence intubation performed (n = 17)	56.2	20–120

perceived TLT were 17.9s (95% CI 14.5–21.2) and 18.0 s (IQR 6–29), respectively (Table 3).

We calculated high time distortion as having a difference greater than 29 s between actual TLT and perceived TLT. Patient age, paramedic years of experience, the use of RSI, presence of excess secretions or difficult airway anatomy, and multiple intubation attempts showed no statistically significant association with high time distortion (Table 4).

DISCUSSION

To our knowledge, this is the first study to investigate situational awareness of paramedics during prehospital intubations. Overall, our data shows that our paramedics had a first-pass success rate of 83% when using video laryngoscopes compared to a historic first-pass rate of 51% and overall intubation success rate of 61% in 2009, prior to the introduction of video laryngoscopes in the department.[11] Our reported first-pass success rate is higher compared to that of other systems, such as the Seattle Fire Department (63%),[12] and from large, multicenter studies such as the Pragmatic Airway Resuscitation Trial (51%)[13]; however, accurate comparison of first-pass rates between our cohort and that of other departments may be complicated by our relatively smaller sample size and differences in departmental protocol and training.

Our data shows an average paramedic-perceived TLT that was significantly lower than the measured TLT. This result is similar to that of previous studies of stressful situations conducted in a hospital setting. One study, following intern physicians, resident physicians, and nurses during in-hospital cardiopulmonary resuscitation simulations, found that clinicians underestimated cardiac arrest duration by 22.5 s when asked during the simulation.[14] A similar underestimation was found in physicians and nurses during neonatal resuscitation simulations when asked to estimate time from birth to several checkpoint interventions.[8] Finally, a study of emergency physicians examining time perception in actual emergency department RSIs found a significant underestimation of procedure time, 23 vs 45.5 s. This study also found that accuracy in determining the time elapsed worsened as more time passed during intubation.[9]

The clinical implication of underestimating elapsed time during intubation is potentially lethal. Even with preoxygenation, it takes just 10 minutes for the pulse oximetry to drop below 80% in a healthy, non-obese adult. However, a critically ill patient is more likely to have the presence of shunting, increased metabolic demand, anemia, volume depletion, and decreased cardiac output, all of which have been shown to reduce both oxygen storage in the lungs and safe apnea time.[15] This effect would be reasonably amplified even further in cardiac arrest patients with a prolonged down time. Our results showed a median time underestimation of 18 s compared to the actual TLT. While it is not clear whether an overall difference of 18 s is significant, any time dilation could result in a longer than expected apnea time and a poor clinical outcome.

Table 3. Comparison of mean and median actual vs perceived total laryngoscopy time among all included intubations (n = 103), excluding 9 outliers.

Sample	Actual TLT	Perceived TLT	Difference	*P*-value
All intubations				
Mean (95% CI)	50.0 s (43.7–56.3)	27.8 s (24.6–31.0s)	22.2 s (15.5–28.9)	<0.001
Median [IQR]	43.0 s [31.0–57.5]	20.0 s [15.0–30.0]	18.5 s [6–30]	<0.001
Excluding outliers				
Mean (95% CI)	44.6 s (41.2–48.1)	26.8 s (23.7–29.8)	17.9 s (14.5–21.2)	<0.001
Median [IQR]	43.0 s [31.0–56.0]	20.0 s [15.0–30.0]	18.0 s [6–29]	<0.001

TLT, total laryngoscopy time; *s*, seconds; *IQR*, interquartile range; *CI*, confidence interval.

Table 4. Univariate logistic regression of patient and paramedic variables associated with having high time distortion. (excluding 9 outliers).

Intubation variable	OR (95% CI)	*P*-value
Patient age	0.98 (0.96–1.01)	0.15
Paramedic years of experience	0.94 (0.88–1.00)	0.06
Difficult anatomy	0.39 (0.04–3.25)	0.38
Excess secretions	0.38 (0.12–1.22)	0.11
RSI	1.24 (0.35–4.31)	0.74
Repeat attempts	2.05 (0.61–6.83)	0.24

CI, confidence interval; *RSI*, rapid sequence intubation.

We sought to explore variables that could affect perception of intubation time such as presence of a difficult airway, RSI, past paramedic experience, and repeated intubation attempts. However, these variables were not associated with a statistically significant high time difference. Future research is required to determine which factors, if any, influence accuracy of time perception.

Current education and the body of literature emphasize first-pass success as the benchmark of a successful intubation. Multiple studies have shown an association with an increased risk of adverse events with each successive intubation attempt. However, overemphasis on first-pass success may lead to a fixation on avoiding a second intubation attempt at the cost of a prolonged procedure time and hypoxia. Monitoring for hypoxia during intubation of a critically ill patient poses a significant challenge as pulse oximetry is unlikely to be reliable secondary to poor perfusion. To address this, we propose modifying the current paradigm of a successful intubation from one that emphasizes first-pass success to one that emphasizes overall time awareness with a low threshold for recognizing and aborting a prolonged intubation attempt. Currently, the goal maximum time for a prehospital intubation is not established. In our dataset, 83% of intubation attempts were performed within one minute and attempts that lasted longer than a minute required another 40 s of procedure time, on average. The HCDFRS has implemented a maximum of 60 s for an intubation attempt given these results and the simplicity of remembering one minute per attempt. However, we acknowledge that more research is required to identify a safe maximum prehospital intubation time and that the time threshold may vary with different clinical presentations.

We propose introducing and emphasizing time awareness in prehospital intubation protocols to avoid task fixation. This modification was included in the American Society of Anesthesiologists Difficult Airway Management Guideline in 2022[5] and has been incorporated into the department's most recent airway management protocol. Interventions could include those already used in aviation to reduce task fixation, such as the use of checklists, closed-loop communication, and optimized data presentations.[16,17] Additional interventions can focus on paramedic education. Initial certifying classes and continuing medical education can emphasize time awareness during intubations through focused didactics and frequent, high-fidelity simulations that emphasize the use of an airway algorithm and promote a low threshold for aborting an intubation attempt and moving to a backup airway method. Future research is required to assess the efficacy of these interventions in the prehospital environment and establish the ideal maximum procedural time for ETI.

LIMITATIONS

Our study has significant limitations. First, we used a convenience sample of available prehospital intubations at a single site in which video laryngoscopy data was readily available. As such, our sample size is small, and we did not conduct a formal sample size calculation for this study. The ability of our conclusions to be generalized to other systems is limited and will warrant an additional, more robust study with more comprehensive sampling. Second, the data is reliant on the paramedic documenting their perceived intubation time during completion of the prehospital care report (PCR). While the department emphasizes completing the PCR upon completion of the patient transport, the paramedic has up to 24 hours to complete their it, which may affect the paramedic's ability to accurate remember the perceived procedure time.

Additionally, this study evaluated only video laryngoscopy. Due to difficulties inherent with retrospective chart review, it was not possible to evaluate pulse oximetry or clinical status at time of intubation attempt; thus, it is not known whether there was an actual difference in rates of hypoxia with longer intubation times, although previous literature would support this assumption. This will warrant additional studies incorporating clinical data for patients who are intubated. Finally, not all possible secondary variables that may affect perception of intubation time were captured or analyzed by this study. Other variables that possibly warrant additional investigation include patient gender, indication for intubation, and estimated patient weight, among others.

