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# *Western Journal of Emergency Medicine:*

## Integrating Emergency Care with Population Health

### Indexed in MEDLINE



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# *Western Journal* of *Emergency Medicine*:

Integrating Emergency Care with Population Health

Indexed in **MEDLINE, PubMed, and Clarivate Web of Science, Science Citation Index Expanded**





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

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## JOURNAL FOCUS

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

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*Western Journal of Emergency Medicine* (*West*JEM): Integrating Emergency Care with Population Health (*West*JEM) is the premier open-access Medline-indexed EM journal in the world. As the official journal of the California Chapter of the American College of Emergency Physicians (ACEP), American College of Osteopathic Emergency Physicians (ACOEP), and the California chapter division of the American Academy of Emergency Medicine (AAEM), the journal focuses on how emergency care affects health and health disparities in communities and populations. Additionally, *West*JEM focuses on how social conditions impact the composition of patients seeking care in emergency departments worldwide. *West*JEM is distributed electronically to 19,000 emergency medicine scholars and 2,800 in print. This includes 83 academic department of emergency medicine subscribers and 7 AAEM State Chapters.

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# Fall 2020 American College of Osteopathic Emergency Medicine (ACOEP) FOEM Competition Abstracts

The Foundation for Osteopathic Emergency Medicine (FOEM) promotes research and graduate medical education to advance the science of patient centric holistic emergency care consistent with the osteopathic philosophy. Each year the FOEM hosts a number of research competitions that are presented at the American College of Osteopathic Emergency Physicians (ACOEP) fall scientific assembly and spring seminar. The *Western Journal of Emergency Medicine* (*West*JEM) annually sponsors the research paper competition at the fall scientific assembly and is considered the premier research award at the competition. This *West*JEM issue highlights FOEM research presented at the 2020 ACOEP Fall Scientific Assembly.

John Ashurst, DO, MSc
Kingman Regional Medical Center

## 1 Frequency of Abnormal and Critical Laboratory Results in Patients Presenting to a Rural Community Emergency Department with Syncope

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**Introduction:** Broad panel laboratory testing with complete blood count (CBC) and basic metabolic profile could identify potentially reversible causes of syncope in older adults, including anemia, dehydration, and electrolyte abnormalities. Current guidelines note that routine laboratory testing in syncope is not useful. Recently, a large proportion of patients who presented to 11 large academic emergency departments (ED) with syncope had normal laboratory studies and rarely had critically abnormal labs. In this study, we sought to determine the proportion of abnormal and critical laboratory values obtained from CBC and complete metabolic profile (CMP) laboratory testing at a community ED.

**Methods:** We performed a retrospective chart review of laboratory values included in the CBC and CMP of patients with a complaint of syncope who presented to a 34-bed rural community ED with an annual volume of approximately 50,000 patients between June 1, 2019–May 31, 2020. We excluded patients if their presentation included the following: intoxication; medical or electrical intervention to restore consciousness; and a presumptive cause of loss of consciousness due to seizure, stroke, transient ischemic attack, myocardial infarction, or hypoglycemia. Reference ranges for lab values were determined by institutional laboratory protocols. We assessed groups' differences for abnormal lab presentation using analysis of variance.

**Results:** A total of 308 patients were included in the study with 18.5% presenting with one abnormal lab value, 51.6% presenting with between 2-4 abnormal lab values, and 20.5% with more than four abnormal lab values; 22.1% of the sample showed at least one critical lab value. Rates of presentation for abnormal lab values varied by age group (under 35 years = 82%; 36-65 years = 91.9%; over 65 years = 97.9%). The lab with the highest rate of abnormal values (47.1%) across all ages was glucose (106 milligrams per deciliter or higher), while the highest rate of critical values (20.1%) was chloride (107 milliequivalents per liter or higher). The three age groups in this study did not show a uniform presentation of the most common abnormal lab value (under 35 [27% white blood cell count(10.9^3/ul]; 36-65 [44.1% glucose]; over 65 [72.2% glucose]). Chloride was the most common critical value (under 35 [11%]; 36-65 [24.3%],;over 65 [24.7%]) across all age groups. Females presented with fewer abnormal lab values than males (P = 0.003), and age was positively correlated with the number of abnormal lab values (p<0.001).

**Conclusion:** Unlike previous research, we found that a large percentage of patients who present to a community ED with syncope will have abnormal laboratory values on CBC or CMP. However, further research should be conducted to determine whether these lab abnormalities alter clinical care.

## 2 Clinical Characteristics and Outcomes of Patients Admitted to an Intensive Care Unit for Severe COVID-19 Infection at a Community Emergency Department

C Rondon-Clavo, MD[1], K Caine, OMS-IV[2], A Santarelli, PhD[3], T Brinkerhoff, MD[1], E Bremmer, DO[1], J Ashurst, DO[1]/ [1]Kingman Regional Medical Center, Department of Emergency Medicine, Kingman, Arizona; [2]Midwestern University, College of Osteopathic Medicine, Glendale, Arizona; [3]Kingman Regional Medical Center, Department of Graduate Medical Education, Kingman, Arizona

**Introduction:** With the rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-COV-2) and resulting novel coronavirus disease 2019 (COVID-19), it is vital to recognize the early signs of poor clinical outcomes requiring a higher level of care and increased resource allocation. Initial data from Wuhan, China, and Italy suggest that abnormal liver enzymes, lymphocytopenia, and elevated C-reactive protein were predictive of transfer to the intensive care unit (ICU). The objective of the study was to determine whether specific clinical

and laboratory values could predict the need for ICU admission at a community hospital.

**Methods:** We conducted a retrospective chart review of all patients who required hospital admission between March 1, 2020–July 31, 2020 with confirmed SARS-CoV-2 infection by positive result on polymerase chain reaction testing of a nasopharyngeal sample and included them in our analysis. Patients were considered to have confirmed infection if the initial test result was positive, or if it was negative but repeat testing conducted up to 14 days following hospitalization was positive. All patients were reviewed by data abstractors to ensure that the admission was COVID-related and the patient was not an asymptomatic carrier. Data collected included patient demographics, comorbidities, initial emergency department (ED) laboratory tests, and outcomes. We compared groups along with risk factors using chi-square test and intake lab values with a t-test.

**Results:** A total of 125 patients with confirmed SARS-CoV-2 infection were admitted to the hospital during the study period with 25 being admitted to the ICU. The mean age of patients admitted to the ICU was 57.12 years old; 52% were female. Patients admitted to the ICU were American Indian or Alaskan Native (36%), White (48%), Hispanic (8%), and other (8%); 44% were affected by type 2 diabetes and 60% had hypertension. Patients were statistically more likely to be admitted to the ICU if they exhibited concomitant bacterial infection confirmed by a positive culture test (60%) ($P<0.001$) upon ED admission. Patients admitted to the ICU also showed higher intake lab values for glucose (204.3ICU vs 156.0Non-ICU; $P = 0.026$); bilirubin (1.4ICU vs 0.7Non-ICU; $P = 0.001$); aspartate transaminase (115.5ICU vs 51.0Non-ICU; $P<0.001$); alamine transaminase (56.2ICU vs 34.4Non-ICU; $P = 0.001$); alkaline phosphatase (106.9ICU vs 86.6Non-ICU; $P = 0.009$); procalcitonin (0.4ICU vs 0.2Non-ICU; $p=0.018$); and C-reactive protein (13.8ICU vs 9.6Non-ICU; $P = 0.001$), while showing lower intake lab values for calcium (8.1ICU vs 8.6Non-ICU; $P = 0.001$).

**Conclusion:** As in previous research we detected that patients admitted to the ICU following SARS-CoV-2 infection presented to the ED with abnormal liver function. Additionally, patients with a concurrent bacterial infection were more likely to require admittance to the ICU. However, the degree to which intake labs can predict ICU admission at a community hospital remains to be elucidated. Further research and greater sampling need to be conducted to determine whether intake lab values can be used to model ICU admissions for COVID-19 patients in the community setting.

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# Persistent and Widespread Pain Among Blacks Six Weeks after MVC: Emergency Department-based Cohort Study

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Editor note: The following paper deals with a potentially delicate subject, as it considers a medical condition specifically in the African American patient population. Note that a companion paper addressing the same medical condition and risk factors has already been published in White, non-Hispanic patients. The journal applauds these researchers for studying an underserved population subject to significant health inequities. This research is entirely consistent with the journal subtitle: Integrating Emergency Care with Population Health, and the newly established Section on Health Equity.

**Introduction:** Blacks in the United States experience greater persistent pain than non-Hispanic Whites across a range of medical conditions, but to our knowledge no longitudinal studies have examined the risk factors or incidence of persistent pain among Blacks experiencing common traumatic stress exposures such as after a motor vehicle collision (MVC). We evaluated the incidence and predictors of moderate to severe axial musculoskeletal pain (MSAP) and widespread pain six weeks after a MVC in a large cohort of Black adults presenting to the emergency department (ED) for care.

**Methods:** This prospective, multi-center, cohort study enrolled Black adults who presented to one of 13 EDs across the US within 24 hours of a MVC and were discharged home after their evaluation. Data were collected at the ED visit via patient interview and self-report surveys at six weeks after the ED visit via internet-based, self-report survey, or telephone interview. We assessed MSAP pain at ED visit and persistence at six weeks. Multivariable models examined factors associated with MSAP persistence at six weeks post-MVC.

**Results:** Among 787 participants, less than 1% reported no pain in the ED after their MVC, while 79.8 (95% confidence interval [CI], 77.1 – 82.2) reported MSAP and 28.3 (95% CI, 25.5 – 31.3) had widespread pain. At six weeks, 67% (95% CI, 64, 70%) had MSAP and 31% (95% CI, 28, 34%) had widespread pain. ED characteristics predicting MSAP at six weeks post-MVC (area under the curve = 0.74; 95% CI, 0.72, 0.74) were older age, peritraumatic dissociation, moderate to severe pain in the ED, feeling uncertain about recovery, and symptoms of depression.

**Conclusion:** These data indicate that Blacks presenting to the ED for evaluation after MVCs are at high risk for persistent and widespread musculoskeletal pain. Preventive interventions are needed to improve outcomes for this high-risk group. [West J Emerg Med. 2021;22(1)139–147.]

## INTRODUCTION

Millions of Americans present to emergency departments (ED) each year for care after motor vehicle collisions (MVC).[1] More than 90% do not have serious physical injury and are discharged home after their ED evaluation.[2] Most individuals who have pain develop it in the "axial" regions (back, neck or shoulders).[3] It is expected that most individuals will recover in the first several days after their accident, but a subset of individuals will develop persistent pain, which is pain that lasts beyond normal healing time.[4-6] In addition, some post-MVC pain may become widespread over the body, which might portend a risk for the development of fibromyalgia, a condition associated with disability.[3,4,7,8]

Persistent or widespread musculoskeletal pain develops in at least 20% of non-Hispanic White individuals who experience "minor" MVCs.[5,6] A recently published companion study of a cohort of non-Hispanic White, post-MVC ED patients, evaluated risk factors for persistent pain and demonstrated that initial severity of pain in the ED, neck pain, somatic symptoms (eg, nausea, dizziness), and pain catastrophizing were predictive of persistent pain at six weeks post-MVC.[4] Although these findings from non-Hispanic White, post-MVC ED patients are important, they might not generalize to other races and ethnicities. There are reasons to believe the incidence of persistent or widespread pain among other racial and ethnic groups could be higher. In particular, Blacks are a historically understudied population that has consistently been shown to experience an increased burden of pain in other settings.[9-18] Reasons for this increased burden of pain remain poorly understood. While some of this increased vulnerability to pain may be due to greater socioeconomic disadvantages,[19] data from other clinical conditions suggests that worse health outcomes such as chronic pain among Blacks are not likely to be accounted for by socioeconomic differences alone.[20]

To our knowledge the incidence of persistent pain in Blacks experiencing an MVC has never been reported. In this study, we evaluated the incidence and predictors of persistent moderate or severe axial pain (MSAP) and widespread pain six weeks after MVC in a large cohort of Blacks who presented to the ED for initial care. We hypothesized that rates of MSAP and widespread pain would be higher than those previously observed in another prospective MVC cohort of non-Hispanic White Americans,[4] and that pain, somatic symptoms, and acute psychological symptoms would be leading predictors of chronic pain outcomes.

*Population Health Research Capsule*

What do we already know about this issue?
*Persistent musculoskeletal pain develops in at least 20% of non-Hispanic Whites who experience minor injury after a motor vehicle collision (MVC).*

What was the research question?
*What are the incidence and predictors of persistent and widespread pain 6 weeks after MVC among Blacks who presented to the emergency department (ED)?*

What was the major finding of the study?
*Blacks presenting to the ED for evaluation after MVC are at high risk for persistent and widespread musculoskeletal pain.*

How does this improve population health?
*Pain and psychological comorbidities could be important targets to prevent the transition from acute to chronic pain in this high-risk population.*

## METHODS

### Study Design and Setting

This prospective, multicenter cohort study enrolled individuals (n = 930) who presented to the ED within 24 hours of an MVC and were discharged home after evaluation. Data were collected at the ED visit via patient interview and self-report surveys at six weeks after the ED visit via internet-based, self-report survey or telephone interview. Participants were enrolled at 13 EDs across the United States: University of Alabama at Birmingham Hospital (Birmingham, AL); University of Florida Health Jacksonville (Jacksonville, FL); Henry Ford Hospital (Detroit, MI); Sinai-Grace Hospital (Detroit, MI); Albert Einstein Medical Center (Philadelphia, PA); Detroit Receiving Hospital (Detroit, MI); St. Joseph Mercy Ann Arbor Hospital (Ypsilanti, MI), Medstar Washington Hospital Center (Washington DC); Boston Medical Center (Boston, MA); St. Joseph's Regional Medical Center (Paterson, NJ), Spectrum Health Butterworth Hospital (Grand Rapids, MI); William Beaumont Hospital (Royal Oak, MI); and Baystate Medical Center (Springfield, MA) between September 2012– September 2016. The study was approved by the institutional review boards at each of the study sites, and all participants provided written informed consent. This study conforms with STROBE reporting guidelines and further details of study methodology are described elsewhere.[21]

### Study Population

Patients 18–65 years old who presented to a study ED within 24 hours of an MVC and were unlikely to require hospitalization were screened for study eligibility. We excluded patients who were admitted to the hospital, had any fractures other than phalangeal fractures, had more than four lacerations requiring sutures or a single laceration more than 20 centimeters in length, or had intracranial or spinal injuries. Spinal injury

was defined by the presence of a fracture, dislocation, or new neurologic deficit. We selected these criteria to have a study sample with relative homogeneous injuries (eg, isolated musculoskeletal pain only) and to match enrollment criteria in a companion cohort of non-Hispanic White MVC patients.[4] Patients who were not alert and oriented also were excluded, but those with loss of consciousness and return to normal were eligible for the study. We also excluded pregnant patients, inmates, and patients unable to read and understand English. Enrollment was limited to individuals who self-identified as non-Hispanic Black or African-American, in order to focus on a traditionally understudied, high-risk population. This study was also one of two cohort studies evaluating pain pathogenesis after MVC. The first cohort was conducted in non-Hispanic White patients of self-identified European-American ancestry and the second cohort (presented in this investigation) recruited non-Hispanic Black patients of self-identified African ancestry. The rationale for separate cohorts was because the aims of the parent study included genetic analyses, and studies involving genetic analyses require a more homogeneous population.[22] The non-Hispanic White cohort closed first and results have been published elsewhere[4]; the analyses are therefore not included here to avoid duplicated publication.