CONCLUSION

In this single-site study, the total time for video laryngoscopy intubation was significantly longer than perceived by the intubating paramedic. Emphasis should be placed on limiting the intubation time to avoid potentially catastrophic desaturation events.

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Compartment Syndrome Following Snake Envenomation in the United States: A Scoping Review of the Clinical Literature

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Introduction: Local tissue destruction following envenomation from North American snakes, particularly those within the Crotalinae subfamily, has the potential to progress to compartment syndrome. The pathophysiology of venom-induced compartment syndrome (VICS) is a debated topic and is distinct from trauma/reperfusion-induced compartment syndrome. Heterogeneity exists in the treatment practices of VICS, particularly regarding the decision to progress to fasciotomy. Associations with functional outcomes and evolution in clinical practice since the introduction of Crotalidae polyvalent immune Fab (FabAV) have not been well defined. Our goal was to identify the potential gaps in the literature regarding this phenomenon, as well as illuminate salient themes in the clinical characteristics and treatment practices of VICS.

Methods: We conducted this systematic scoping-style review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Records were included if they contained data surrounding the envenomation and hospital course of one or more patients who were envenomated by a snake species native to North America and were diagnosed with compartment syndrome from 1980–2020.

Results: We included 19 papers: 10 single- or two-patient case reports encompassing 12 patients, and nine chart reviews providing summary statistics of the included patients. In case reports, the median compartment pressure when reported was 60 millimeters of mercury (interquartile range 55–68), 66% underwent fasciotomy, and functional outcomes varied. Use of antivenom appeared to be more liberal with FabAV than the earlier antivenin Crotalidae polyvalent. Rapid progression of swelling was the most commonly reported symptom. Among the included retrospective chart reviews, important data such as compartment pressures, consistent laboratory values, and snake species was inconsistently reported.

Conclusions: Venom-induced compartment syndrome is relatively rare. Existing papers generally describe good outcomes even in the absence of surgical management. Significant gaps in the literature regarding antivenom dosing practices, serial compartment pressure measurements, and functional outcomes highlight the need for prospective studies and consistent standardized reporting. [West J Emerg Med. 2024;25(4)651–660.]

INTRODUCTION

The venomous snakes of North America capable of causing significant soft tissue damage fall under the family Viperidae and the subfamily Crotalinae (also referred to as crotalids).[1] Snakes in this category consist of the genera *Crotalus* (rattlesnakes), *Sistrurus* (pygmy rattlesnake and massasauga), and *Agkistrodon* (cottonmouth and copperheads). These genera are often colloquially referred to as pit vipers due to the presence of heat-sensing pits behind their nostrils.[2] Crotalid venom is a complex mixture of more than 100 macromolecules, glycoproteins, and metals. Phospholipase A2, inflammatory mediator analogues, and metalloproteinases damage endothelium and disrupt normal coagulation cascades, primarily manifesting as local tissue destruction and hematologic toxicity, although neurotoxicity can develop after envenomation from some species.[3,4] In severe cases, tissue destruction and swelling due to crotalid envenomation has the potential to progress to compartment syndrome. In contrast, elapid venom found in North American coral snakes results in little to no local tissue destruction.[5,6]

The nature of venom-induced compartment syndrome (VICS) is a debated topic, as local symptoms common to crotalid envenomation such as pallor, edema, paresthesia, and pain with passive movement can mimic trauma or reperfusion-associated compartment syndrome. However, true compartment syndrome is thought to be rare after envenomation, as the associated symptoms are more likely due to direct myonecrosis rather than elevated compartment pressures and associated tissue ischemia.[3,5–7] As a result, some advocate against using the term compartment syndrome to describe the condition. Consequently, there is heterogeneity in how clinicians approach suspected cases of VICS, including the role of fasciotomy.

This treatment inconsistency also stems from historic misguidance of suspected cases of compartment syndrome following envenomation, which reached its nadir in the 1970s–1980s when fasciotomy was considered the gold standard of treatment. Numerous reviews and animal models suggest that prompt antivenom administration precludes the need for fasciotomy, as antivenom treatment alone has been shown to reduce intracompartmental pressures in animal models.[8,9] In a 2011 review, Cumpston concluded that current evidence did not support the use of fasciotomy in Crotalinae envenomation with elevated compartment pressures and might even worsen outcomes.[7] Of note, the majority of articles included in that review describe patients treated with antivenin Crotalidae polyvalent (ACP), prior to the introduction of Crotalidae polyvalent immune Fab (FabAV), adding significance to an additional review.

At our institution, we were recently consulted in two copperhead envenomations in which local tissue damage progressed to alleged compartment syndrome with elevated compartment pressures; fasciotomy was performed in both cases. This led our team to question how often this clinical scenario occurs and what literature exists to guide management and inform prognosis. Therefore, we performed a review of literature reporting compartment syndrome following North American snake envenomation to gather data regarding symptomatology, laboratory/pressure abnormalities, interventions, and outcomes and to identify gaps in the literature surrounding this phenomenon, particularly concerning functional outcomes.

Population Health Research Capsule

What do we already know about this issue?
Compartment syndrome is a rare complication of envenomation by certain snake species; clinical data regarding this phenomenon is poorly described.

What was the research question?
What are the clinical characteristics, treatment paradigms and functional outcomes of venom-induced compartment syndrome (VICS)?

What was the major finding of the study?
For 19 papers, the median compartment pressure was 60 mm Hg (IQR 55–68) and 66% underwent fasciotomy. Functional outcomes varied but were generally good.

How does this improve population health? (165 characters max)
This review distills what is known about VICS and highlights important gaps in the literature, including long-term functional outcomes.

METHODS

We conducted a systematic review of published studies reporting compartment syndrome following North American snake envenomation from January 1, 1980–November 18, 2020. Our team included three medical toxicologists, one resident physician, and an information specialist (librarian MSW). We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement as the guideline for conducting this review.[10] According to the guidelines of the Emory University Institutional Review Board, this study was not human subjects research and did not require review.

After consultation with other team members, the information specialist developed a search strategy; six

databases were searched. We searched terms "compartment syndromes," "snake bite," "snake bites," and "North America." The systematic searches were performed in Agricola (Ebscohost), Cochrane Central Register of Controlled Trials (CENTRAL via Cochrane Library), Embase (Elsevier), Global Health (CAB Direct), PubMed (NLM), and Web of Science (core collections via Clarivate) databases on November 18, 2020. The complete search terms and strategies are included as supplemental information. We filtered search results for English language and journal articles only; editorials and letters were excluded in each database. In addition, where applicable, we also sought conference abstracts and reviews if we felt that there were sufficient data points within the abstract. During the search process, if there were fewer than five records retrieved, filters such as English language and article type were not applied.

All records (278) were imported into Covidence (Melbourne, Australia), and duplicate citations were removed by Covidence prior to the review. Fifty-four duplicates were removed, and 224 records were set to be screened. Records were eligible for inclusion if they contained demographic and bite-related data regarding one or more patients who were envenomated by a snake species native to North America and were diagnosed with compartment syndrome. One resident and two medical toxicologists reviewed the records, and a third medical toxicologist resolved records in dispute. Results are presented in descriptive and tabular format. No formal statistical analyses were performed.