**Baseline Measures**

During the ED interview, participants completed a structured research assistant (RA)-administered survey using web-based forms on laptop computers. This interview elicited information about pre-MVC characteristics and also contained a series of questions related to the patient's current and past pain and other pain-related characteristics. The initial interview captured sociodemographic characteristics (eg, age, gender, education level, income level, employment status, marital status), pre-MVC health status, medical history, medication history, and MVC characteristics (eg, position in the vehicle, speed, seatbelt use). Pain assessments included locations of pain, number of body regions with pain, severity of pain in each body region, and whether or not the pain was related to the MVC. Severity of pain was assessed using the "0–10" numerical rating scale (NRS), a valid assessment of pain in ED patients.[23] Additional pain-related symptoms were assessed using the following instruments: post-MVC psychological distress (per the Peritraumatic Distress Inventory[24]); dissociation (distorted memory, awareness, or perception of trauma characterized per Michigan Critical Events Perception Scale[25]); anger (per State-Trait Personality Inventory Form Y[26]); and somatic symptoms (per Pennebaker Inventory for Limbic Languidness[27]). Each of these assessments has been detailed elsewhere along with complete study methodology.[21] W abstracted data regarding participants' injuries from the ED health record. Baseline measures from these instruments were used as possible candidate predictors for the modeling of the outcomes of MSAP and widespread pain at six weeks post-MVC.

**Outcome Definitions: Moderate to Severe Axial Pain, Widespread Pain**

We selected the six-week follow-up time point for evaluation because chronic pain trajectories after MVC are generally established within 6-8 weeks of MVC,[19,28,29] and because this facilitated comparison with six-week outcomes of non-Hispanic European Americans reported in a previous study employing similar design and methods.[4] Pain location and severity at six-week follow-up were assessed using the same methods employed at baseline evaluation, except that if a participant reported pain in a body region they were also then asked whether the pain was due to the MVC. As in our previous studies, we used only pain reported as due to MVC in outcome analyses. MSAP was defined by a pain score of ≥ 4 in the neck, shoulder, or upper or lower back regions[30]; and widespread pain was defined by the presence of axial pain plus pain in one or more body regions above and below the waist and on the left and right side.[31]

**Analysis Plan**

We performed descriptive and inferential statistics and predictive modeling using Stata MP 13.0 statistical software (StataCorp, 2013, College Station, TX) and SAS 9.1.3 software (SAS Institute Inc., 2016, Cary, NC). Chi-squared tests were performed to evaluate for possible selection bias due to loss to follow-up by comparing the sociodemographic characteristics of those participants retained in the cohort at six weeks vs those who did not complete their six-week follow-up.

**Predictive Modeling**

We developed a list of candidate predictors based on substantive knowledge of factors likely to be associated with the development of persistent or widespread pain following a MVC.[3,4,7,8,29,32-35] These candidate predictors were sociodemographic characteristics, MVC characteristics, pain and somatic symptoms reported immediately after the MVC, and baseline psychological and cognitive characteristics. Log-binomial regression with a robust error estimation method was used to evaluate the association (risk ratio) between each candidate predictor and the primary outcomes of MSAP and widespread pain at week six post-MVC. If a candidate predictor was a scale from a survey instrument, we categorized the scores according to established cut-offs or divided them into tertiles based on the score. Forest plots were used to depict the estimates of the risk ratio and associated 95% confidence intervals (CI) for the primary outcomes and the candidate variables.

Predictors showing evidence of association with the outcomes in bivariate analyses were used as candidate predictors in multivariate analyses ($p<0.20$). We performed multivariate analyses using a least absolute shrinkage and selection operator (LASSO). LASSO (log-binomial) regression was chosen for the following reasons: 1) we aimed to replicate

the analyses performed in the companion cohort of non-Hispanic White MVC patients in order to draw qualitative comparisons between the two groups and LASSO was used in that analysis; 2) LASSO performs automatic variable selection; and 3) LASSO can result in selection of fewer variables than other techniques leading to a model that is easier to interpret. We used a 10-fold cross-validation approach to limit model over-fitting and selected the model with the lowest root-mean squared error as the final model.[36] The maximum number of predictors allowed in our predictive model was based on the "rule of 10s" (10 events per predictor).[37]

We tested model performance using the area under the receiver operating characteristic curve (ROC) and calibration plots. An area under the ROC curve (AUC) value of 0.70 or greater was considered to have a fair predictive ability.[38] Because different modeling techniques could yield a different set of predictors or perform differently in a given dataset, we conducted a sensitivity analysis using two other common modeling approaches: forward stepwise regression; and recursive partitioning (ie, classification and regression trees [CART]). Performance in these models was assessed using the AUC and compared to the results from the principal analyses.

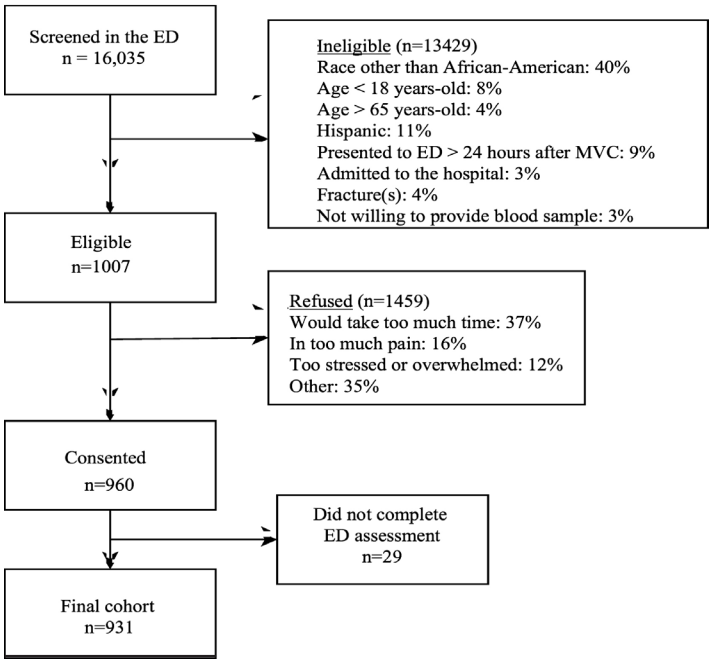


**Figure 1.** Screening, eligibility and enrollment of individuals. *ED,* emergency department; *MVC,* motor vehicle collision.

**Missing Data**

Predictors of the outcome were recorded with minimal missingness; over 95% of the baseline covariates had no more than 1% missing values, and the maximum proportion of missing for any baseline covariate was 6.4%. Missingness in the outcome variables also was minimal. We did not identify any systematic reasons for the missing values and therefore believe the data are missing completely at random; hence, the main analyses used only the complete cases. We performed a sensitivity analysis to evaluate the impact of missing data on our point estimates by repeating the primary analyses in a multiply imputed dataset. We performed multiple imputation of missing covariate data using chained equations and by specifying the conditional models for all of the variables with missing values.[39,4]

## RESULTS

**Participant Characteristics**

Figure 1 displays the screening, eligibility, and enrollment of the study cohort. Of the 931 individuals enrolled, six-week follow-up data were obtained in 84.6% of participants (n = 787); the remainder were lost to follow-up. The majority of participants were women (> 60%), the median age was 32 years (interquartile range [IQR] 24, 45), 99% of the participants had isolated musculoskeletal injuries (< 1% also had phalangeal fractures), and most participants had an annual household income of less than $40,000 per year. We obtained six-week follow-up data in 787/931 (85%) of participants; there were no significant differences in the sociodemographic characteristics of participants who did and did not follow-up. Table 1 provides an overview of participant characteristics.

**Participant Pain Characteristics in the ED**

Table 2 shows pain-related characteristics reported by participants during the ED visit and at the six-week follow-up. At baseline, less than 1% of participants reported no pain in the ED and nearly 95% reported pain scores ≥ 4; the median pain score was 7.5 (IQR 6, 9). Approximately 80% (95% CI, 77.1, 82.2%) of all participants reported moderate to severe pain in the back, neck, or shoulders (axial). The median number of body regions with pain was 5 (IQR 2, 8), and 28.3% (95% CI, 25.5, 31.3%) had widespread pain in the ED. Reported pain (pain scores and proportion of patients with moderate or severe pain) was decreased at the six-week follow-up, but participants reported more body areas with pain and more somatic symptoms.

**Participant Pain Characteristics at Six-week Post-MVC Follow-up**

Among the 787 participants completing the six-week follow-up, 78% reported moderate to severe pain in at least one body area. Figure 2 depicts the proportion of participants reporting moderate to severe pain by body region; 67% (95% CI, 63.9, 69.9%) reported moderate to severe pain in the axial region. Widespread pain was reported by 30.5% (95% CI, 27.7, 33.6%) of participants.

**Associations Between Demographic and Collision Characteristics and Adverse Pain Outcomes at Six-weeks Post-MVC Follow-up**

Sociodemographic characteristics associated with moderate to severe axial musculoskeletal pain and widespread pain at six weeks included increasing age, female gender, and not

**Table 1.** Characteristics of participants at enrollment and retained at six-week post-motor vehicle collision follow-up.

| | Baseline (n =931) | | 6-week follow-up (n=787) | | P-value |
|---|---|---|---|---|---|
| | n | % | n | % | p< |
| Age | | | | | 0.93 |
| 18-27 | 346 | 37.2 | 287 | 36.5 | |
| 28-41 | 292 | 31.4 | 253 | 32.2 | |
| 42-65 | 292 | 31.4 | 247 | 31.4 | |
| Gender | | | | | 0.33 |
| Male | 352 | 37.9 | 280 | 35.6 | |
| Female | 578 | 62.2 | 507 | 64.4 | |
| Education | | | | | 0.80 |
| High school or less | 370 | 40.1 | 305 | 39.0 | |
| Some college or trade school | 380 | 41.2 | 321 | 41.1 | |
| College/postgraduate degree | 173 | 18.7 | 156 | 20.0 | |
| Annual income | | | | | 0.99 |
| <$20,000 | 253 | 34.7 | 216 | 34.6 | |
| $20,000 to $40,000 | 222 | 30.5 | 189 | 30.2 | |
| $40,000 to $80,000 | 194 | 26.6 | 168 | 26.9 | |
| >$80,000 | 60 | 8.2 | 52 | 8.3 | |
| Works full time | | | | | |
| No | 426 | 46.0 | 358 | 45.6 | |
| Yes | 501 | 54.1 | 428 | 54.5 | |

**Table 2.** Motor vehicle collision-related (MVC) characteristics at baseline in the emergency department and six-week post-MVC follow-up.

| Characteristics | ED (Baseline) n=787 | 6 Weeks n=787 |
|---|---|---|
| Pain intensity (NRS) | 7.2 (7.1 – 7.4) | 6.0 (5.8 – 6.2) |
| Body regions with pain (n) | 5.9 (5.6 – 6.2) | 7.7 (7.3 – 8.1) |
| Overall pain (%) | | |
| No | 0.7 (0.3 – 1.5) | 8.4 (6.6 – 10.5) |
| Mild | 4.7 (3.5 – 6.3) | 13.1 (10.9 – 15.7) |
| Moderate | 27.2 (24.4 – 30.2) | 28.1 (25.1 – 31.4) |
| Severe | 67.4 (64.3 – 70.4) | 50.4 (46.9 – 53.9) |
| Moderate to severe axial pain (%) | | |
| Yes | 79.8 (77.1 – 82.2) | 67.0 (63.9 – 69.9) |
| Widespread pain (%) | 28.3 (25.5 – 31.3) | 30.5 (27.7 – 33.6) |
| Somatic symptoms (n) | 3.5 (3.5 – 3.7) | 9.1 (8.6 – 9.6) |

Continuous data are presented as means and 95% confidence intervals (CI); categorical data are displayed as proportions (%) and 95% CIs.
*ED,* emergency department; *NRS,* numerical rating scale.

working full time (Figure 3). Higher income was associated with being protective against widespread pain, and showed a trend toward being protective against moderate to severe axial musculoskeletal pain. Collision characteristics were generally not associated with adverse pain outcomes, with the exception that being in a vehicle traveling 41-90 miles per hour vs a stopped vehicle was associated with increased risk of both moderate to severe axial musculoskeletal pain and widespread pain. Severity of pain in the ED (Figure 4), the presence of catastrophizing symptoms (a negative, exaggerated response to actual or anticipated pain) and peritraumatic distress (Figure 5) were all associated with increased risk of both moderate to severe axial musculoskeletal pain and widespread pain. Contrary to our a priori belief, milder (vs severe) depressive symptoms and being certain of recovery were associated with an increased risk of MSAP in these bivariate analyses, but this did not hold true in the multivariable predictive model.

### Multivariable Predictive Models of Persistent Pain at Six Weeks Post-Motor Vehicle Collision Follow-up

In multivariable analyses, increasing age, history of significant depressive symptoms (yes/no), presence of peritraumatic dissociation (yes/no), moderate to severe pain in the ED (NRS ≥ 4), and being uncertain of recovery in the ED most efficiently predicted continued MSAP six weeks after MVC (AUC = 0.74; 95% CI, 0.72, 0.76). In multivariable analyses,

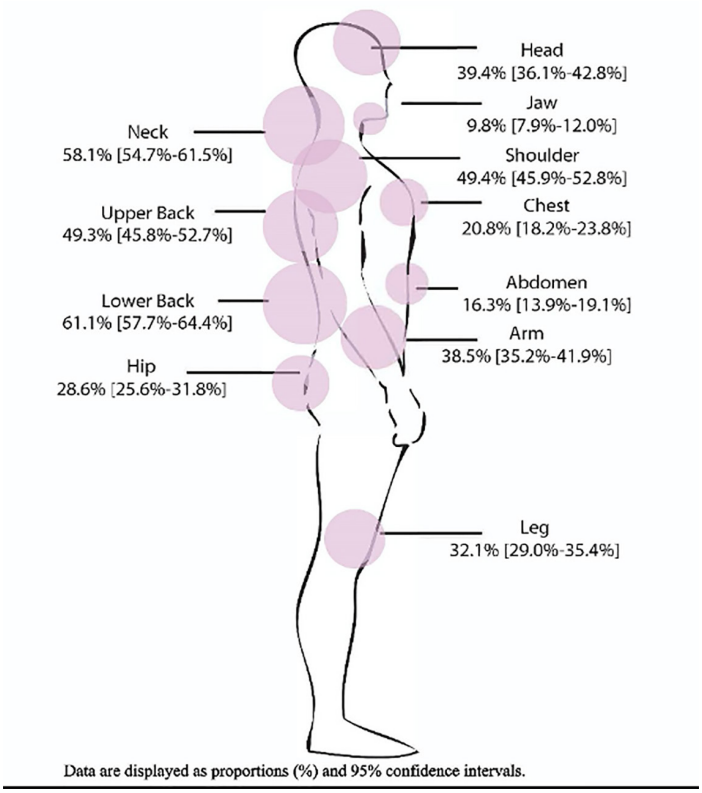


**Figure 2.** Patients reporting moderate to severe pain by body region.

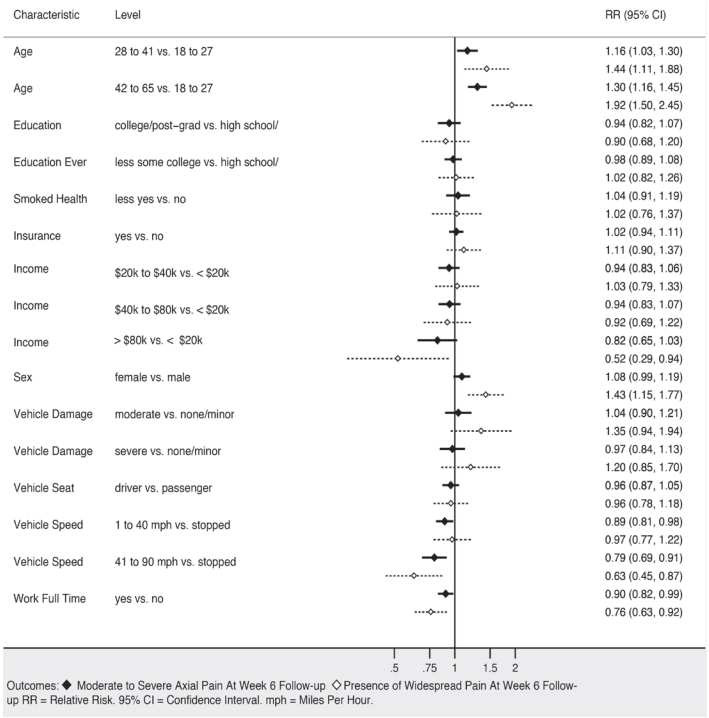


**Figure 3.** Sociodemographic and crash characteristics associated with persistent pain at six weeks post-motor vehicle collision (univariable).

widespread musculoskeletal pain six weeks after MVC was most efficiently predicted by increasing age, female gender, vehicle speed, history of pre-MVC neck pain, overall pain severity in the ED, widespread pain in the ED, presence of somatic symptoms, depressive symptom severity in the ED, and pain catastrophizing (AUC = 0.74; 95% CI, 0.72, 0.76).

In a sensitivity analysis that re-examined the main analyses using two alternative modeling approaches (recursive partitioning, CART, and forward stepwise regression) model performance was similar for each approach and for both outcomes (AUCs ranged from 0.71 to 0.76). In addition, all six models that we constructed in the primary and sensitivity analyses (3 approaches x 2 outcomes) displayed adequate calibration (generally linear line along the 45° axis ($R^2 > 0.9$)), indicating good agreement between the observed outcomes and predictions. For moderate to severe axial musculoskeletal pain, the three modeling approaches identified all of the predictors included in the LASSO model (increasing age, history of significant depressive symptoms (yes/no), presence of peritraumatic dissociation (yes/no), moderate to severe pain in the ED (NRS $\geq$ 4), and being uncertain of recovery in the ED). In addition, recursive partitioning also identified vehicle speed and number of somatic symptoms as predictors and stepwise regression for moderate to severe axial musculoskeletal pain also identified education as a predictor. All three approaches yielded the same minimum set of predictors for the development of widespread pain: increasing age, female gender, vehicle speed, history of pre-MVC neck pain, overall pain severity in the ED, widespread pain in the ED, presence of somatic symptoms, depressive symptom severity, and pain catastrophizing.

## DISCUSSION

Multiple lines of evidence would suggest that Blacks experience a greater burden of adverse outcomes than non-Hispanic White Americans (a much more commonly studied group), and yet this study constitutes the first large-scale, prospective study of pain outcomes among Blacks experiencing an MVC. Blacks continue to be underrepresented in many fields of clinical research. The greatest utility of this study is that it identifies the profound burden of acute and persistent musculoskeletal pain experienced by Blacks presenting to the ED after MVC. Nearly 95% of Blacks presenting to the ED after MVC, at 13 ED sites across the US, had acute moderate or severe musculoskeletal pain. Even more striking, nearly 80% of Blacks experienced persistent moderate or severe MVC-related pain and more than 3 in 10 individuals experienced MVC-related widespread pain at the six-week follow-up. These rates are over twice that previously reported in our large companion cohort of non-Hispanic White MVC patients that used similar methods,[4] and suggest an urgent need for further studies to understand chronic pain pathogenesis and improve outcomes in this high-risk group.

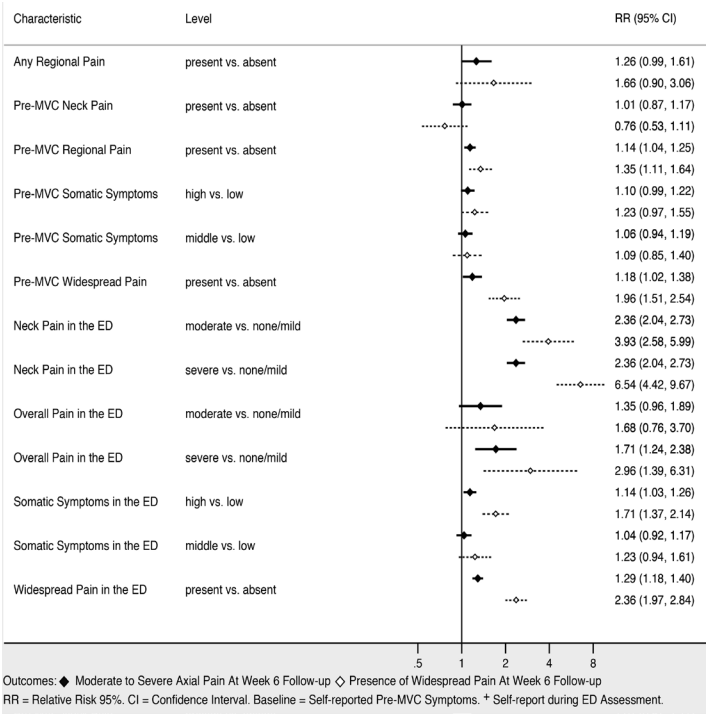


**Figure 4.** Pain and somatic symptoms associated with persistent pain at six weeks post-motor vehicle collision.

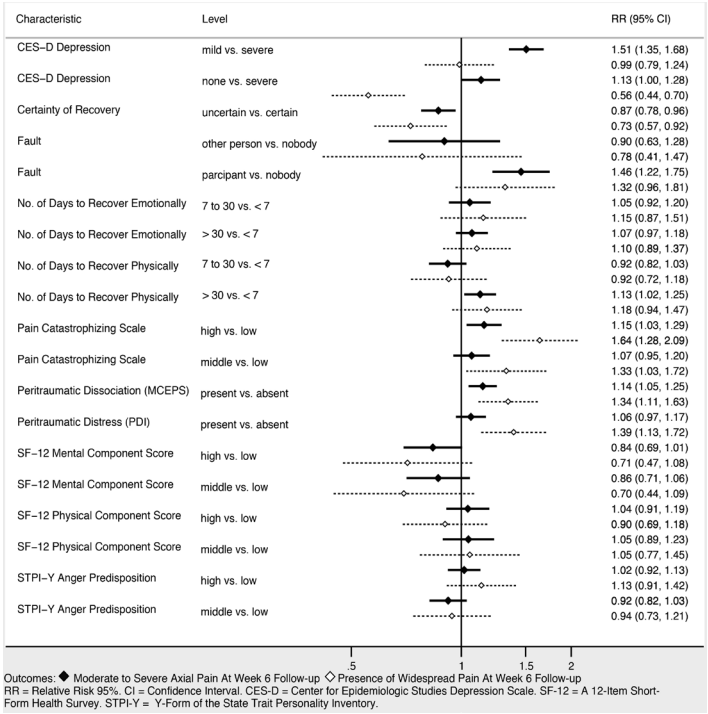


**Figure 5.** Psychological and cognitive characteristics associated with persistant pain at six weeks post-motor vehicle collision.

In other settings, Blacks have been found to have relatively increased sensitivity to experimentally induced pain as compared to non-Hispanic Whites.[9-18] Reasons for this increased burden of pain remain poorly understood. While some of this increased vulnerability to pain may be due to greater socioeconomic disadvantages, data from other clinical conditions suggests that worse health outcomes such as chronic pain among Blacks are not likely to be accounted for by socioeconomic differences alone.[41]

Increasing age, female gender, and the presence of pain catastrophizing and peri-traumatic distress were associated with persistent pain, unadjusted for other characteristics. More severe depressive symptoms reported in the ED were paradoxically associated with improved outcomes. The converse was true in the multivariable model, suggesting the presence of confounding in the unadjusted analyses. In multivariable predictive modeling, acute pain, increasing age, and a history of depression were predictive of both moderate to severe musculoskeletal pain and widespread pain six weeks after MVC in this Black cohort. This information may also be informative for subsequent interventions. For example, non-opioid medications such as serotonin-norepinephrine inhibitors have shown promise in the prevention and treatment of chronic pain, and their impact appears to be modified by the presence of depression: they are more effective in depressed patients.[42]

While a majority of patients in this study had ongoing MSAP at week 6, a smaller but still sizeable proportion of participants had widespread pain. Predictors of widespread pain were different than persistent moderate to severe pain in this cohort, suggesting that the pathogenesis of widespread pain is different. Gender, a history of chronic pain, having widespread pain, and somatic symptoms while in the ED were predictive of widespread pain at six weeks, but not MSAP. These predictors align with factors that are known to be associated with fibromyalgia, a condition associated with disability and impaired function.[43] In addition, different prevalence and predictors may indicate that different interventions are needed in the subgroup at risk for widespread pain compared to those who are not at risk for widespread pain development.

There were some similarities in predictors of pain in both the Black MVC patients in this study and the previously published non-Hispanic White cohort.[4] Specifically, the severity of acute pain in the ED was the only variable to appear in all models for both cohorts. Since acute pain appears to be a ubiquitous predictor in the development of persistent moderate to severe or widespread pain, it is important to further investigate what impacts the development of acute pain and whether interventions that improved acute pain also improve more distal pain outcomes. In a secondary analysis of these two MVC cohorts, Blacks were identified to have a higher burden of acute pain in the ED.[44] The differences in acute pain may be directly related to the development of persistent MSAP and widespread pain weeks later. It is unclear whether these differences persist over time (months or years later) and whether interventions that improve acute pain in the ED are capable of altering the transition to chronic

pain. An ongoing large and diverse cohort of trauma patients (n = 5000) recruited across the US is currently underway (the AURORA study) and may be able to answer some of these important remaining questions.[45]

## LIMITATIONS

This investigation has several limitations. Although conducting the study at multiple EDs likely increases its external validity, the findings might not be similar among those who declined study participation or whose sociodemographic characteristics were different than those who participated in the study (eg, low health literacy). It is unknown, however, whether the study findings are externally valid to other clinical settings (eg, primary care) and other racial or ethnic groups. In addition, the study relies on self-report and multiple questionnaires; self-reported outcomes are subject to reporting bias. Pain is subjective as are many of the other measurements, so no objective measures are possible for much of the data collected. However, the instruments used are commonly employed in several other studies, which permit comparisons to other settings. We performed multiple unadjusted bivariate associations. This was meant to be exploratory in nature and provide formative data for other work; multiple associations should be interpreted cautiously.

In addition, understanding factors that predict the outcome does not imply a causal relationship and should be interpreted cautiously. In addition, because the outcomes were common, a predictive model has limited utility as a risk-stratification tool in clinical practice. Rather, the predictive model provides insight into the risk of pain development and might provide substantive information for future interventions aimed at reducing the transition to chronic pain. Model performance and metrics of performance were not improved with other modeling techniques. This observation suggests that additional improvements in model performance might require other unmeasured predictors (eg, genetics) or using other techniques such as machine-based algorithms with the ability to "learn" complex interactions between predictors.

## CONCLUSION

In a large study of Black ED patients receiving care after motor vehicle collisions, moderate to severe axial musculoskeletal pain was the norm and widespread pain was also common six weeks later. The incidence rates of both types of pain were higher than has been reported in a cohort of non-Hispanic White patients with a similar trauma exposure. This finding suggests that Blacks are at higher risk than non-Hispanic White patients regarding the transition to chronic pain and that further research in this population is needed. Some factors, such as age, vehicle speed, and history of chronic pain help to predict risk, but are clearly not targets for intervention. Conversely, pain and certain psychological characteristics (eg, depression) could be important in future interventions aimed at targeting the transition from acute to chronic pain.

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# Emergency Department Patients Who Leave Before Treatment Is Complete

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**Introduction:** Emergency department (ED) patients who leave before treatment is complete (LBTC) represent medicolegal risk and lost revenue. We sought to examine LBTC return visits characteristics and potential revenue effects for a large healthcare system.

**Methods:** This retrospective, multicenter study examined all encounters from January 1–December 31, 2019 at 18 EDs. The LBTC patients were divided into left without being seen (LWBS), defined as leaving prior to completed medical screening exam (MSE), and left subsequent to being seen (LSBS), defined as leaving after MSE was complete but before disposition. We recorded 30-day returns by facility type including median return hours, admission rate, and return to index ED. Expected realization rate and potential charges were calculated for each patient visit.

**Results:** During the study period 626,548 ED visits occurred; 20,158 (3.2%) LBTC index encounters occurred, and 6745 (33.5%) returned within 30 days. The majority (41.7%) returned in <24 hours with 76.1% returning in 10 days and 66.4% returning to index ED. Median return time was 43.3 hours, and 23.2% were admitted. Urban community EDs had the highest 30-day return rate (37.8%, 95% confidence interval, 36.41-39.1). Patients categorized as LSBS had longer median return hours (66.0) and higher admission rates (29.8%) than the LWBS cohort. There was a net potential realization rate of $9.5 million to the healthcare system.

**Conclusion:** In our system, LSBS patients had longer return times and higher admission rates than LWBS patients. There was significant potential financial impact for the system. Further studies should examine how healthcare systems can reduce risk and financial impacts of LBTC patients. [West J Emerg Med. 2021;22(2)148-155.]

## INTRODUCTION

Emergency department (ED) crowding has major implications for a healthcare system. One population of patients directly affected by crowding are those who arrive to the ED for evaluation and ultimately leave before treatment is complete (LBTC). Losing these patients prior to visit completion can result in harm for the patient and missed revenue opportunities for the healthcare system. Many systems use LBTC or the vernacular left without being seen (LWBS) as a marker for ED performance. The Hospital Outpatient Quality Reporting Program through the Centers for Medicare and Medicaid Services (CMS) collects pay for quality data, which requires hospitals to submit information on certain metrics to measure patient care outcomes.[1]

"Timely and effective care-Emergency Department (ED) throughput," OP-22, a metric that tracks LWBS, is

one of many ED metrics collected to determine quality.[2] The national average LWBS is 2%, and many hospitals strive to have an LWBS at or below the national average. The Fourth Emergency Department Benchmarking Alliance (EDBA) Summit published the most updated definitions of key language and vocabulary that should be used when defining key terminology for regulatory definitions. We have chosen to use the standardized definitions from the EDBA consensus statement published in 2020.[3] In the most current EDBA definitions, the LBTC metric includes patients who LWBS, left against medical advice (AMA), and eloped. In their current definitions, LWBS is defined as "the proportion of patients who leave the ED before initiation of the medical screening exam (MSE)."

The EDBA additionally defines the group of AMA and eloped patients together as left subsequent to being seen (LSBS), as follows: "the proportion of patients who leave the ED after evaluation by licensed care provider qualified to complete a medical screening examination and initiation treatment but before the disposition decision by the care provider." For simplicity in separating these two groups, we will use the terminology LWBS as patients who left without MSE completed, and LSBS as patients who had an MSE completed and ultimately eloped or left AMA.