RESULTS

After initial screening of the 224 records retrieved, 161 studies were deemed irrelevant, usually due to bites from animals other than snakes, envenomation by a non-native species of snake, or bites that took place outside the United States. Upon review of the complete articles, we excluded an additional 44 due to absence of significant documented outcome measures, leaving 19 studies for study inclusion (Figure). Of the 19 studies included, 10 were single- or two-patient case reports providing patient-level data[11–20] (Tables 1–3) and nine were chart review summaries providing summary statistics of the included patients[5,21–28] (Table 4). All species causing VICS in this review fall under the Crotalinae subfamily (crotalids). In total, 88 cases were extracted: 12 from single- or two-patient case reports, and 76 cases from retrospective chart reviews.

Case reports included a total of 12 patients with an age range of 1–59 years; 9/12 (75%) were male (Table 1). Species reported were the following: copperhead (3/12, 25%); western diamondback rattlesnake (2/12, 17%); great basin rattlesnake (2/12, 17%); cottonmouth (1/12, 8%); eastern diamondback rattlesnake (1/12, 8%); pygmy rattlesnake (1/12, 8%); and black-tailed rattlesnake (1/12, 8%). Bites were inflicted on the hands (4/12, 33%), dorsal foot (2/12, 17%) and anterior lower extremity (2/12, 17%). All females (3/3) suffered lower extremity bites.

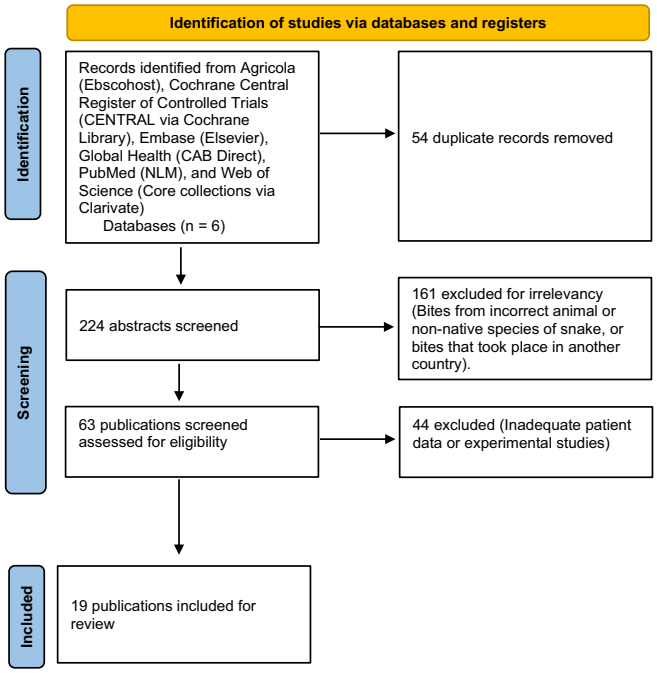

Figure. PRISMA flow diagram.

Signs and symptoms reported included the following: rapid progression of swelling and edema (11/12, 92%); firm compartments (10/12, 83%); and pain (9/12, 75%). Erythema was not as commonly reported (3/1225%, Table 2). Compartment pressures were reported for all 12 patients, with a median compartment pressure of 60 millimeters of mercury (interquartile range [IQR] 55–68). All patients received antivenom. In six (50%) cases the authors did not specify which antivenom was used. For analytic purposes, we assumed that case reports from the 1980s and 1990s[11–13] employed ACP and that another report from 2011[17] used FabAV. In cases employing ACP, the median number of vials employed was 10 (IQR 7–15) and in cases employing FabAV the median was 21 (IQR 15–32). Fasciotomy was performed in 8/12 (66%) cases: 3/5 ACP and 4/6 FabAV (Table 3). With both antivenoms, patients undergoing fasciotomy received fewer vials than those who did not receive surgical management, keeping in mind the small number of patients in each group. Two patients who underwent fasciotomy reported motor deficits, compared to zero patients treated with medical therapy alone.

Chart review publications included data from 947 patients (Table 4). Three (33%) studies reported the snake species involved. Eight (89%) reported the location of bite. Only one (11%) study reported physical examination findings. Four (33%) studies reported specific compartment pressures. In total, 49 (5.2%) patients were diagnosed with compartment syndrome, and 44 of those patients underwent fasciotomy. Of patients who received fasciotomies, only six (12%) had

Table 1. Demographics for case reports.

Publication	Age (y)	Gender	Snake species	Bite location
Roberts et al, 1985 [13] (patient 1)	14	M	Pygmy rattlesnake	Finger
(Patient 2)	39	M	Cottonmouth	Volar hand
Seiler et al, 1994 [14]	8	M	Not specified	Posterior lower extremity
Padda and Bowen, 1995 [15]	5	M	Copperhead	Ankle
Rosen et al, 2000 [16]	59	M	Western diamondback	Dorsal foot
Gold et al, 2003 [17]	43	M	Western diamondback	Volar hand
Hardy et al, 2006 [18]	35	F	Black-tailed rattlesnake	Anterior lower extremity
Thomas et al, 2011 [19]	8	F	Great Basin rattlesnake	Ankle
(Patient 1) (Patient 2)	2	M	Great Basin rattlesnake	Finger
Mazer-Amirshahi et al, 2014 [20]	1	F	Copperhead	Dorsal foot
Brys et al, 2015 [21]	9	M	Copperhead	Dorsal hand
McBride et al, 2017 [22]	48	M	Eastern diamondback	Anterior lower extremity

M, male; *F*, female.

Table 2. Symptoms and compartment pressures for case reports.

Publication	Pain (passive)	Edema	Erythema	Rapid swelling	Firm compartment	Other	Pressure (mm Hg)
Roberts et al, 1985 [13] (Patient 1)	Yes	Yes	No	Yes	Yes	Paresthesia, numbness, diminished pulses	60
(Patient 2)	Yes	Yes	No	Yes	Yes	Paresthesia, diminished pulses	60
Seiler et al, 1994 [14]	Yes	Yes	No	Yes	Yes	Paralysis	55
Padda and Bowen 1995 [15]	No	No	No	Yes	Yes	Paresthesia	35
Rosen et al, 2000 [16]	Yes	Yes	No	Yes	Yes	None	46
Gold et al, 2003 [17]	Yes	Yes	Yes	Yes	Yes	Paresthesia	55
Hardy et al, 2006 [18]	Yes	Yes	No	Yes	No	Paresthesia, paralysis	68
Thomas et al, 2011 [19] (Patient 1)	Yes	Yes	Yes	Yes	Yes	None	68
(Patient 2)	No	Yes	No	Yes	Yes	Poikilothermia, weak pulses	60
Mazer-Amirshahi et al, 2014 [20]	Yes	Yes	Yes	Yes	No	None	85
Brys et al, 2015 [21]	Yes	Yes	No	Yes	Yes	None	56
McBride et al, 2017 [22]	No	Yes	No	No	Yes	None	72

mm Hg, millimeters of mercury.

objective compartment pressures reported. Although the chart reviews inconsistently reported which antivenom was used, it was assumed that publications from before 2001 employed ACP. The incidence of compartment syndrome in chart reviews from the ACP era was 8.3% (42 compartment syndrome diagnoses from 508 cases) compared to 1.6% (seven compartment syndrome diagnoses from 439 cases) after 2001. The number of vials of antivenom administered and information regarding the temporal association between antivenom administration and fasciotomy was not consistently reported.

DISCUSSION

After an intensive screening process, we included 19 articles in this review. Most of the included retrospective cohort studies did not report individual patient-level data.

Table 3. Treatments and outcomes for case reports.

Publication	Antivenom	# of vials	Fasciotomy performed	Length of hospitalization (days)	Outcome	Follow-up time
Roberts et al, 1985 [13] (Patient 1)	Not specified*	7	Yes	4	Complete resolution	4 days
(Patient 2)	Not specified*	10	Yes	5	Complete resolution	5 days
Seiler et al, 1994 [14]	Not specified*	5	Yes	Not specified	Residual motor deficit	1 year
Padda and Bowen 1995 [15]	Not specified*	Not specified	Yes	4	Not specified	N/A
Rosen et al, 2000 [16]	ACP	15	No	2	Pain with walking	1 week
Gold et al, 2003 [17]	ACP	30	No	3	Complete resolution	6 days
Hardy et al, 2006 [18]	FabAV	12	Yes	12	Abscess, motor deficit	2 months, 2 years
Thomas et al, 2011 [19] (Patient 1)	Not specified#	32	No	6	Not reported	N/A
(Patient 2)	Not specified#	15	Yes	5	Not reported	N/A
Mazer-Amirshahi et al, 2014 [20]	FabAV	26	No	4	Not reported	2 weeks
Brys et al, 2015 [21]	FabAV	16	Yes	Not specified	Not reported	2 weeks
McBride et al, 2017 [22]	FabAV	54	Yes	15	Not reported	N/A

*Assumed to be ACP based on year of publication. #Assumed to be FabAV.
ACP, antivenin Crotalidae polyvalent; *FabAV*, Crotalidae polyvalent immune Fab.

Venom-induced compartment syndrome is a rarely reported disease process, as we identified only 88 cases consisting of 12 from case reports and 76 cases from larger retrospective reviews despite reviewing more than 40 years of literature. While the true prevalence is likely to be higher than the number of published reports, this nonetheless represents a small number in comparison to the approximately 6,000 snake envenomations occurring each year in the US.[29]

A clinically salient theme apparent in the data is that VICS portends better outcomes in comparison to trauma-induced compartment syndrome. In this review, only two patients from the included case reports (Table 3) were recorded to have residual motor deficits following VICS treatment, both of whom received a fasciotomy. No cases in the included published literature led to amputation or were associated with death. In contrast, following diagnosis and treatment of trauma or reperfusion-associated compartment syndrome, motor deficits range from 18–44%,[30,31] and amputation rates range from 5.7–12.9%.[31–34] While the pathology underlying venom-induced vs traumatic compartment syndrome is very different, the expected clinical course and functional outcome are important points to address when counseling patients at the bedside. It should be noted that follow-up times reported were variable and generally quite short—on the order of days to weeks; so patients' final functional outcome(s) are unknown, identifying an important gap in the snakebite literature.

One interesting juxtaposition that became apparent during analysis was how the data differs between the articles published during the ACP and FabAV time periods. FabAV was approved for use in 2000, and the manufacture of ACP was discontinued in 2001. Looking at the case reports (Tables 1–3), four patients with compartment syndrome underwent fasciotomy in each antivenom "era": ACP and FabAV. The median number of antivenom vials employed in the ACP (pre-2001) reports was 10 vials, while the median number of vials in patients receiving FabAV was 21. The manufacturer of ACP recommended an initial dose for severe envenomation of 10–15 vials with additional antivenom as needed based upon the clinical response.[35] Considering real-world experience, a retrospective study of 414 patients treated for presumed rattlesnake envenomation reported a mean dose of 38 vials.[36] The prescribing information for FabAV recommends an initial dose of 4–6 vials, followed by an additional 4–6 vials if needed to gain initial control of the envenomation, and an additional two vials every six hours for 18 hours (total dose of 14–18 vials).[37] Clinical experience suggests that most patients achieve control of swelling with

Table 4. Summary statistics for cumulative data studies.

Study	Methods	Patient/bite characteristics	Signs and symptoms	Treatment(s)	Outcome(s)
Downey et al, 1991 [23]	Single-center, retrospective chart review using orthopedic operation logs and hospital admission records over an 11-year period.	36 patients, 28 (78%) male. Median age 21 years (range 2–71). 5 (14%) foot/ankle bites, 7 (19%) leg bites, 20 (56%) hand bites, 2 (6%) forearm and 2 (6%) upper arm bites. Snake species not recorded. Most common activities before being bitten included alcohol use, playing outside, and handling a pet snake.	Study used modified Wood, Hoback, and Green (McCollough, N and Gennaro, J et al1968) envenomation scale. 5 (14%) grade 1, 27 (75%) grade 2, and 3 (8%) grade 3 bites. Of the 25 (69%) patients diagnosed with compartment syndrome, 7 were in the digit, 9 in the hand/forearm, 1 in the arm, and 8 in the foot/leg. 25 diagnosed with compartment syndrome.	Antivenom used in 22 (61%) of all bites and in 11/15 (73%) of patients under the age of 18, with a total dose ranging from 1–15 vials. Serum sickness occurred in 1 patient receiving antivenom. All 25 patients diagnosed with compartment syndrome received fasciotomies; 3 patients had objective compartment pressures.	4 postoperative infections occurred, including 1 secondaryto the fasciotomy procedure.
Cowin et al, 1998 [24]	Single-center, retrospective chart review using diagnosis codes for snakebites over a 3-year period. Some upper extremity bites were evaluated in a hand surgery clinic or by telephone for outcome data.	73 patients, 20 (74%) male. 27 (37%) lower extremity bites and 46 (63%) upper extremity. 24 pygmy rattlesnake bites, 11 diamondback rattlesnake, 15 cottonmouth, 9 coral snake.	No patient-level data reported; 3 patients diagnosed with compartment syndrome.	9/27 (33%) lower extremity and 22/46 (48%) upper extremity bites received antivenom. All 3 patients diagnosed with compartment syndrome received fasciotomy.	4/14 (29%) patients seen in clinic reported residual pain and tissue atrophy at the bite site. One patient who underwent fasciotomy had numerous deficits noted on physical exam. Patients contacted by telephone (n=10) reported subjective numbness (7/10), local tissue loss (2/10), and stiffness (2/10).
Tanen et al, 2001 [7]	Single-center, retrospective chart review of bite patients admitted to a medical toxicology service over a 6-year period.	236 patients, 191 (81%) male; 138 (56%) over the age of 13; 142 (60%) upper extremity bites, 39% lower extremity bites. It took an average of 1.7 hours between the time of the bite and arrival at a healthcare facility, and 5.3 hours on average from bite to antivenom infusion.	14% of children and 24% of adults developed hemorrhagic bullae. Compartment syndrome was diagnosed in 8 (3.3%) patients. Compartment pressures were only reported in one patient (80 mm Hg). Diagnosis was based on clinical signs included coldness to the touch and pulselessness in the other cases.	ACP administered to 77% of patients. An average of 28.5 vials were given. Fasciotomy performed on 3 patients, digital dermotomy on 5 patients	Mean hospital stay was 2.5 days, no long-term outcomes reported.