Prior studies have characterized the LWBS population to determine the acuity of complaints, risk of missed diagnosis, return patterns, and admission rates. One recent study in a multi-hospital academic health system demonstrated that LWBS patients tended to have lower-acuity complaints and increased ED utilization.[4] Another study in an academic pediatric ED showed that LWBS patients with higher acuity level and increased number of ED visits had high rates of admission on return visits.[5] LWBS rates have been shown to increase during the night shift and when EDs are on diversion status.[6] When examining return characteristics of LWBS patients, many studies have demonstrated that this patient population seeks additional medical care after leaving the ED.[7-9]

As a method of reducing risk, many EDs have successfully implemented programs to reduce LWBS such as creating door-to-room time goals.[10-12] One study focused on Emergency Severity Index (ESI) level 2, a higher risk group of patients, and implemented a direct bedding protocol to reduce LWBS and found that odds of LWBS were lower after intervention.[13] Another study examined optimal door-to-room times to minimize LWBS and found that times less than 20 minutes and more than 35 minutes were associated with significant differences in LBTC rates.[10]

Preventing LBTC patients from leaving is also a financial opportunity for healthcare systems. One study examined front-end practices by placing a physician in triage to study effects on LWBS and financial implications. Even with increased operating costs secondary to placing a physician in triage, the study still found a total earnings and cash flow benefit with a reduction in LWBS.[14]

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency department patients who leave before treatment is complete (LBTC) represent medicolegal risk and lost revenue.*

What was the research question?
*We sought to examine LBTC return visits characteristics and potential revenue effects for a large healthcare system during 2019.*

What was the major finding of the study?
*Of the LBTC visits examined, 41.7% returned in <24 hours and 23.2% were admitted with a net potential realization rate of $9.5 million.*

How does this improve population health?
*Further studies should examine how healthcare systems can reduce the medical risk and financial impacts of this high-risk population.*

The goal of our study was to examine all patients who LBTC in a large integrated health system over a one-year period. We further defined LBTC as patients who left before MSE was complete (LWBS) and patients who left after MSE was complete but before disposition (LSBS), as per EDBA definitions. We sought to determine overall 30-day return rate within our own system, whether patients returned to the index ED where they presented on their first visit, median time to return, and admission rate. We studied factors that could contribute to differences such as ED facility type and whether patients were primarily LWBS or LSBS. Additionally, we explored the potential revenue effects on professional and technical billing fees from patients categorized as LBTC.

## METHODS

### Study Design

This was a retrospective multicenter study involving 18 EDs across a large, integrated healthcare system. This study was approved by the institutional review board of the healthcare system as a quality improvement project.

### Setting

All EDs were included in the analysis. The EDs in the healthcare system were comprised of two urban academic teaching EDs, four urban community EDs, four suburban community EDs, six free-standing EDs (FSED), and two pediatric EDs (PED), with a total annual census of 626,548 patient encounters during the time period of the study. All sites used the same electronic health record (EHR) system

allowing for common accessibility and data acquisition across the system.

**Intervention and Data Collection**

We included all ED visits in the analysis. Data were collected on all patients within the system who were categorized as LBTC – defined in our EHR as any patients with the following dispositions from January 1, 20191– December 31, 2019: LWBS; eloped; or AMA. To better describe the group that eloped and AMA based on using the most recent EDBA definitions, we characterized this group as LSBS. A visit was excluded if the patient had been deemed "Arrived in Error." We collected data for the following: return rate within 30 days within the system; time elapsed from initial presentation calculated in median hours; return rate to index ED; and admission rate to the hospital.

Time elapsed from initial presentation was split into four categories: 0-23 hours; 24-47 hours; 2-10 days; and 11-30 days. Additionally, we then divided the data by facility type and whether patients were categorized as LWBS or LSBS. Additional markers collected on patient visits included whether patients returned to the index ED or to a different ED in the system, as well as admission rate to the hospital upon return. We collected data for the system as a whole, which we then examined by ED facility type. Facility types were defined as urban academic, urban community, suburban community, free-standing ED, and dedicated PED.

We collected financial data on all patients who met criteria for LWBS and LSBS populations and created a model to determine potential lost revenue. The revenue calculations were modeled as if the patient had hypothetically never left the ED. To model the financial impacts we collected patient acuity information. Acuity was based on the Emergency Severity Index (ESI) triage tool and recorded as an ESI level 1-5.[15] The average acuity-specific charges during the study time period were also collected for each of the individual EDs in the system. Data from the EHR allowed for determination of patient insurance information, and data from the healthcare system's administrative financial reporting system provided payor-specific contractual adjustment rates and site-specific realization rates as defined by "professional" charges, or physician fees, and "technical" charges, or facility fees. Average realization rate was defined as the insurance payment divided by total charges.

If there was no acuity recorded for an encounter, the visit was defaulted to ESI-4 and assigned fees accordingly. The encounters were defaulted to ESI-4 as we did not want to overestimate the financial impact of these encounters. All LBTC visits with either missing or "suboptimal" charges were included in the model. We defined suboptimal charges as either a professional or technical charge existing on the encounter that was less than the site-specific, acuity-specific average charge. Because insurance information could be collected as well, the average realization rate was calculated for each patient encounter during the study time period.

Two other processes were modeled to ensure the LWBS population was accounted for in the financial data as these patients did not complete an MSE. First, for patients who were charged less than the site-specific average during the study time period for their corresponding acuity level, we calculated the difference between the average and their own professional and technical fees charged. Second, once LWBS patients identified with suboptimal charges or no charges had undergone the process above, we then applied the average site-specific realization rate to professional and technical fees, as insurance carriers were recorded for all patients. We did not calculate actual realization rate but instead calculated an expected realization, based on applying actual insurance information to modeled charge details. We used this hypothetical model to project potential reimbursements. We did not include bad debt or charity care but did include co-pays into the model. We did not examine whether patients returned and, therefore, did not subtract this payment from our initial projected payment.

We conducted statistical analyses using SAS software (SAS Institute, Inc., Cary, NC). Descriptive univariate and quantile statistics were computed, with confidence intervals (CI) for the proportion of admits and returns, as well as medians and means for the other variables studied (return hours, etc). A significance level of 0.05 was used for all tests.

**RESULTS**

During the study period, the hospital system had a total of 626,548 ED visits. There were 20,158 index encounters LBTC on this initial ED visit (3.2%). Of these index encounters, 2753 (13.7%) had no acuity recorded and 62% of this group did not return within 30 days. Within 30 days of their initial visit, 33% (6745) of these patients returned to an ED in the system. The majority of these patients (41.7%) returned in less than 24 hours; 10.6% of returns occurred within 24-47 hours; 23.8% within 2-10 days; and 23.8% within 11-30 days, (Figure 1). Overall, 5138 (76.2%) patients returned in the first 10 days of the index encounter. The median return hours for all 30-day return patients was 43.3 hours (95% CI, 41.5 - 45.3), while 66.4% (95% CI, 65.2 - 67.5) returned to the index ED with a median return of 59.8 hours (95% CI, 50.9 - 65.6) and 33.6% (95% CI, 32.5 - 34.8) returned to a different ED within the healthcare system with a median return of 20.5 hours (95% CI, 18.2 - 22.8). The admission rate for all patients categorized as LBTC was 23.2% (95% CI, 22.2- 24.2) compared to the healthcare system admission rate, which was 25.4%, (Table 1).

When examining the disposition by facility type, the largest percentage of the total system 30-day returns originated from our two urban academic sites. When examining percentage of returns by index ED category, 34% (95% CI, 33.0 – 35.2) of urban academic LBTC encounters returned within 30 days, representing 37.3% of the healthcare system's total 30-day LBTC returns. Free-standing EDs and

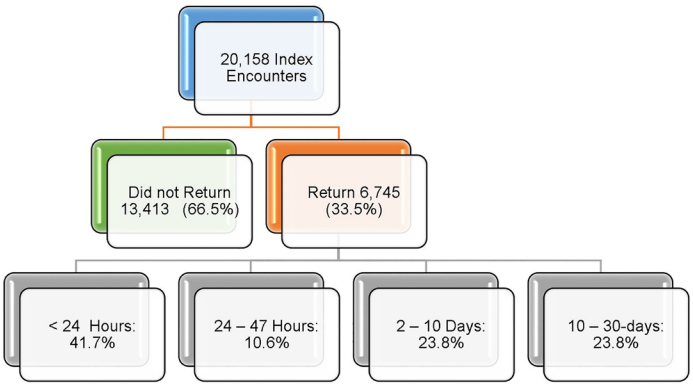


**Figure 1.** Descriptive characteristics of patients who left before treatment was completed.

dedicated PEDs had the lowest number of 30-day returns at 28.5% (95% CI, 26.6 – 30.4) and 21.6% (95% CI, 18.5 – 24.7), respectively, representing 8.9% and 2.2% of the system's total 30-day returns. Urban and suburban community hospitals had 37.8% (95% CI, 36.4 - 39.1) and 32.0% (95% CI, 30.7 - 33.3), respectively, at 30 days, representing 27.8% and 23.8% of the system's total 30-day returns.

We found a significant difference when comparing median time of return for FSED and urban community; when analyzing the difference between median return hours, the urban community and urban academic comparisons were significant at the 0.05 level. All hospital types had the highest return rate in the first 24 hours. When examining admission rates, we found that suburban community and FSEDs had the highest rates at 28.7% (95% CI, 26.5 - 30.9) and 27.1% (95% CI, 23.5 - 30.6), respectively. Pediatric EDs had the lowest admission rate at 7.33% (95% CI, 03.1 - 11.6). However, when compared to the admission rate for the dedicated PEDs in the system (10.4%) it was not significantly lower. When examining by facility type, most patients returned to the index ED with the exception of FSED patients who only returned back to the index ED 47.7% (95% CI, 43.7 - 51.7) of the time (Table 2).

When examining the differences in patients categorized as LWBS vs LSBS, we found that 35.6% (95% CI, 34.6 - 36.7) returned within 30 days with a median return hours of 23.9 (95% CI, 21.9 - 27.9), and admission rate of 14.5% (95% CI, 13.3 - 15.8), compared to 32.0% (95% CI, 31.1 - 32.8) of LSBS who returned within 30 days with a median return hours of 66.0 (95% CI, 59.3 - 68.7) and admission rate was 29.8% (95% CI, 28.4 - 31.3). In both categories, the percentage who returned to the index ED was 64.0% (95% CI, 62.3 - 65.7) and 68.2% (95% CI, 66.7 - 69.7), respectively (Table 2). When comparing the differences between patients categorized as LWBS to LSBS, there were no significant differences that indicated a particular type of ED facility had effects on 30-day return encounters, hours between visits, admission rate, or return to index ED. Overall results for time elapsed since index ED visit, LBTC categorization, and admissions rates are shown in Table 3.

Across the system, the potential net revenue annualized from LWBS and LSBS approximated 9.5 million dollars (Table 4). The annualized potential net professional revenue was two million dollars, and the potential net technical revenue equaled 7.5 million dollars. When comparing facility type, urban academic EDs had the most potential revenue for professional and technical fees (Table 4). When comparing disposition category by examining the potential net revenue from patients who left from the ED waiting room before MSE was complete (LWBS) vs patients who left after MSE was complete either from the waiting room or from the ED (LSBS), LWBS patients amounted to a significant unrealized potential net professional and technical charge of 5.6 million dollars (Table 5).

## DISCUSSION

Patients who leave the ED prior to completion of their visit represent potential medicolegal risk as well as lost revenue for the healthcare system. Examining when these patients leave during the course of the emergency visit is important so that hospital systems can create initiatives to ensure that patients

**Table 1.** Left before treatment complete (return encounter characteristics for the healthcare system and based on hospital type).

| | System total | Urban academic | Urban community | Suburban community | FSED | PEDs |
|---|---|---|---|---|---|---|
| LBTC encounters N | 20,158 (3.2%) | 7,364 (5.9%) | 4,966 (3.1%) | 5,019 (2.7%) | 2,114 (1.9%) | 695 (1.5%) |
| Overall 30-day LBTC returns N (%) | 6,745 (33.5%) | 2,513 (34.1%) | 1,875 (37.8%) | 1,605 (32.0%) | 602 (28.5%) | 150 (21.6%) |
| Median return (Hours) | 43.1 | 41.0 | 53.7 | 40.0 | 37.2 | 33.2 |
| 30 day admit rate N (%) | 1,565 (23.2%) | 565 (22.5%) | 365 (19.5%) | 461 (28.7%) | 163 (27.1%) | 11 (7.3%) |
| 30-day returns to index ED N (%) | 4,476 (66.4%) | 1,626 (64.7%) | 1,382 (73.7%) | 1,082 (67.4%) | 287 (47.7%) | 99 (66.0%) |

*LBTC*, left before treatment complete; *FSED*, free-standing emergency department; *PED*, pediatrics; *ED*, emergency department.

complete their visits and receive emergency care. Our study was unique in that we attempted to characterize not only time-to-return hours and admission rate, but we also examined factors that may play a role in return practices of these patients. To achieve this goal and determine whether there were significant differences, we examined all LWBS patients and LSBS patients. Our study found that patients who left after being roomed in the ED had a longer median hour to return albeit with significantly higher admission rates. There seemed to be no difference between the two groups when examining the percentage return rate, return to the index ED, or facility type to which they initially presented.

To our knowledge, this is the first study to examine and differentiate the entire population of patients that leaves the ED. Previous studies have examined LWBS patients in an effort to determine medical complexity and risk to the healthcare system but only examined the group that leaves before being seen by a physician. Li et al found that this group of patients likely had lower acuity chief complaints and higher return rates, with an overall lower admission rate.[3] While previously lumped together in this broad category, this group is not homogeneous. Our study also included the eloped and AMA population, as well, to clearly delineate the characteristic differences between these two patient groups

**Table 2.** Comparing patients who left without being seen vs patients who left subsequent to being seen.

| | LWBS | LSBS | System total |
|---|---|---|---|
| LBTC encounters N | 8,206 | 11,952 | 20,158 |
| Overall 30-day LBTC returns N (%) | 2,924 (35.6%) | 3,821 (32.0%) | 6,745 (33.5%) |
| Median return (Hours) | 23.7 | 66.0 | 43.1 |
| 30-day admit rate N (%) | 425 (14.5%) | 1,140 (29.8%) | 1,565 (23.2%) |
| 30-day returns to index ED N (%) | 1,871 (64.0%) | 2,605 (68.2%) | 4,476 (66.4%) |

*LWBS*, left without being seen; *LSBS*, left subsequent to being seen; *LBTC*, left before treatment complete; *ED*, emergency department.

**Table 3.** Comparing dispositions when patients left without being seen vs. who left subsequent to being seen.

| | 0 - 23 Hours | 24 - 48 Hours | 2 - 10 Days | 10 - 30 days | Total 30-day returns |
|---|---|---|---|---|---|
| Index ED disposition: all left before treatment complete | | | | | |
| Overall | | | | | |
| Return encounters | 2,815 | 716 | 1,607 | 1,607 | 6,745 |
| Return encounters: admitted | 680 | 153 | 368 | 364 | 1,565 |
| % Admitted (of total returns) | 24.2% | 21.4% | 22.9% | 22.7% | 23.2% |
| Hours between visits (average) | 7.7 | 37.1 | 125.0 | 453.7 | 144.9 |
| Hours between visits (median) | 5.2 | 38.5 | 116.1 | 445.6 | 43.3 |
| Index ED disposition: LWBS | | | | | |
| Overall | | | | | |
| Return encounters | 1,465 | 286 | 601 | 572 | 2,924 |
| Return encounters: admitted | 216 | 36 | 80 | 93 | 425 |
| % Admitted (of total returns) | 14.7% | 12.6% | 13.3% | 16.3% | 14.5% |
| Hours between visits (average) | 6.7 | 36.8 | 126.2 | 455.4 | 121.8 |
| Hours between visits (median) | 2.8 | 37.9 | 116.9 | 452.4 | 23.9 |
| Index ED disposition: LSBS | | | | | |
| Overall | | | | | |
| Return encounters | 1,350 | 430 | 1,006 | 1,035 | 3,821 |
| Return encounters: admitted | 464 | 117 | 288 | 271 | 1,140 |
| % Admitted (of total returns) | 34.4% | 27.2% | 28.6% | 26.2% | 29.8% |
| Hours between visits (average) | 8.9 | 37.3 | 124.2 | 452.8 | 162.7 |
| Hours between visits (median) | 7.3 | 38.8 | 115.6 | 441.8 | 66.0 |

*LWBS*, left without being seen; *LSBS*, left subsequent to being seen; *LBTC*, left before treatment complete; *ED*, emergency department.

who left from the waiting room before MSE was complete and those patients who left the ED after MSE was complete.