(*Continued on next page*)

Table 4. Continued.

Study	Methods	Patient/bite characteristics	Signs and symptoms	Treatment(s)	Outcome(s)
Tokish et al, 2001 [25]	Five-center, retrospective chart review of hospital admissions following snake bite over a 5-year period	163 patients, 89 (55%) male. Mean age 29 (range 1–81). 55% of bites were to the lower extremities, with one torso bite. 12% were intoxicated when bitten, and 29% were purposefully handling a snake. 98% of bites were from rattlesnakes. 10 (6%) of patients were treated with the "cut and suck" prehospital intervention, 7 (4%) used a constriction band, and 6 (4%) used a tourniquet.	6 (4%) patients developed compartment syndrome, and 16 (11%) developed necrosis in the inoculation site.	90% of patients received antivenom, with an average of 19 vials (range 0–75). The 6 patients with compartment syndrome received a fasciotomy, 1 patient received a finger amputation, and the 16 patients with necrosis all received surgical debridement. Surgery was more common in those receiving prehospital interventions such as incision and venom suction.	Mean hospital stay of 2.8 days.
Shaw et al, 2002 [26]	Single-center, retrospective chart review of pediatric bite patients over a 10-year period.	24 pediatric patients, 18 (75%) male. 14 (58%) upper extremity bites, 10 (42%) lower extremity bites.	2 patients developed necrosis of the tips of the digits. One patient developed compartment syndrome of the leg when antivenom administration was stopped after 5 vials due to an urticarial reaction. Anterior and posterior compartment pressures were 45 mm Hg.	Patients received an average of 12.5 vials of ACP antivenom except for one patient who received 4 vials of FabAV, then 5 vials of equine antivenom. The 2 patients with necrosis of the tips of the digits underwent limited debridement. One patient with compartment syndrome of the leg underwent fasciotomy.	Mean hospital stay of 3 days (range 1–10).
Campbell et al, 2007 [27]	Single-center, retrospective chart review of bite patients over a 10-year period	114 pediatric patients, 68% male. Mean age 4.2 years (range 1–17). 71 (62%) lower extremity bites. 65 (57%) copperhead, 9 (8%) rattlesnake, and 7 (6%) cottonmouth bites.	Compartment syndrome diagnosed in 2 (1.8%) patients. Compartment pressures in both patients exceeded 60 mm Hg. One patient was bitten by a cottonmouth, and the other by a copperhead.	7 (6%) patients received FabAV antivenom, 2 patients with compartment received fasciotomies.	No patient outcomes reported.
Correa et al, 2014 [28]	Single-center, retrospective chart review of pediatric patients envenomated over a 6-year period.	151 pediatric patients, 150 (66 %) male. 91 (60%) lower extremity bites, 58 (38%) upper extremity bites, 1 (1%) groin bite, 1 (1%) face bite. 65 copperhead, 5 cottonmouth, 3 coral snake, 3 pit viper, 1	Study used internal bite-severity scale, but patient-level data not reported. At least 2 (1.3%) patients diagnosed with compartment syndrome.	52 (34%) patients received antivenom (FabAV) with a median dose of 6 vials (range 1–16). 4 patients had surgery, and there was no significant difference between patients treated with	Median hospital stay was 2 days.

(*Continued on next page*)

Table 4. Continued.

Study	Methods	Patient/bite characteristics	Signs and symptoms	Treatment(s)	Outcome(s)
		pygmy rattlesnake, 1 fer de lance, and 1 timber rattlesnake bite.		antivenom and those not treated with antivenom. The operations included 2 fasciotomies for compartment syndrome, 1 full thickness skin graft, and 1 wound debridement. No mention of pressures.	
Theilen et al, 2014 [29]	Single-center, retrospective chart review of surgical outcomes of patients after a snake bite in an academic referral center over a 4-year period	45 patients, no other demographic data reported.	No patient-level data reported.	36 (80%) received antivenom, with 16 (35.6%) requiring additional dosing. One case involved a minor dermotomy of the finger. 16/19 adult patients only required monitoring in the ED.	Mean hospital stay of less than 2 days.
Darracq et al, 2015 [30]	Retrospective case series from a statewide (California) poison center database over an 11-year period. Bites where fasciotomy was either discussed or performed were reviewed.	105 patients. 28 (27%) patients underwent fasciotomy, with 79% being male and 68% being upper extremity bites. Of the 74 cases where fasciotomy was discussed but not performed, 77% were male and 68% were upper extremity bites.	Compartment pressures were only recorded in 2 patients receiving fasciotomy and were elevated in both (36 and 70 mm Hg).	In patients receiving fasciotomy, a median of 4.5 vials of FabAV antivenom was preoperatively and 13.5 vials postoperatively, vs. a median of 18 vials in the group that did not receive a fasciotomy.	Length of stay was significantly longer in patients receiving fasciotomy (6.15 vs 3.45 days).

ACP, antivenin Crotalidae polyvalent; *FabAV*, Crotalidae polyvalent immune Fab; *mm Hg*, millimeters of mercury; *ED*, emergency department.

this regimen; additional dosing, when required, is typically directed toward hematotoxicity.[9,38]

The relatively low median ACP dose and somewhat high median FabAV dose noted in our review may reflect early discontinuation of ACP due to hypersensitivity reactions or fear of serum sickness, both of which are far less common with FabAV.[36] This pattern aligns with a National Poison Data System review that revealed increased clinician use of antivenom, especially following *Agkistrodon* genus envenomation, after the year 2000.[29] Alternately, this could indicate a premature decision to proceed with surgical management, prior to appropriate dosing of antivenom, during the ACP era. Expanding on this theme, analysis of the chart review studies (Table 4) revealed that the incidence of compartment syndrome in patients receiving ACP was 8.3% compared to 1.6% in patients receiving FabAV. While this decrease could reflect differences in the culprit snake species, or publication bias, as reports of VICS may no longer be considered novel or worthy of publication, the studies cited in Table 4 were generally comprehensive reviews of all snakebite patients evaluated by a center or physician group, not just the most interesting or severely envenomated patients. Therefore, it is plausible that the incidence of VICS may indeed be lower than prior to the introduction of FabAV, reflecting adequate control of tissue injury with appropriately dosed antivenom rather than fasciotomy.

Lastly, there was inconsistent reporting of data, particularly among the larger retrospective chart review studies. Laboratory abnormalities were also rarely reported but when they were, definitions of certain derangements such as coagulopathy and hypofibrinogenemia tended to differ between institutions precluding any analyses of or conclusions regarding these values. Although objective compartment pressure measurement prior to surgical management is the expert-recommended practice,[39,40] many studies did not record these values. Based on the data

available to us we could not determine whether these values were not obtained or simply not reported in articles.

LIMITATIONS

As we conducted a scoping review, we did not perform a formal assessment of the included articles' methodologies or risk of bias.[41] We had access only to published articles and did not have access to original datasets. Without access to identifying information, it is possible that some of the case reports were also included in the retrospective chart-review studies. Although we employed a systematic search strategy, it is possible that we did not cast a wide enough net and that some studies meeting inclusion criteria were missed. Additionally, we only searched for published research that included cases of diagnosed compartment syndrome and did not analyze the clinical characteristics of patients who were not diagnosed with compartment syndrome. While objective measurement of compartment pressures is recommended, compartment syndrome is ultimately a clinical diagnosis that may vary between physicians, particularly those from different specialties (eg, medical and surgical), and it is possible that the diagnosis may be over- or under-reported depending on the author of each paper.

Many data points were scarcely reported, including laboratory values, compartment pressures, and vials of antivenom administered. It was also sometimes difficult to discern the order of events, particularly the timing of evaluations and interventions including antivenom administration, measurement of compartment pressures, and fasciotomy. Also, none of the included cases used the recently introduced Crotalidae immune F(ab')2 antivenom, and we are unable to comment on its possible efficacy in VICS. These limitations highlight the importance of rigorous, prospective data collection and reporting through centralized, enduring databases such as the North American Snakebite Registry.

CONCLUSION

Compartment syndrome following North American snake envenomation is a rare disease process, and heterogeneity exists in its treatment despite global evidence discouraging fasciotomy. The seemingly increased tolerability of FabAV compared to ACP and the relatively positive short-term outcomes following suspected venom-induced compartment syndrome supports liberal antivenom usage, proceeding to fasciotomy only after careful clinical assessment with compartment pressure measurement and toxicology consult. Additionally, no amputations or deaths were reported in the reviewed articles. We illuminate several significant gaps in the literature, including the need for prospective studies assessing differences in long-term outcomes between treatment modalities, as well as the ideal timing of antivenom employment and subsequent fasciotomy.

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Bicarbonate and Serum Lab Markers as Predictors of Mortality in the Trauma Patient

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Introduction: Severe trauma-induced blood loss can lead to metabolic acidosis, shock, and death. Identification of abnormalities in the bicarbonate and serum markers may be seen before frank changes in vital signs in the hemorrhaging trauma patient, allowing for earlier lifesaving interventions. In this study the author aimed to evaluate the usefulness of serum bicarbonate and other lab markers as predictors of mortality in trauma patients within 30 days after injury.

Methods: This retrospective, propensity-matched cohort study used the TriNetX database, covering approximately 92 million patients from 55 healthcare organizations in the United States, including 3.8 million trauma patients in the last two decades. Trauma patients were included if they had lab measurements available the day of the event. The analysis focused on mortality within 30 days post-trauma in comparison to measured lab markers. Cohorts were formed based on ranges of bicarbonate, lactate, and base excess levels.

Results: Before propensity score matching, a total of 1,275,363 trauma patients with same-day bicarbonate, lactate, or base excess labs were identified. A significant difference in mortality was found across various serum bicarbonate lab ranges compared to the standard range of 21–27 milliequivalents per liter (mEq/L), post-propensity score matching. The relative risk of death was 6.806 for bicarbonate ≤5 mEq/L; 8.651 for 6–10; 6.746 for 11–15; 2.822 for 16–20; and 1.015 for bicarbonate ≥28. Serum lactate also displayed significant mortality outcomes when compared to a normal level of ≤2 millimoles per liter. Base excess showed similar significant correlation at different values compared to a normal base excess of −2 to 2 mEq/L.

Conclusion: This study, approximately 100 times larger than prior studies, associated lower bicarbonate levels with increased mortality in the trauma patient. While lactate and base excess offer prognostic value, lower bicarbonate values have a higher relative risk of death. The greater predictive value of bicarbonate and accessibility during resuscitations suggests that it may be the superior prognostic marker in trauma. [West J Emerg Med. 2024;25(4)661–667.]

INTRODUCTION

Trauma is a leading cause of mortality among individuals <45 years of age and the elderly.[1] Hemorrhage-induced hypovolemia can result in inadequate oxygen delivery to tissues, leading to metabolic acidosis. Early identification of shock in trauma patients is crucial as it can facilitate interventions that mitigate ongoing tissue damage and improve survival. Metabolic acidosis is a significant prognostic indicator for the severity of hemorrhage in trauma cases.[2]

Both vital signs and laboratory measurements provide essential guidance for improving the outcomes of resuscitation in critically ill patients.[3,4] Several studies have attempted to predict mortality in major trauma patients using acid-base measures.[4,5] Many of these studies have revealed that serum lactate is a reliable predictor of mortality in severely injured patients[4,6,7] and may even outperform arterial base deficit as a predictive tool.[8,9] Additionally, some smaller studies have indicated that both arterial and venous bicarbonate values can effectively predict mortality in critical care settings.[2,7,8] Serum bicarbonate and base deficit have been found to be approximately equivalent in their predictive capacity in other studies.[7] Given that lactic acid measurements and arterial base deficit may not be immediately available at the time of a patient's initial presentation,[9] further exploration of the predictive value of bicarbonate measures becomes critical.

The author's primary objective in this study was to assess the utility of serum bicarbonate and other acid-base markers in the evaluation of trauma patients who present to the emergency department. This evaluation was conducted using a comprehensive retrospective healthcare database. The specific aim was to determine the predictive value of serum bicarbonate and other laboratory markers in forecasting mortality in trauma patients up to 30 days after their injury.

Population Health Research Capsule

What do we already know about this issue?
Base excess and lactate levels are strong predictors of mortality in trauma patients. Bicarbonate levels, while related, are a more convenient and possibly superior alternative.

What was the research question?
Is serum bicarbonate level the superior prognostic marker in trauma?

What was the major finding of the study?
Lower bicarbonate values (ranges from 20 to ≤5) were strongly associated with increasing risks of mortality ($P < 0.001$).

How does this improve population health?
This study suggests that serum bicarbonate is superior to lactate and base excess in predicting trauma mortality.

METHODS

Design

This was a retrospective, propensity-matched cohort study using the TriNetX database. TriNetX is a large, global research network that provides de-identified medical information. The United States Collaborative Network in TriNetx represents approximately 92 million patients and 55 large healthcare organizations (HCO) within the US. The network accesses electronic health record information that includes diagnoses, procedures, medications, and laboratory data.[10] The TriNetX database includes admitted and discharged patients, as well as office visits, in contrast to the National Trauma Data Bank, which only includes admitted patients. For this analysis, the author included health records over a 20-year period from November 2, 2002–November 2, 2022.

Participants

Cohort exposure was defined as serum bicarbonate level at baseline (bicarbonate [moles/volume] in serum, plasma, or blood, TMX: 9021) with any trauma-related International Classification of Diseases, Rev 9 or 10 (ICD-9 or ICD-10 code (ICD10CM: T14; ICD-9 xxx). Approximately 90% of the bicarbonate values were obtained from venous samples, with the remaining 10% from arterial samples. Persons <18 years old or without lab values available from the day of event were excluded. The measured outcome was death within 30 days of the indexed traumatic event. At least 94% of the HCOs in the TriNetX database are linked to the US National Death Registries. Patients were excluded if the indexed traumatic event occurred greater than 20 years from date of analysis.