This data gives the healthcare system a better representation of true risk between these two patient groups. It helps characterize whether there are specific differences among these populations and whether targeted interventions could be applied for each population. One could reason that LSBS patients may have higher acuity issues, as they stayed long enough to finish the MSE and potentially be seen in the main ED in the first place. Additionally, once the population of LSBS left, this group may have had more of a workup and been given some insight into return precautions, causing longer median return times for their second visit.

Another unique aspect of our study was its examination of ED facility type to determine whether significant differences existed among the patient groups. We found that only FSEDs and PEDs had significantly lower rates of return. Additionally, FSEDs had fewer patients return back to the index ED when compared to other facility types. It is possible that this group of patients may have re-presented to an alternative ED in the system that had inpatient capabilities with the thought that they might need to be admitted. All facilities had the majority of their returns in the first 24 hours. Admission rates were similar across different ED facility types with the exception of the dedicated PEDs, which had comparable admission rates to their lower typical specialty-population admission rate. Future studies should examine how each of these LBTC patient groups individually present at certain types of EDs to determine whether targeted interventions by ED type could facilitate a drop in LBTC numbers.

When we examined the LBTC group as a whole, our study found many of these patients returned to the same ED within 24 hours and had admission rates similar to our typical hospital admission rates (23.2% vs 25.4%). A prior study examined admission rates for this vulnerable population and found lower admission rates (11.5%) than their overall ED average, likely based on the findings that these patients more frequently presented with lower acuity complaints.[3] However, when further categorized into LWBS and LSBS, admission rates differed. Importantly, despite generally lower acuity, patients categorized as LWBS had an admission rate of 14.5% on return visit. Differentiating the LWBS from the LSBS population might allow more directed or targeted interventions for these groups, recognizing that patients who leave from the waiting room prior to MSE have overall lower admission rates and quicker return rates when compared to the LSBS patient population, which includes those patients who elope or leave AMA.

When attempting to quantify unrealized revenue effects, our study demonstrated that the LWBS population has significant potential financial impact on the healthcare system. Overall, LWBS patients have more opportunity loss than LSBS patients, as many of these patients do not stay long enough into their visit to incur the professional and technical charges that would be incurred if they had completed a full visit. Additionally, many of the AMA patients received full charges for their visits. This population of AMA patients likely does not provide significant additional revenue opportunities.

Healthcare systems should consider initiatives aimed at keeping patients within their own system to improve market share and increase overall ED revenue (and potential hospital revenue resulting from subsequent admissions) by addressing

**Table 4.** Overall system and emergency department facility type comparison of potential professional and technical fees for patient who left before treatment was completed.

| | Potential professional fees | | | | | |
|---|---|---|---|---|---|---|
| ED category | Encounters missing charges | Charges | Avg. additional charge/encounter | Avg. realization rate | Net | Net per encounter |
| System overall | 16,723 | $8,332,286 | $498 | 24.2% | $2,020,273 | $121 |
| Urban academic | 6,591 | $2,691,244 | $408 | 29.2% | $785,575 | $119 |
| Urban community | 3,785 | $1,987,387 | $525 | 17.3% | $343,604 | $91 |
| Suburban community | 4,203 | $2,820,195 | $671 | 20.8% | $587,756 | $140 |
| FSED | 1,514 | $491,224 | $324 | 31.5% | $154,683 | $102 |
| PED | 630 | $342,237 | $543 | 19.6% | $67,201 | $107 |
| | Potential technical fees | | | | | |
| System overall | 17,749 | $29,171,876 | $1,644 | 25.9% | $7,547,629 | $425 |
| Urban academic | 6,893 | $13,118,331 | $1,903 | 26.7% | $3,497,287 | $507 |
| Urban community | 4,134 | $5,693,974 | $1,377 | 21.0% | $1,193,706 | $289 |
| Suburban community | 4,419 | $7,463,106 | $1,689 | 28.2% | $2,101,090 | $475 |
| FSED | 1,644 | $2,116,398 | $1,287 | 28.6% | $604,826 | $368 |
| PED | 659 | $780,066 | $1,184 | 26.4% | $205,939 | $313 |

*ED*, emergency department; *LBTC*, left before treatment complete; *Avg*, average; *FSED*, free-standing emergency department; *PED*, pediatric emergency department.

the issue of LWBS patients who leave the waiting room early in their visit prior to MSE and addressing processes that influence LWBS decisions. Ultimately, we created this hypothetical financial model to better understand the costs for additional resources that would be needed (nursing, physician extenders, physicians, etc) to fund initiatives to reduce LBTC. Further studies should examine opportunity cost for developing programs that reduce LWBS and LSBS to improve patient safety outcomes and reduce financial losses.

## LIMITATIONS

In this study we were unable to account for patients who may have re-presented to EDs outside of our healthcare system. While patients may have returned to other hospitals outside of our system, our healthcare system does have multiple hospitals throughout the area and holds a large percentage of the market share. Second, we were unable to account for inter-rater reliability for ESI triage levels at different EDs within the system in that patients could have been mis-triaged or potentially up/downgraded in triage. As different staff at our facilities are triaging patients at each hospital, it could account for differences in ESI acuity levels on re-presentation. Our healthcare system used the EDBA definitions and our classifications of disposition were determined by our frontline waiting room staff. Nursing was educated on these definitions, but we cannot exclude that some patients may have been mischaracterized.

Further, because we did not examine the subtype population of patients with high-frequency ED utilization, we were not able to account for whether patients who returned were having different chief complaints from their initial presenting complaint prior to LBTC. Additionally, when comparing LWBS and LSBS patients, we were not able to adjust for ED type or ESI level. While we attempted to study the entire LBTC group as a whole, we also acknowledge that each group has different characteristics and further examination of each subtype may better help create projects that reduce leaving from the ED before the visit is complete. Lastly, since we were looking at markers for the healthcare system as a whole to make recommendations for overall system improvement, some sites may have characteristics that differ from our primary findings.

Regarding financial data limitations there is no ideal method to calculate realization rates per encounter. We attempted to account for this revenue stream by defaulting any encounters without an ESI acuity level to ESI level 4. These triage complaints could have been ultimately higher or lower acuity level. Additionally, for suboptimal charges, we had to take the average site encounter charge for particular ESI levels and calculate the difference between the billed charge and the average site-encounter charge. However, because we were able to gather the insurance information for all of these patients, we were able to get a net realization charge for potential lost revenue.

Another major limitation of our financial model is that we did not account for return after leaving the ED, ie, this initial financial calculation was only meant to demonstrate the potential income stream lost by patients who leave the ED. Further analysis would have to account for patients who subsequently return and create a financial model to adjust for re-captured revenue. Our study demonstrated that more financial opportunity was available for patients categorized as LWBS before MSE was completed and that decreasing the rate of leaving would increase financial opportunities for the healthcare system.

## CONCLUSION

In our multicenter study, patients who left AMA or eloped (LSBS) had longer time to return and much higher admission rates with resultant less financial loss to the healthcare system than patients who left without being seen before a medical screening exam was completed. Facility type had less influence on these factors. Further studies should examine how healthcare systems can reduce the prevalence of patients who leave before treatment is completed since this group of patients represents an area of lost revenue for the healthcare system.

**Table 5.** Comparison of potential professional and technical fees for left before treatment complete patients.

| | Potential professional fees | | | | | | |
|---|---|---|---|---|---|---|---|
| Dispo category | Original $0 charges | Original charges < average* | Charges | Avg. additional charge/encounter | Avg. realization rate | Net | Net per encounter |
| System overall | 12,048 | 4,675 | $8,332,286 | $498 | 24.2% | $2,020,273 | $121 |
| LWBS* | 8,175 | 24 | $5,501,374 | $671 | 21.7% | $1,193,498 | $146 |
| LSBS** | 3,873 | 4,651 | $2,830,913 | $332 | 26.7% | $755,876 | $89 |
| | Potential technical fees | | | | | | |
| System overall | 8,357 | 9,392 | $29,171,876 | $1,644 | 25.9% | $7,547,629 | $425 |
| LWBS* | 7,610 | 585 | $16,108,900 | $1,966 | 27.4% | $4,413,713 | $539 |
| LSBS** | 747 | 8,807 | $13,062,975 | $1,367 | 24.6% | $3,208,764 | $336 |

*LWBS (left without being seen): patients who leave the ED before initiation of medical screening examination.
**LSBS (left subsequent to being seen): patients who leave the ED after evaluation by licensed care provider qualified to complete a medical screening examination and initiate treatment but before the disposition decision by the care provider.
*Avg*, average.

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# The Utility of Pain Scale to Assess Verifiable vs Non-Verifiable Pain in United States Emergency Departments

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**Introduction:** We sought to examine the utility of self-reported pain scale by comparing emergency department (ED) triage pain scores of self-reported but non-verifiable painful conditions with those of verifiable painful conditions using a large, nationally representative sample.

**Methods:** We analyzed the National Hospital Ambulatory Medical Care Survey (NHAMCS) 2015. Verifiable painful conditions were identified based on the final diagnoses in the five included International Classification of Diseases 9th revision codes. Non-verifiable painful conditions were identified by the five main reasons for visit. Only adults 18 years of age or older were included. The primary outcome variable was the pain scale from 0 to 10 at triage. We performed descriptive and multivariate analyses to investigate the relationships between the pain scale and whether the painful condition was verifiable, controlling for patient characteristics.

**Results:** There were 55 million pain-related adult ED visits in 2015. The average pain scale was 6.49. For verifiable painful diagnoses, which were about 24% of the total visits, the average was 6.27, statistically significantly lower than that for non-verifiable painful conditions, 6.56. Even after controlling for the confounding of patient characteristics and comorbidities, verifiable painful diagnoses still presented less pain than those with non-verifiable painful complaints. Older age, female gender, and urban residents had significantly higher pain scores than their respective counterparts, controlling for other confounding factors. Psychiatric disorders were independently associated with higher pain scores by about a half point.

**Conclusion:** Self-reported pain scales obtained at ED triage likely have a larger psychological component than a physiological one. Close attention to clinical appropriateness and overall patient comfort are more likely to lead to better health outcomes and patient experiences than focusing on self-reported pain alone. [West J Emerg Med. 2021;22(2):156-162.]

## INTRODUCTION

It is well established that pain is both physiological and psychological.[1-4] Treating pain has been aggressively emphasized by hospitals and particularly emergency departments (ED) since the late 1980s, and self-reported pain scales have been treated as the fifth vital signs.[5,6] Since the early 1990s, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and the Veterans Health Administration have promoted adequate pain control as a quality measure.[7] In 2005, the American Pain Society published guidelines recommending that pain needed to be assessed and promptly treated in various settings.[8]

Because of these efforts, nearly all EDs in the US use some variations of self-reported pain scale at triage and likely again at nursing assessment. JCAHO recommended that extensive resources be used to assess and manage pain in the ambulatory setting.[9] Many emergency physicians use the pain scale in their determination of diagnosis and decision to prescribe pain medications.[10] The underlying but unverified assumption is

that the reported pain scale has a clinical utility. In particular, if the pain scale were predictive of the severity of diseases and adverse clinical outcomes, the resources used to document and alleviate pain would be well justified. Unfortunately, few studies have addressed this issue. One study found that the reported pain scale did not predict patients' desire for analgesia.[11] Other studies showed that pain scale was not associated with vital signs in EDs[12] or in prehospital settings.[13]

A recent study demonstrated that a high initial pain score did not predict the cause of pain identified by computed tomography, the need for admission, or surgery,[14] suggesting that the severity of certain pathologies did not correlate well with reported pain. In contrast, in an earlier study of combat injuries, pain scale was significantly proportional to the severity of injuries, although not correlated with abnormal vital signs.[15] This raises the question: If the pain scale correlates with the severity of disease in truly painful conditions, such as injuries, which can be verified by exam or imaging, how does it correlate with patients' self-reported painful conditions with no verifiable painful diagnoses, such as non-specific abdominal or chest pain? Our objective in the current study was to compare the self-reported pain scales of verifiable painful conditions with those of non-verifiable painful conditions at ED triage among adults using nationally representative data of EDs in the US. Patient characteristics and comorbidities associated with the reported pain scales were also identified.

*Population Health Research Capsule*

What do we already know about this issue?
*Nearly all emergency departments (ED) use subjective pain scales at triage. Several studies have showed that the clinical relevance of pain scales is limited.*

What was the research question?
*How do self-reported pain scales of non-verifiable painful conditions compare with those of verifiable painful conditions in adult ED visits?*

What was the major finding of the study?
*The self-reported pain scale was higher for non-verifiable painful conditions than that for verifiable painful diagnoses.*

How does this improve population health?
*Understanding the limited utility of pain scales helps to more efficiently allocate resources for managing pain, which has been recognized as a public health challenge.*

## METHODS

### Data

We analyzed data from the National Hospital Ambulatory Medical Care Survey (NHAMCS) 2015, representing about 137 million ED adult and pediatric visits (sample size n = 21,061) in the US in 2015. Key data elements of the NHAMCS included patient characteristics, visit characteristics, vital signs, tests and procedures performed, medications given, discharge status, up to five chief complaints and up to five diagnoses in *International Classification of Diseases 9th revision* (ICD-9) codes. More details of the NHAMCS can be found at the US Centers for Disease Control and Prevention website (http://www.cdc.gov/nchs/ahcd.htm). Pain-related ED visits were extracted from the data and dichotomized into visits with verifiable and non-verifiable painful conditions.

Verifiable painful conditions were identified based on the final diagnoses in the five included ICD-9 codes: injuries to various body parts; acute myocardial infarction (AMI); nephrolithiasis/ureterolithiasis; and intestinal obstruction.[10,16] Due to the small cell sizes for isolated intrathoracic, abdominal and pelvic injuries, respectively, they were grouped into one category. We created an additional category of multisystem injuries to encompass injuries that involved more than one body part.

The NHAMCS extracted the free text of the five main reasons for a visit and standardized the text into codes. Symptoms, including pain and injuries, accounted for over 90% of all ED visits.[17] Following prior studies using the NHAMCS data to study pain-related visits,[16,18] pain-related descriptors in the main reasons for a visit included pain, tenderness, burning or stinging, soreness, ache, cramps, spasms, discomfort, and injuries. For visits with self-reported pain from multiple body parts in chief complaints, an additional category was created. If any of the five main reasons reported was an injury, the visit was classified as injury-related, regardless of the remaining main reasons for the visit. A visit was considered having verifiable painful conditions if it had the previously described painful diagnoses, regardless of whether the main reasons for the visit were pain-related or not.

### Inclusion and Exclusion Criteria

We included an ED visit in the sample for analyses if one of these criteria was met: 1) one of the five self-reported main reasons for the visit was related to pain or injuries; 2) the pain scale (0-10) at triage was >0 regardless of the main reasons for the visit; and 3) one or more of the final diagnoses was a verifiable painful condition as previously defined. The following visits were excluded: 1) persons younger than 18 years of age; 2) pain scale was not reported; and 3) arrival by ambulance/emergency medical services (EMS) because whether pain medications were given by EMS was not included in the data.

### Statistical Analyses

The dependent variable was the pain scale from 0 to 10 at triage. A patient's age, gender, race/ethnicity, metropolitan

statistical area (MSA) status, and geographic region of the ED were also included to examine the independent effect of verifiable vs non-verifiable painful conditions. The inclusion of these variables was based on findings from the studies cited previously.[3,10,12,13] Chronic diseases have been demonstrated to be associated with pain.[19-21] Several chronic comorbidities were included in the analyses: diabetes; asthma; chronic obstructive pulmonary disease, coronary artery disease, depression, hyperlipidemia, hypertension, and substance abuse. The NHAMCS included a total of 22 chronic conditions. Chronic comorbidities with a sample proportion <5% were not included in the multivariate analyses as independent variables.