The control cohort was defined as all persons with trauma who had a normal bicarbonate level (21–27 milliequivalents per liter [mEq/L]) at baseline. There are variable definitions of the normal ranges for bicarbonate, lactate, and base excess (BE) in the literature; therefore, round cutoffs were chosen for interpretation purposes. The control cohort was compared to other cohorts with a varying range of bicarbonate values. These ranges of bicarbonate included ≤5, 6–10, 11–15, 16–20, and ≥28 mEq/L. For comparative effectiveness analysis, the author then repeated the analysis for lactic acid and BE as they have been studied in previous research. The control cohort was a normal lactic acid of ≤2.0

millimoles per liter (mmol/L). The control cohort was compared to lactic acid levels at varying ranges, at 2 mmol/L increments. For BE, our control group was a normal BE, between −2.0–2.0 mmol/L. The BE control group was matched against cohorts at varying ranges of BE, at 2 mmol/L increments. All BE measurements were obtained from arterial samples.

Statistical Analysis

To control for potential confounding demographic factors, the propensity matching tool in TriNetX was used. Using these matches, the researcher can estimate the difference between both groups without the influence of the confounding variables.[10]

The cohort was analyzed descriptively using univariate and bivariate frequencies with chi square and t-testing to assess differences. All eligible persons in the cohort were analyzed using both binary event estimation with risk ratios (RR), 95% confidence intervals (CI), and probability values. Using the TriNetX database, the author employed a 1:1 propensity match using logistic regression for age, gender, race, and ethnicity for maximum generalization to the US population. Greedy nearest-neighbor matching was used with a tolerance of 0.1 and difference between propensity scores ≤0.1. Comparisons were made between cohort before and after propensity matching. This study methodology has been previously validated in the TriNetX platform.[11] Statistical significance was set at a two-sided alpha <0.05. TriNetX provides data that has been de-identified; therefore, IRB review was not required for this study.[12] The final analysis was run on November 2, 2022.

RESULTS

There were 92,529,034 patients in the US Collaborative Network from 55 HCOs within the TriNetX database. There were a total of 3,892,737 patients with a traumatic mechanism, and 28,967,134 patients with serum bicarbonate lab values. A total of 1,275,363 trauma patients were identified before propensity matching, who had received a bicarbonate, lactate, or BE lab on the same day of a trauma incident (Table 1).

Table 1. Cohort demographics.

Demographics	Mean	±SD
Age	55	±22
	Percentage	
Gender		
Male	53%	
Female	45%	
Unknown	2%	
Ethnicity		
Not Hispanic or Latino	76%	
Hispanic or Latino	8%	
Unknown Ethnicity	16%	
Race		
White	68%	
Black	17%	
American Indian or Alaskan	1%	
Asian	1%	
Native Hawaiian or other Pacific Islander	0%	
Unknown race	12%	
Other race	1%	
Common comorbidities		
Hypertensive diseases	49%	
Other forms of heart diseases	42%	
Other anxiety disorders	30%	
Overweight and obesity	24%	
Diabetes mellitus	23%	

Bicarbonate

For the bicarbonate group, a total of 1,275,363 patients were identified before propensity matching: 814,895 patients with bicarbonate 21–27 mEq/L (control); 2,643 with bicarbonate ≤5 mEq/L; 5,949 with bicarbonate 6–10 mEq/L; 25,882 with bicarbonate 11–15 mEq/L; 160,886 with bicarbonate 16–20 mEq/L; and 265,108 with bicarbonate ≥28 mEq/L. After propensity matching, patients with bicarbonate 6–10 mEq/L had the highest risk of death when compared to control at 25.9% vs 3.0% (RR 8.65, 95% CI 7.432–10.070, $P < 0.001$), and decreased as bicarbonate decreased, with the lowest being ≥ 28 mEq/L at 3.5% vs 3.4% (RR: 1.015, 95% CI 0.986–1.044, $P = 0.32$) which was not statistically significant. When compared to control, patients with bicarbonate ≤5 mEq/L (19.8%, RR 6.8) had similar risks of mortality as 11–15 mEq/L (20.0%, RR 6.9). Mortality followed a similar trend before propensity matching (Table 2).

Lactate

For the lactate group, a total of 326,562 patients were identified before propensity matching: 195,457 patients with lactate ≤ 2 moles/volume (control); 86,989 with lactate 2.01–4 moles/volume; 23,120 with lactate 4.01–6 moles/volume 9,540 with lactate 6.01–8 moles/volume, and 11,456 with ≥8.01 moles/volume. After propensity matching, mortality was shown to increase as lactate levels increased. When compared to the control, the lowest RRs for mortality were within the 2.01–4 moles/volume range at 9.2% vs 5.1% (RR 1.814, 95% CI 1.751–1.880, $P < 0.001$), and reached the highest risks when ≥8.01 moles/volume at 31.7% vs 4.9% (RR 6.420, 95% CI 5.895–6.991, $P < 0.001$). Mortality followed a similar trend before propensity matching (Table 3).

Table 2. 30-day mortality when compared to normal serum bicarbonate (21–27 milliequivalents per liter).

	Before propensity score matching			After propensity score matching		
Serum bicarbonate (mEq/L)	**Mortality**	**RR (95% CI)**	***P*-value**	**Mortality**	**RR (95% CI)**	***P*-value**
≤5	19.8%	6.8 (6.3, 7.4)	<0.001	19.8%	6.8 (5.3, 8.6)	<0.001
21–27	2.9%			2.9%		
6–10	25.9%	8.9 (8.5, 9.4)	<0.001	25.9%	8.7 (7.4, 10.1)	<0.001
21–27	2.9%			3.0%		
11–15	20.0%	6.9 (6.7, 7.1)	<0.001	20.0%	6.7 (6.3, 7.3)	<0.001
21–27	2.9%			3.0%		
16–20	8.2%	2.8 (2.8, 2.9)	<0.001	8.2%	2.8 (2.7, 2.9)	<0.001
21–27	2.9%			2.9%		
≥28	3.5%	1.2 (1.2, 1.2)	<0.001	3.5%	1.0 (1.0, 1.0)	0.32
21–27	2.9%			3.4%		

CI, confidence interval; *RR*, risk ratio; *mEq/L*, milliequivalents per liter.

Table 3. 30-day mortality when compared to normal lactate (≤2 moles/volume) before propensity score matching.

	Before propensity score matching			After propensity score matching		
Lactate (moles/volume)	**Mortality**	**RR (95% CI)**	***P*-value**	**Mortality**	**RR (95% CI)**	***P*-value**
2.01 – 4	9.2%	1.8 (1.7, 1.8)	<0.001	9.2%	1.8 (1.8, 1.9)	<0.001
≤2	5.2%			5.1%		
4.01 – 6	17.4%	3.3 (3.2, 3.4)	<0.001	17.4%	3.5 (3.3, 3.4)	<0.001
≤2	5.2%			5.0%		
6.01 – 8	26.2%	5.0 (4.8, 5.2)	<0.001	26.2%	5.2 (4.7, 5.7)	<0.001
≤2	5.2%			5.0%		
≥8.01	31.7%	6.0 (5.8, 6.2)	<0.001	31.7%	6.4 (5.9, 7.0)	<0.001
≤2	5.2%			4.9%		

CI, confidence interval; *RR*, risk ratio.

Table 4. 30-day mortality when compared to normal base excess (−2 to 2 millimoles per liter).