We first calculated the average pain scales by verifiable and non-verifiable conditions, respectively. Descriptive statistics were obtained for patient characteristics and comorbidities. Multivariate regressions were performed to control for the possible confounding of patient characteristics and comorbidities. We used two models. The first model used a single dummy variable to represent all verifiable painful diagnoses and contrasted it with all non-verifiable conditions. To provide more details in regard to which specific conditions were different, a second model used non-verifiable abdominal pain, the most common reason for ED visits, as the comparison group, and contrasted each individual non-verifiable and verifiable conditions again this group. To further examine the consistency of the estimates obtained by the two models we used two specifications under each model: one included the comorbidities, while the other did not. To provide nationally representative estimates, the complex sampling design of the NHAMCS was controlled for in all analyses. We used statistical software Stata (StataCorp, College Station, TX). Statistical significance was defined as $p < 0.05$.

## RESULTS

There were a total of 105 million adult ED visits in the US in 2015, among which about 55 million were related to painful conditions. The average pain scale was 6.49. For verifiable painful diagnoses, which were about 24% of the total visits, the average was 6.27, statistically significantly ($p < 0.05$) lower than that for non-verifiable painful conditions, 6.56. Figure 1 illustrates the distributions of the pain scale for both groups. Noticeably, there were higher proportions of pain scales of 8, 9 and 10 for non-verifiable painful conditions than those for verifiable painful diagnoses.

Figure 2 reports the detailed average pain scale for each non-verifiable painful condition and the corresponding proportion. Back pain that was not related to injuries had the highest pain scale, 7.38, followed by leg pain that was not related to injuries, 7.27. The lowest pain scale was for chest pain that was not related to injuries, 5.63, followed by injuries, 5.74. As expected, pain in abdomen and pelvis had the highest proportion in main reasons for visits, 22.31%. Figure 3 is the counterpart of Figure 2 for verifiable painful diagnoses. The most painful diagnosis was kidney and ureteral stones, with an average pain scale of 7.59, followed by injuries to thorax, abdomen, or pelvis, 6.81. The lowest was head injuries, 4.77, followed by deep soft tissue injuries, 5.16. The highest proportion of verifiable painful diagnoses was superficial soft tissue injuries, 45.62%, followed by deep soft tissue injuries, 19.92%.

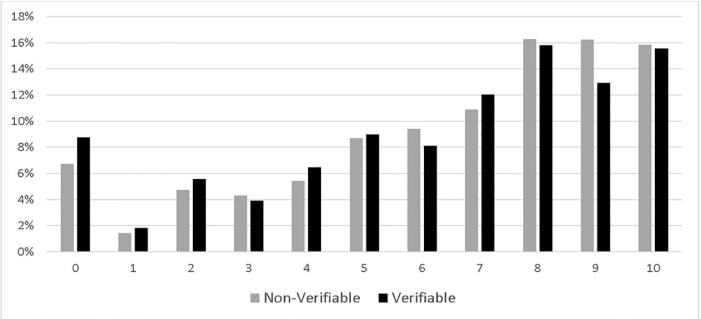


**Figure 1.** Pain scale: non-verifiable versus verifiable conditions.

Descriptive statistics of patient characteristics and comorbidities are shown in Table 1. About 13.70% were elderly patients and 58.77% were females. Slightly less than two-thirds were non-Hispanic Whites, and non-Hispanic Blacks were about 21.04%. The majority, 84.03%, were visits made in urban EDs. About 35.70% visits were in the South region and 16.98% in the Northeast. Over one-fourth of patients had hypertension, 12.12% had diabetes, and 10.17% had depression.

Table 2 reports the results from multivariate regressions. Of note, the estimates are very consistent in both the direction (positive or negative association) and the magnitude, regardless of the models and specifications. Controlling for the confounding of patient characteristics, on average, verifiable painful diagnoses presented with 0.185 ($p = 0.04$) less pain on the 0-10 scale at ED triage. Compared to non-verifiable abdominal pain, non-verifiable chest pain, pain from injuries, pain with no body part mentioned reported significantly lower pain scores, whereas non-verifiable back and leg pain reported higher pain scores. Among verifiable painful diagnoses, deep soft tissue injuries, head injuries, and other injuries had significantly lower pain scores than non-verifiable abdominal pain, whereas kidney and ureteral stones had significantly higher pain scores.

Age, gender, and MSA were consistently significant and similar in magnitude across all model specifications. Controlling for other confounding factors, elderly persons reported a lower level of pain than their younger counterparts by -0.865 to -0.971, depending on the model and specification. Females had higher pain scores than males, by 0.233 to 0.331. Urban patients reported higher pain scores than rural patients, by 0.679 to 0.699. Interestingly, among comorbidities, psychiatric disorders, depression, and substance abuse, were independently associated with higher pain scores by 0.493 to 0.528, and 0.430 to 0.433, respectively. The only non-psychiatric comorbidity that was statistically significant was diabetes, with an average of 0.347 to

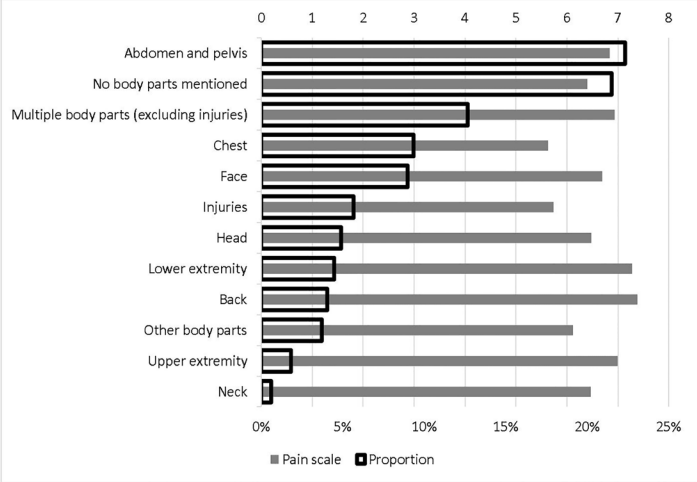


**Figure 2.** Painful chief complaints: proportion and pain scale.

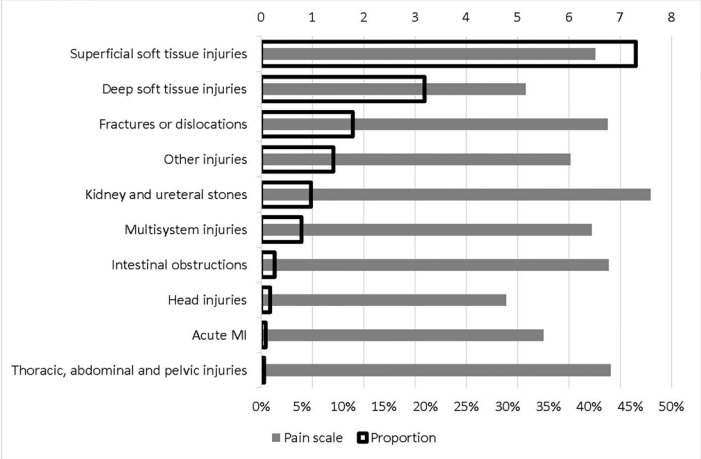


**Figure 3.** Verifiable painful diagnoses: proportion and pain scale.

0.350 higher pain score than in non-diabetics.

## LIMITATIONS

There are several limitations of the current study. First, we used a nationally representative data set for secondary data analyses. All potential biases and pitfalls inherent to secondary data analyses are possible. Second, only adult ED visits were included to ensure the validity of the self-reported pain scale. Consequently, the results are not generalizable to the pediatric population. Third, we included only up to five diagnoses and five main reasons for visits in the data. More complex presentations and diagnoses may have been omitted but the proportion should be very small. Fourth, the exclusion of patients brought in by ambulance/EMS may have skewed the severity mix of the visits. As previously discussed, ambulance/EMS arrivals were excluded because whether pain medications were given en route was unknown. We compared the mean pain scales between the ambulance subsample with the sample included in the analyses, which were 6.05 and 6.49, respectively, and the *P* value for the difference was <0.01. This suggests that pain medications were likely given en route, as we would expect that EMS arrivals usually have higher acuity and severity. In addition, we compared the mean pain scores between verifiable conditions (mean = 5.88) and non-verifiable conditions (mean = 6.14) within the ambulance subsample. The difference was not significant, possibly due to a much smaller sample size of ambulance arrivals.

## DISCUSSION

This is the first study that compared self-reported pain scales at ED triage between verifiable painful diagnoses and non-verifiable painful chief complaints in adult ED visits using a large, nationally representative data set. It is interesting to note that patients with non-specific pains, such as non-traumatic abdominal, back and leg pain, had higher self-reported pain scores than those with fractures and bowel obstruction. This points to the possibility that in the ED setting, self-reported pain scale may have a much larger psychological component than previously thought. The large psychological component is further illustrated by the independent effects of depression and

**Table 1.** Patient characteristics.

| Patient characteristics | Proportion % |
|---|---|
| Age ≥ 65 years | 13.70 |
| Female | 58.77 |
| Race/ethnicity | |
| Non-Hispanic white | 61.21 |
| Non-Hispanic black | 21.04 |
| Hispanic | 15.24 |
| Other races | 2.50 |
| MSA | 84.03 |
| Region | |
| Northeast | 16.98 |
| Midwest | 24.84 |
| South | 35.70 |
| West | 22.49 |
| Comorbidities | |
| Diabetes | 12.12 |
| Asthma | 10.13 |
| COPD | 5.05 |
| CAD | 5.97 |
| Depression | 10.17 |
| Hyperlipidemia | 9.15 |
| Hypertension | 27.07 |
| Substance abuse | 7.48 |

*MSA*, metropolitan statistical area; *COPD*, chronic obstructive pulmonary disease; *CAD*, coronary artery disease.

substance abuse on elevated self-reported pain scale found in this study, confirming the results from prior research indicating that substance abusers and patients with psychiatric comorbidities experience higher levels of pain.[22-24] Patients with a chronic pain diagnosis usually have psychological diagnoses, and among them, ED patients were found to have a higher propensity for opioid abuse than pain clinic patients.[25,26] In addition, personality disorders, anxiety, and panic attack were diagnoses more commonly associated with aberrant prescription behaviors.[26]

Understanding this association is particularly important in deciding how to treat non-verifiable painful complaints as the medical community is turning away from opioid-based treatments for pain. The key findings from the current study provided another piece of evidence showing that opioids may not be effective in treating non-verifiable painful conditions because of its large psychological component. Alternative and non-addictive treatment options need to be explored. Research has demonstrated the safety and efficacy of non-

**Table 2.** Results from multivariate regressions.

| | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Est. | p | Est. | p | Est. | p | Est. | p |
| Verifiable Dx | -0.185 | 0.04 | -0.155 | 0.08 | | | | |
| Pain in CC (vs. abdominal pain in CC) | | | | | | | | |
| Pain of head | | | | | -0.272 | 0.25 | -0.269 | 0.25 |
| Pain of face | | | | | -0.153 | 0.42 | -0.142 | 0.46 |
| Pain of neck | | | | | -0.258 | 0.50 | -0.215 | 0.58 |
| Pain of chest | | | | | -1.049 | 0.00 | -1.100 | 0.00 |
| Pain of back | | | | | 0.631 | 0.00 | 0.614 | 0.00 |
| Pain of upper extremity | | | | | 0.244 | 0.40 | 0.245 | 0.38 |
| Pain of lower extremity | | | | | 0.541 | 0.01 | 0.528 | 0.02 |
| Pain of other body parts | | | | | -0.651 | 0.16 | -0.683 | 0.15 |
| Pain of multiple body parts (excluding injuries) | | | | | 0.131 | 0.43 | 0.122 | 0.46 |
| Pain from injuries | | | | | -0.956 | 0.00 | -0.997 | 0.00 |
| Pain but no body parts mentioned | | | | | -0.358 | 0.04 | -0.417 | 0.02 |
| Verifiable painful Dx (vs. abdominal pain in CC) | | | | | | | | |
| Fractures or dislocations | | | | | 0.191 | 0.43 | 0.208 | 0.38 |
| Superficial soft tissue injuries | | | | | -0.221 | 0.17 | -0.209 | 0.20 |
| Deep soft tissue injuries | | | | | -1.476 | 0.00 | -1.442 | 0.00 |
| Head injuries | | | | | -1.828 | 0.02 | -1.783 | 0.02 |
| Thoracic, abdominal and pelvic injuries | | | | | 0.109 | 0.94 | 0.199 | 0.88 |
| Other injuries | | | | | -0.691 | 0.02 | -0.686 | 0.02 |
| Multisystem injuries | | | | | -0.143 | 0.73 | -0.155 | 0.71 |
| Acute MI | | | | | -0.794 | 0.31 | -1.019 | 0.20 |
| Kidney and ureteral stones | | | | | 0.841 | 0.00 | 0.893 | 0.00 |
| Intestinal obstructions | | | | | 0.455 | 0.42 | 0.430 | 0.46 |
| ≥ 65 years old | -0.971 | 0.00 | -0.877 | 0.00 | -0.921 | 0.00 | -0.865 | 0.00 |
| Female | 0.331 | 0.00 | 0.307 | 0.00 | 0.259 | 0.00 | 0.233 | 0.01 |
| Race/ethnicity (vs. Non-Hispanic white) | | | | | | | | |
| Non-Hispanic black | 0.181 | 0.14 | 0.217 | 0.07 | 0.186 | 0.14 | 0.225 | 0.06 |
| Hispanic | -0.188 | 0.19 | -0.141 | 0.32 | -0.205 | 0.15 | -0.153 | 0.28 |
| Other races | -0.450 | 0.16 | -0.434 | 0.15 | -0.438 | 0.15 | -0.414 | 0.15 |
| MSA | 0.699 | 0.01 | 0.697 | 0.01 | 0.683 | 0.01 | 0.679 | 0.01 |

**Table 2.** continued.

| | Model 1 | | | | Model 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Est. | p | Est. | p | Est. | p | Est. | p |
| Region (vs Northeast) | | | | | | | | |
| Midwest | -0.077 | 0.82 | -0.092 | 0.78 | -0.089 | 0.79 | -0.113 | 0.73 |
| South | 0.181 | 0.55 | 0.196 | 0.51 | 0.171 | 0.57 | 0.185 | 0.53 |
| West | 0.011 | 0.98 | 0.009 | 0.98 | 0.017 | 0.96 | 0.018 | 0.96 |
| Comorbidities | | | | | | | | |
| Diabetes | | | 0.347 | 0.02 | | | 0.350 | 0.02 |
| Asthma | | | 0.098 | 0.50 | | | 0.145 | 0.29 |
| COPD | | | 0.121 | 0.54 | | | 0.200 | 0.31 |
| CAD | | | 0.030 | 0.87 | | | 0.168 | 0.34 |
| Depression | | | 0.493 | 0.00 | | | 0.528 | 0.00 |
| Hyperlipidemia | | | -0.303 | 0.10 | | | -0.292 | 0.12 |
| Hypertension | | | -0.142 | 0.19 | | | -0.117 | 0.26 |
| Substance abuse | | | 0.433 | 0.01 | | | 0.430 | 0.01 |

*Dx*, diagnosis; *CC*, chief complaints; *MI*, myocardial infarction; *MSA*, metropolitan statistical area; *COPD*, chronic obstructive pulmonary disease; *CAD*, coronary artery disease.

opioid therapies, including ketamine,[27] metoclopramide for acute migraine headache,[28] and other targeted therapies such as ketorolac for renal colic.[29] These therapies can lead to a significant reduction in opioid use[30] without leading to decreases in patient satisfaction.[31]

Physicians have been under increased scrutiny to provide adequate analgesia to patients for the past 20 years.[32] There have even been initiatives to match opioid analgesia to specific pain intensities,[33] despite findings showing that demographic factors such as race, age, insurance, and ED utilization lend to variability in self-reported pain scoring.[34] Furthermore, pain scores do not accurately reflect ED patient experience or correlate well with the appropriateness of triage and treatment decisions.[35] In fact, one study found that patient-reported visual analog pain scales were not indicative of their desire for analgesia among those with acute pain.[11] These factors have important implications in physician's decision-making regarding pain management in the ED. If self-reported pain does not correlate with the severity of disease or health outcome,[14] strategies for more efficient use of resources need to be developed. More focus should be put on the overall patient comfort with less emphasis on pain scores.

## CONCLUSION

The current study used a large, nationally representative ED sample to demonstrate the limitation of self-reported pain scores in the ED setting. In particular, pain scales obtained at triage likely have a larger psychological component than a physiological one, as the self-reported pain score is higher in non-verifiable painful conditions than that in verifiable painful conditions. Close attention to clinical appropriateness and overall patient comfort are more likely to lead to better health outcomes and patient experiences than focusing on self-reported pain alone.

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# Four-factor Prothrombin Complex Concentrate for Reversal of Factor Xa Inhibitors versus Warfarin in Life-threatening Bleeding

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**Introduction:** Factor Xa (fXa) inhibitor reversal for life-threatening bleeding is controversial due to a lack of high-quality evidence. The purpose of this study was to determine the hemostatic efficacy of four-factor prothrombin complex concentrate (4F-PCC) for the reversal of fXa inhibitors compared to warfarin for life-threatening bleeding.

**Methods:** This was a multicenter, retrospective cohort study at two academic medical centers between January 1, 2014–December 31, 2019, which included patients who presented to the emergency department with a life-threatening bleed necessitating anticoagulation reversal with 4F-PCC. The primary endpoint was achievement of hemostatic efficacy after 4F-PCC administration.

**Results:** Of the 525 patients who had an order for 4F-PCC during the study period, 148 patients met the criteria for inclusion (n = 48 fXa inhibitor group; n = 100 warfarin group). Apixaban (52.1%) and rivaroxaban (45.8%) were the most commonly used fXa inhibitors. Effective hemostasis was similar between groups (79.2% fXa inhibitor group vs 85% warfarin group, p = 0.38). This was consistent across all types of bleeding. Thrombotic events were rare in both groups (2% vs 3%).

**Conclusion:** This multicenter, retrospective cohort study demonstrated that using 4F-PCC for treatment of life-threatening bleeding produced effective hemostasis in patients on fXa inhibitors and warfarin. [West J Emerg Med. 2021;22(2)163-169.]

## INTRODUCTION

Factor Xa (fXa) inhibitors (eg, apixaban and rivaroxaban) are a class of direct oral anticoagulants that are widely used for a variety of indications, including venous thromboembolism and atrial fibrillation.[1,2] Use of these agents has steadily increased over the last decade. This is in part because of their ease of use compared to warfarin, which requires frequent laboratory monitoring and dietary modifications and which interacts with numerous medications due to metabolism by a number cytochrome P450 enzymes, posing safety risks. Compared to warfarin, fXa inhibitors appear to have a lower rate of intracerebral hemorrhage, with annual rates of 0.1-0.2% compared to 0.3-0.6% of patients on warfarin.[3,4] However, whereas four-factor prothrombin complex concentrate (4F-PCC) and vitamin K are generally considered the standard of care for reversal of life-threatening bleeding secondary to warfarin (due to warfarin's availability it has been more extensively studied), reversal of fXa inhibitors in this setting remains controversial due to a lack of high-quality evidence.[5-8]

Several national and international guidelines endorse

the use of 4F-PCC for the reversal of fXa inhibitors; however, its exact place in therapy overall and in relation to andexanet alfa is discordant among these guidelines.[1,2,9-11] Although andexanet alfa was specifically designed for reversal of fXa inhibitors, it has not seen widespread use because many institutions have not approved it due to a lack of robust evidence, including a comparator group in the available studies, questionable risk of thromboembolism, and the poor value proposition and cost-effectiveness of the therapy.[12,13] The range of recommendations for its use include the following: 4F-PCC as a first-line therapy for fXa inhibitor reversal[1,10,11]; 4F-PCC as a first-line therapy as an alternative to discontinuation of fXa inhibitors alone (eg, meaning that perhaps no reversal agent would be appropriate)[2]; and 4F-PCC as a second-line agent after andexanet alfa.[9] These differences stem from the relatively poor quality of evidence for both agents and include a degree of expert opinions. The limited data available are comprised of small, single-center studies that lack a comparator group.[14-20] The purpose of this study was to determine the hemostatic efficacy of 4F-PCC for the reversal of fXa inhibitor-related, life-threatening bleeding compared to 4F-PCC for warfarin-related life-threatening bleeding.

*Population Health Research Capsule*

What do we already know about this issue?
*Factor Xa (fXa) inhibitors are used for venous thromboembolism and atrial fibrillation. Evidence regarding their reversal in the setting of life-threatening bleeding is limited.*

What was the research question?
*What was the hemostatic efficacy of four-factor prothrombin complex concentrate (4F-PCC) for the reversal of fXa inhibitor-related life-threatening bleeding compared to 4F-PCC for warfarin-related life-threatening bleeding?*

What was the major finding of the study?
*Effective hemostasis was similar between groups and was consistent across all types of bleeding; thrombotic events were rare in both groups.*

How does this improve population health?
*Using 4F-PCC for treatment of life-threatening bleeding produced effective hemostasis in patients on both fXa inhibitors and warfarin.*

## METHODS

This was a multicenter, retrospective cohort study conducted at two urban, academic medical centers between January 1, 2014–December 31, 2019. The study included patients who presented to the emergency department (ED) with a life-threatening bleed necessitating anticoagulation reversal with 4F-PCC. To be included in the study, there had to be confirmation of warfarin or fXa inhibitor use (ie, apixaban, betrixaban, edoxaban, or rivaroxaban) prior to presentation, which necessitated rapid reversal for life-threatening bleeding. Patients were excluded if any of the following criteria were present: age less than 18 years; receipt of 4F-PCC outside of the ED setting or at an outside hospital prior to arrival; receipt of 4F-PCC for any indication aside from life-threatening bleeding; concurrent factor VII use; history of heparin-induced thrombocytopenia; or known disseminated intravascular coagulation. Both institutions' institutional review boards approved the research protocol.

Life-threatening bleeding was treated according to institutional protocols at the discretion of the treating services. Both institutions preferentially used 4F-PCC for the reversal of life-threatening bleeding in patients on fXa inhibitors or warfarin during the study period. Institutional protocols at both sites recommended dosing of 4F-PCC at 50 factor IX units per kilogram for fXa inhibitor reversal and between 25-50 IX units/kg for warfarin reversal based on a pre-treatment international normalized ratio (INR) value. The primary endpoint was achievement of hemostatic efficacy after 4F-PCC administration as defined by the Scientific and Standardization Subcommittee on Control of Anticoagulation of the International Society of Thrombosis and Hemostasis Scientific (ISTH) for the assessment of the effectiveness of major bleeding management.[21]

Hemostasis for intracranial hemorrhage was defined as stabilization at or less than a 35% increase in hematoma volume on imaging. All patients had repeat imaging based on treatment protocols. Hemostasis for visible bleeding was defined as cessation of visible bleeding within four hours of 4F-PCC administration. Hemostasis for non-visible bleeding was defined as stable hemoglobin at 48 hours post-4F-PCC administration. Hemostasis was assessed by one of the study investigators upon data collection. Secondary endpoints were the number of transfusions of packed red blood cells, platelet, and fresh frozen plasma, discharge disposition, intensive care unit length of stay, hospital length of stay, and hospital and 30-day mortality. Safety endpoints were any adverse event during hospitalization (ie, deep vein thrombosis [DVT], pulmonary embolism, ischemic stroke, arterial thrombus, myocardial infarction, hypersensitivity reaction, transfusion-related acute lung injury, and transfusion-associated circulatory overload).

### Statistical Analyses

Baseline and clinical characteristics were characterized

using descriptive statistics. We assessed normality of continuous variables using the Shapiro-Wilk test. Normally distributed continuous variables were analyzed using Student's t-test. We used the Mann-Whitney U test to analyze on-parametric data. A chi-square or Fisher's exact test was used to compare categorical variables, as appropriate. We analyzed data using STATA version 15 (StataCorp, College Station, TX).

## RESULTS

Of the 525 patients who had an order for 4F-PCC during the study period, 148 patients met the criteria for inclusion (n = 48 fXa inhibitor group; n = 100 warfarin group; Figure 1). The most common reasons for exclusion were receipt of 4F-PCC outside of the ED (n = 270) and use for non-life-threatening bleeding (n = 98).

Baseline demographics were similar between groups (Table 1). Patients in the fXa inhibitor group were older (78.4 years fXa inhibitor group vs 73.9 years warfarin group, $P = 0.03$), while patients in the warfarin group had a higher incidence of end-stage renal disease (2.1% vs 18%, $P < 0.01$). Apixaban (52.1%) and rivaroxaban (45.8%) were the most commonly used fXa inhibitors, with only one patient (2.1%) on edoxaban. Most patients in both groups were on an oral anticoagulant for atrial fibrillation-associated stroke prevention. Anticoagulation for mechanical mitral valve only occurred in the warfarin group (0% vs 19%, $P < 0.01$). Concomitant antiplatelet use was similar between groups, with aspirin being the most common agent (29.7% vs 26%, $P = 0.69$), followed by clopidogrel (16.7% vs 21%, $P = 0.53$). Only two patients, both in the warfarin group, were on dual antiplatelet therapy.

The most common indication for 4F-PCC in both groups was intracranial bleeding, which occurred more frequently in the warfarin group (52.1% vs 67%, $P = 0.02$; Table 2). Visible bleeding was more common in the fXa inhibitor group (31.3% vs 15%, $P = 0.02$), while non-visible bleeding was similar between groups (16.7% vs 17%). Four-factor prothombin complex concentrate was administered more often during weekdays and day shifts in both groups. Baseline laboratory parameters were similar between groups, although warfarin patients had higher INR (1.2 vs 3.2, $P < 0.01$). Patients in the fXa-group received a higher total and weight-based dose of 4F-PCC than the warfarin group. Most doses in both groups were deemed appropriate according to institutional guidelines. There was little difference between groups in time to 4F-PCC initiation (106.5 minutes vs 140 minutes, $P = 0.12$).

The primary endpoint of effective hemostasis was similar between groups (79.2% vs 85%, $P = 0.38$; Table 3). This was consistent across all types of bleeding with no differences observed in intracranial bleeding, visible bleeding, or non-visible bleeding hemostasis. No patients received additional hemostatic agents or coagulation factors at 48 hours after 4F-PCC. All efficacy and safety secondary endpoints were similar between groups. Only three adverse effects occurred overall. One patient in each group developed DVT and one ischemic stroke occurred in the warfarin group.

## DISCUSSION

This multicenter, retrospective cohort study demonstrated that using 4F-PCC for treatment of life-threatening bleeding produced effective hemostasis in patients on both fXa inhibitors and warfarin. Hemostasis was high overall, occurring in 79.2% of the fXa inhibitor group and 85%

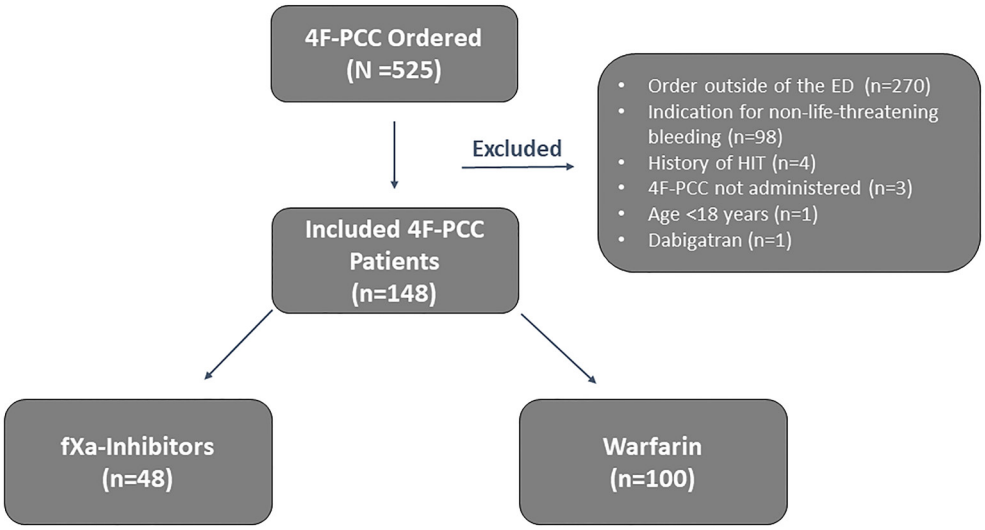


**Figure 1.** Study diagram.
*4F-PCC,* four-factor prothrombin complex concentrate; *ED,* emergency department; *HIT,* heparin-induced thrombocytopenia; *fXa,* factor Xa.

of the warfarin group. Hemostasis rates were consistent with previously reported literature.[8,15,19,20] The addition of a comparator group (eg, warfarin) in our study allowed for a frame of reference to be available, unlike prior studies that analyzed 4F-PCC use in fXa inhibitor-induced bleeding. This is important as 4F-PCC is generally considered the treatment of choice for warfarin-related bleeding, but guideline recommendations are more heterogeneous when it comes to

**Table 1.** Baseline characteristics of patients treated for life-threatening bleeding.

| Characteristic | fXa-Inhibitors (n=48) | Warfarin (n=100) | P-value |
|---|---|---|---|
| Male gender, n (%) | 28 (52.1) | 64 (64) | 0.17 |
| Age at bleed (years), median (IQR) | 78.4 (68.9 – 83.9) | 73.9 (62.6 – 82.3) | 0.03 |
| BMI (kg/m2), median (IQR) | 26.8 (24 – 31.8) | 28.6 (28.6 – 32.3) | 0.24 |
| Race, n (%) | | | 0.67 |
| Black | 9 (18.8) | 20 (20) | |
| White | 31 (64.6) | 55 (55) | 0.11 |
| Hispanic | 3 (6.3) | 9 (9) | 0.11 |
| Other | 5 (10.4) | 16 (16) | <0.01 |
| Comorbidities | | | 0.19 |
| Atrial fibrillation | 40 (83.3) | 70 (70) | 0.53 |
| Cancer | 13 (27.1) | 16 (16) | 0.24 |
| End-stage renal disease | 1 (2.1) | 18 (18) | 0.34 |
| Heart failure | 13 (27.1) | 38 (38) | -- |
| Venous thromboembolism | 8 (16.7) | 21 (21) | |
| SOFA score on admission, median (IQR) | 3 (2 – 5) | 2 (1 – 5) | |
| GCS score on admission, median (IQR) | 14 (10 – 15) | 15 (11 – 15) | |
| Anticoagulation, n (%) | | | |
| Warfarin | -- | 100 (100) | |
| Rivaroxaban | 22 (45.8) | -- | |
| Apixaban | 25 (52.1) | -- | |
| Edoxaban | 1 (2.1) | -- | |
| Indication for anticoagulation, n (%) | | | |
| Atrial fibrillation | 39 (81.3) | 68 (68) | 0.12 |
| Cancer-related venous thromboembolism | 1 (2.1) | 1 (1) | 0.59 |
| Deep venous thrombosis | 8 (16.7) | 10 (10) | 0.25 |
| History of venous thromboembolism | 2 (4.2) | 7 (7) | 0.50 |
| Mechanical mitral valve | 0 (0) | 19 (19) | <0.01 |
| Pulmonary embolism | 4 (8.3) | 8 (8) | 0.95 |
| Ventricular assist device | 0 (0) | 4 (4) | 0.16 |
| Concomitant antiplatelet, n (%) | | | |
| Aspirin | 11 (29.7) | 26 (26) | 0.69 |
| Clopidogrel | 8 (16.7) | 21 (21) | 0.53 |
| Prasugrel | 2 (4.2) | 1 (1) | 0.20 |
| Dual antiplatelet therapy | 0 (0) | 2 (2) | 0.33 |
| Baseline laboratory parameters, median (IQR) | | | |
| INR | 1.2 (1.1 – 1.9) | 3.2 (2.4 – 6.3) | <0.01 |
| Hemoglobin, g/dL | 11.3 (8.2 – 13.2) | 11.5 (9.8 – 13.2) | 0.53 |
| Platelets, x$10^9$/L | 219 (161 – 257) | 212 (172 – 257) | 0.82 |