	Before propensity score matching			After propensity score matching		
Base excess (mmol/L)	**Mortality**	**RR (95% CI)**	***P*-value**	**Mortality**	**RR (95% CI)**	***P*-value**
−4 to −2.01	6.3%	1.1 (0.9, 1.2)	0.30	6.3%	1.3 (1.1, 1.5)	0.001
−2 to 2	5.9%			4.8%		
−6 to −4.01	8.2%	1.4 (1.2, 1.6)	<0.001	8.2%	1.7 (1.4, 2.0)	<0.001
−2 to 2	5.9%			4.8%		
−8 to −6.01	11.6%	2.0 (1.7, 2.2)	<0.001	11.6%	2.5 (2.0, 3.0)	<0.001
−2 to 2	5.9%			4.7%		
−10 to −8.01	14.7%	2.5 (2.2, 2.9)	<0.001	14.7%	3.2 (2.5, 4.1)	<0.001
−2 to 2	5.9%			4.6%		
≤ −10.01	21.8%	3.7 (3.4, 4.1)	<0.001	21.8%	4.3 (3.6, 5.2)	<0.001
−2 to 2	5.9%			5.1%		

CI, confidence interval; *RR*, risk ratio; *mmol/L*, millimoles per liter.

Base Excess

For the BE group, a total of 34,717 patients were identified before propensity matching: 19,387 patients with BE −2 to2 mmol/L (control); 5,161 with BE −4 to −2.01 mmol/L; 3,525 with BE −6 to −4.01 mmol/L; 2,359 with BE −8 to −6.01 mmol/L; 1,585 with BE −10 to −8.01 mmol/L; and 2,700 with ≤ −10.01 mmol/L. After propensity matching, mortality was shown to increase as BE levels decreased.

When compared to the control range, BE −4 to −2.01 mmol/L showed the lowest mortality risks at 6.3% vs 4.8% (RR 1.308, 95% CI 1.113–1.538, $P = 0.001$), which increased to the highest point when BE was ≤ −10.01 mmol/L at 21.8% vs 5.1% (RR 4.309, 95% CI 3.601–5.156, $P < 0.001$). Mortality followed a similar trend before propensity matching, although RR was somewhat lower (Table 4).

DISCUSSION

In this study the author explored the possibility that serum bicarbonate was a more powerful predictor of mortality at 30 days following a presentation for trauma in the emergency department than lactate or BE. While arterial base deficit likewise demonstrated predictive utility, as in previous studies, this measure required an arterial blood sample.[4,8] This novel finding suggests serum bicarbonate can provide a rapid, easily obtainable assessment of a trauma patient at initial presentation. Lower serum bicarbonate levels were associated with a greater risk of mortality at 30 days than those with normal range bicarbonate levels. Many previous studies have demonstrated a high degree of correlation between serum lactate and serum bicarbonate in the setting of trauma,[8] but none have quantitatively defined that risk in such a dataset. This study is approximately 75 times larger than any other study in the literature that has looked at the relationship between serum bicarbonate levels and 30-day mortality in patients presenting for trauma.

Shane et al showed that a lower serum bicarbonate level is associated with a significant increase in mortality, which is in line with our study. Their study had a smaller sample population of 93.[4] In the Shane study, they proposed that the difference in bicarbonate levels in those who survived was significantly different vs those who expired, especially within 24 hours of trauma sustained. While they also suggested that the underdeveloped area of Uganda and small sample size may have played a role in the data collected, the venous levels of bicarbonate do show that those within a normal range had a statistically significant survival advantage.

Hussein et al performed a small study that showed elevated lactic acid levels were associated with an increase in mortality. They also demonstrated that base deficit could predict mortality in the trauma patient. Their study is somewhat limited as it had a total of 137 patients with only 36 being trauma patients.[8] Hussein et al also demonstrated an increase in mortality with significant differences in base deficit after 24 hours in patients in the surgical intensive care unit, although the initial base deficit was not significantly different. Furthermore, they proposed that the initial base deficit (vs the 24-hour reading) did not correlate with the lactate levels and was not a reliable predictor of mortality, except in the instance of deaths due to trauma (37 of 100 total patients) further showing that acid/base differences can be a predictor of mortality in trauma.[8]

FitzSullivan et al showed a correlation between arterial base deficit and serum bicarbonate and may be used interchangeably in trauma resuscitation. Their study had 3,102 patients with 50,311 matched laboratory datasets.[7] FitzSullivan et al set out to draw a linear correlation between arterial base deficit and serum bicarbonate (HCO_3) in relation to the severity of injury and death. Since the base deficit is acquired through arterial puncture, HCO_3 could provide for a substitute marker as it is normally drawn on admission. Their data showed the predictive ability of HCO_3 in trauma cases with regard to its comparison to base deficit in the same cases.[7] In addition, the bicarbonate outperformed lactic acid in predicting mortality. This further shows that bicarbonate can accurately and reliably be used as a predictor of mortality in trauma patients.

Mutschler et al performed a study with 16,305 patients from a trauma registry and showed a significant correlation between worsening base deficit and mortality.[13] Caputo et al found that lactate and base deficit correlated well with each other as indicators of the presence of occult shock in a group of 100 trauma patients.[14] Callaway et al found that lactate and base deficit were associated with increased mortality in a group of 588 elderly trauma patients.[2] These studies and others[2–4,7,8,13–21] that have evaluated lab markers have a smaller patient population compared to the current study of over three million trauma patients. Because of this, the author considers his study to hold more power and predictive ability in evaluating the serum lab markers in trauma.

While this propensity matched study provides powerful, generalizable estimates of mortality risk with bicarbonate levels, the author also performed non-matched estimations as a sensitivity analysis. These estimates did not meaningfully differ from those that were propensity matched, suggesting that confounders attributable to the demographics were not meaningful in this database.

LIMITATIONS

There are a number of limitations to this study. As with all observational studies in electronic databases, causal effects cannot be inferred. There are many reasons why a patient with trauma might present with metabolic acidosis, such as age, increased likelihood of comorbidities (ie, heart failure, chronic obstructive pulmonary disease [COPD], diabetes mellitus), underlying anemia, or later presentation to emergency services. Clinical details about each patient encounter such as Injury Severity Score (ISS), mechanism of injury, and other resuscitative variables that may affect mortality endpoint are not all captured in the database, which can limit predictability of lab results on mortality. The ISS scores, however, are typically available at discharge, and this study evaluated patients on arrival.

Propensity score matching was employed for demographics such as age, race, ethnicity, and gender; despite this, there could have been other variables that may

have affected outcomes that were not adjusted for in the study. Additionally, covariates chosen for propensity matching were consistent between groups. Variables that may affect one group (ie, renal failure/COPD might affect bicarb but not lactates) were not considered. Labs were gathered on the same date as initial trauma and not specifically the first lab value. There is also a possibility that patients can belong to multiple lab-testing groups. As this study contains a large number of trauma patients, these limitations should minimally affect the data.

CONCLUSION

Metabolic acidosis is an ominous sign in the setting of initial trauma presentation and has been long associated with increased mortality rates. In this retrospective, propensity-matched study of a large cohort of patients presenting to the emergency department with trauma, we found an increased mortality risk with lower serum venous bicarbonate measurements. The serum bicarbonate outperformed lactate and base excess with a higher risk ratio of death for lower bicarbonate values. Because of this greater prognostic value and availability, we recommend routine collection of serum bicarbonate rather than lactate or arterial base deficit at the point of presentation to guide management of the trauma patient.

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