*fXa*, factor Xa; *IQR*, interquartile range; *kg*, kilogram; *m2*, meter squared; *BMI*, body mass index; *SOFA*, sequential organ failure assessment; *GCS*, Glasgow Coma Scale; *INR*, international normalized ratio; *g*, gram; *dL*, deciliter; *L*, liter.

recommending 4F-PCC for fXa-inhibitor-related bleeding due to a paucity of evidence guiding treatment decisions.[1,2,9,11]

Previous studies of fXa inhibitor-related bleeding reversal have observed similar efficacy rates as this study (range: 72.4-85%), although most describe single-center efforts with low patient enrollment rates and no comparator group.[8,15,19,20] The largest retrospective cohort study to date included 663 patients with intracranial hemorrhage, of whom 433 were evaluated for hemostatic efficacy.[8] Within this patient cohort, efficacy was deemed excellent or good (according to hematoma expansion ≤20% or 20.1-35%, respectively) in 81.8% of patients. A prospective observational study of 66 patients receiving a fixed dose of 2000 IX units did a post hoc analysis for effective hemostatic according to ISTH criteria and found 68% of patients achieved effectiveness.[15] A meta-analysis including 10 case series of 340 patients found that only two studies used the ISTH criteria to define hemostasis.[22] In these studies, the effective management of major bleeding was achieved in 69% of patients (95% confidence interval [CI], 61-76%). There was a low rate of thromboembolic events within 30 days (3% [95% CI, 0-6%]). None of the included studies had a comparator arm. Our study enhances the current literature with the addition of a comparator group, which provides a frame of reference for clinicians to consider when determining oral anticoagulant choice and potential outcomes if a life-threatening bleed occurs.

If a reversal agent predisposes patients to developing a thrombotic event following use, its utility may be greatly diminished. Thus, careful monitoring for adverse effects is important. In this study, safety outcomes occurred very infrequently and were similar between groups. One patient experienced a DVT in the fXa inhibitor group, compared to one DVT and one stroke in the warfarin group. The fXa inhibitor patient required subsequent anticoagulation and did not experience any further adverse effects or mortality. Other studies have reported similar adverse effects.[8,15,19,20] A single-center, retrospective cohort study of 4F-PCC used for either reversal of fXa inhibitor induced life-threatening bleeding or need for emergent procedure also found only one adverse effect, a DVT.[14] A large, multicenter study found thrombotic events in 3.8% of patients.[8] Thus, according to this study and previous literature, it appears that 4F-PCC is a relatively safe intervention in the treatment of fXa inhibitor- and warfarin-related bleeding.

## LIMITATIONS

This study has several limitations that warrant consideration. First, despite being one of the largest studies of fXa inhibitor-induced bleeding reversed with 4F-PCC, it is a retrospective cohort study of a relatively limited number of patients, with only 48 patients in the fXa inhibitor group. We attempted to improve upon previous literature by including two academic centers and comparing

**Table 2.** Anticoagulation reversal characteristics.

| Characteristic | fXa-Inhibitors (n=48) | Warfarin (n=100) | P-value |
|---|---|---|---|
| Type of Bleed, n (%) | | | 0.02 |
| Intracranial bleeding | 25 (52.1) | 67 (67) | |
| Visible bleeding | 15 (31.3) | 15 (15) | |
| Non-visible bleeding | 8 (16.7) | 17 (17) | |
| 4F-PCC day of the week, n (%) | | | 0.65 |
| Weekday (Monday – Friday) | 38 (79.2) | 75 (75) | |
| Weekend (Saturday, Sunday) | 10 (20.8) | 25 (25) | |
| 4F-PCC shift, n (%) | | | 0.65 |
| Day (0701 to 1900) | 38 (79.2) | 76 (76) | |
| Evening (1901 to 0700) | 10 (20.8) | 24 (24) | |
| Laboratory parameters, median (IQR) | | | |
| INR after 4F-PCC | 1.2 (1.1 – 1.3) | 1.2 (1.1 – 1.4) | 0.65 |
| Hemoglobin, g/dL, 48 hours | 9.9 (8.9 – 12) | 10.2 (8.7 – 12.2) | 0.93 |
| Platelets, x$10^9$/L, 48 hours | 185 (141 – 226) | 186 (144 – 216) | 0.68 |
| 4F-PCC dose, units, median (IQR) | 3932 (3212 – 4516) | 2265 (1740 – 3136) | <0.01 |
| 4F-PCC dose, units/kg, median (IQR) | 49.9 (47.3 – 52.4) | 27.5 (24.4 – 35.3) | <0.01 |
| Time to 4F-PCC, minutes, median (IQR) | 106.5 (64 – 216) | 140 (77 – 240) | 0.12 |
| Appropriate 4F-PCC dose, n (%) | 43 (89.6) | 84 (84) | 0.35 |

*fXa*, factor Xa; *4F-PCC*, four-factor prothrombin complex concentrate; *IQR*, interquartile range; *g*, gram; *dL*, deciliter; *L*, liter; *INR*, international normalized ratio.

4F-PCC efficacy and safety to warfarin, where it has been established as the standard of care for reversal in the setting of life-threatening bleeding.[1,2,6,9,11] However, this may have introduced bias as fXa inhibitors likely cause less severe bleeding than warfarin.[23] Second, in an attempt to have the most complete data possible in terms of timing and documentation, we excluded the 270 patients experiencing life-threatening bleeding outside of the ED, which may have limited our external validity. Additionally, a previous study found that time to intervention could potentially affect outcomes.[24] While we collected data from ED arrival to administration of 4F-PCC, the time of last dose of anticoagulant was not readily available. Finally, thrombotic adverse effects could have occurred after discharge and may have been missed due to a relatively short follow-up period, especially if patients reported to an outside hospital that was not connected with our electronic health record.

## CONCLUSION

This multicenter, retrospective cohort study demonstrated that using 4F-PCC for treatment of life-threatening bleeding produced effective hemostasis in patients on fXa inhibitors and warfarin. Although larger, prospective comparative studies are needed to determine the efficacy of 4F-PCC as a reversal agent for fXa inhibitor-related, life-threatening bleeding, this study adds to the existing literature supporting use of 4F-PCC for this indication based on the hemostatic efficacy and safety of this intervention.

**Table 3.** Hemostatic efficacy.

| | fXa-Inhibitors (n=48) | Warfarin (n=100) | P-value |
|---|---|---|---|
| Primary endpoint | | | |
| Effective hemostasis, n (%) | 38 (79.2) | 85 (85) | 0.38 |
| Hemostasis by type of bleed | | | |
| Intracranial bleeding hemostasis, n (%) | n = 25 | n = 25 | |
| Hematoma volume stable or increased by <35% compared to baseline | 19 (76) | 59 (86.8) | 0.21 |
| Deterioration in GCS at 24 hours | 2 (8) | 6 (8.8) | 0.90 |
| Need for further hemostatic agents or coagulation factors at 48 hours | 4 (16) | 25 (36.8) | 0.06 |
| Visible bleeding hemostasis, n (%) | n = 15 | n = 15 | |
| Cessation of visible bleeding within 4 hours of 4F-PCC administration | 14 (93.3) | 15 (100) | 0.29 |
| Need for further hemostatic agents or coagulation factors at 48 hours | 12 (80) | 12 (80) | >0.99 |
| Non-visible bleeding hemostasis, n (%) | n = 8 | n = 17 | |
| Stable hemoglobin at 24 hours after 4F-PCC | 8 (100) | 17 (100) | >0.99 |
| Need for further hemostatic agents or coagulation factors at 48 hours | 4 (50) | 12 (75) | 0.32 |
| Secondary outcomes | | | |
| Mortality, n (%) | | | |
| Hospital | 8 (16.7) | 14 (14) | 0.69 |
| 30-day | 9 (18.8) | 17 (17) | 0.81 |
| Length of stay, median (IQR) | | | |
| Intensive care unit | 2 (1 – 7) | 3 (2 – 7) | 0.31 |
| Hospital | 6 (4 – 10) | 7 (4 – 13) | |
| Adverse event during hospitalization, n (%) | 1 (2.1) | 2 (2) | 0.97 |
| Packed red blood cells within 24 hours of 4F-PCC, median (IQR) | 17 (35.4) | 24 (24) | 0.15 |
| Platelet transfusions within 24 hours of 4F-PCC, median (IQR) | 4 (8.3) | 21 (21) | 0.05 |
| Fresh frozen plasma within 24 hours of 4F-PCC, median (IQR) | 6 (12.5) | 23 (23) | 0.13 |

*fXa*, factor Xa; *GCS*, Glasgow Coma Scale; *4F-PCC*, four-factor prothrombin complex concentrate; *IQR*, interquartile range.

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# Diagnostic Uncertainty in Dyspneic Patients with Cancer in the Emergency Department

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**Objective:** Dyspnea is the second most common symptom experienced by the approximately 4.5 million patients with cancer presenting to emergency departments (ED) each year. Distinguishing pneumonia, the most common reason for presentation, from other causes of dyspnea is challenging. This report characterizes the diagnostic uncertainty in patients with dyspnea and pneumonia presenting to an ED by establishing the rates of co-diagnosis, co-treatment, and misdiagnosis.

**Methods:** Visits by individuals ≥18 years old with cancer who presented with a complaint of dyspnea were identified using the National Hospital Ambulatory Medical Care Survey between 2012-2014 and analyzed for rates of co-diagnosis, co-treatment (treatment or diagnosis for >1 of pneumonia, chronic obstructive pulmonary disease [COPD], and heart failure), and misdiagnosis of pneumonia. Additionally, we assessed rates of diagnostic uncertainty (co-diagnosis, co-treatment, or a lone diagnosis of dyspnea not otherwise specified [NOS]) .

**Results:** Among dyspneic cancer visits (1,593,930), 15.2% (95% confidence interval [CI], 11.1-20.5%) were diagnosed with pneumonia, 22.5% (95% CI, 16.7-29.7%) with COPD, and 7.4% (95% CI 4.7-11.4%) with heart failure. Dyspnea NOS was diagnosed in 32.3% (95% CI, 25.7-39.7%) of visits and as the only diagnosis in 23.1% (95% CI, 16.3-31.6%) of all visits. Co-diagnosis occurred in 4.0% (95% CI, 2.0-7.6%) of dyspneic adults with cancer and co-treatment in 12.1% (95% CI, 7.5-18.9%). Agreement between emergency physician and inpatient documentation for presence of pneumonia was 57.7% (95% CI, 37.0-76.1%).

**Conclusion:** Diagnostic uncertainty remains a significant concern in patients with cancer presenting to the ED with dyspnea. Clinical uncertainty among dyspneic patients results in both misdiagnosis and under-treatment of patients with pneumonia and cancer. [West J Emerg Med. 2021;22(2)170-176.]

## INTRODUCTION

Diagnosing the etiology of shortness of breath or dyspnea in emergency department (ED) patients is challenging. ED providers frequently co-diagnose and co-treat multiple pathologies simultaneously, particularly pneumonia, heart failure (HF), and chronic obstructive pulmonary disease (COPD).[1] Diagnostic uncertainty, defined as either co-treatment or co-diagnosis, is compounded in patients with cancer due to multiple patient- and disease-specific factors. The immune response in patients with cancer may be altered due to immunosuppression, obscuring key symptoms that aid in diagnosis.[2-4] Additionally, the presence of effusions and malignant infiltrates can confound imaging results.[5, 6] Diagnostic uncertainty is particularly concerning as it negatively impacts multiple, patient-centered outcomes including increased rates of unnecessary admission, longer lengths of stay, and increased mortality.[7-9] Investigating the diagnostic accuracy associated with dyspnea in this special population is warranted, particularly as there are an estimated 4.5 million yearly visits to EDs

by patients with cancer in the United States.[10, 11] Among this population the symptom of dyspnea is the second most common reason for presentation to the ED.[12]

The appropriate diagnosis and treatment of infectious processes is of particular importance in a cancer patient with a compromised immune system. In particular, pneumonia is a common known complication of systemic therapy and radiotherapy and has been strongly associated with admission and mortality.[13] Retrospective data reveals pneumonia is the most common ED diagnosis for cancer-related visits (4.5%, or approximately 200,000 annual visits) and is associated with a high rate of admission (89%).[10] Appropriate identification of infectious pneumonia predicates appropriate treatment initiation, risk stratification, and disposition.

We examined a sample of patients with cancer presenting to the ED for acute care using a national database. The objective was to identify the rates of co-diagnosis, co-treatment and diagnostic uncertainty among common causes of dyspnea in this sample. We also sought to identify the proportion of patients diagnosed with pneumonia in this sample and the degree of misdiagnosis by emergency physicians by assessing the level of agreement between emergency physicians and inpatient physicians for the diagnosis of pneumonia.

*Population Health Research Capsule*

What do we already know about this issue?
*Dyspnea is the second most common reason for presentation to the ED by patients with cancer. Distinguishing pneumonia from other causes of dyspnea in this population is challenging.*

What was the research question?
*We sought to characterizes the diagnostic uncertainty in patients with cancer presenting to an ED with dyspnea and pneumonia.*

What was the major finding of the study?
*Diagnostic uncertainty in ED patients with cancer and dyspnea results in both misdiagnosis and under-treatment of pneumonia.*

How does this improve population health?
*Improved ED diagnostic accuracy in patients with cancer and dyspnea could improve morbidity and mortality.*

## METHODS

### Study Setting and Population

The National Hospital Ambulatory Medical Care Survey (NHAMCS) is conducted annually to describe ambulatory emergency care at US hospitals.[14] We included data from calendar years 2012 (when the cancer variable was introduced) to 2014. Data from 2015 and beyond were excluded due to the conversion of the *International Classification of Diseases* (ICD) categorization during the 2015 calendar year, limiting direct comparison to prior literature. We identified visits by individuals aged ≥18 years old with a history of cancer presenting with a complaint of dyspnea using the NHAMCS cancer variable. The following reason for visit codes for dyspnea were used: 1415.0 (shortness of breath); 1420.0 (labored or difficult breathing [dyspnea]); 1425.0 (wheezing); 1430.0 (breathing problems); 1430.1 (disorders of respiratory sound); and 1403.2 (rapid breathing).[1]

To allow comparison with previous literature[1, 15] and to exclude patients who had clear etiologies of their dyspnea (eg, atrial fibrillation with rapid ventricular response), we limited analyses of co-treatment, co-diagnosis, and diagnostic uncertainty to the subset of patients with ED diagnoses of pneumonia, COPD, or HF.

### Key Outcome Measures and Definitions

The primary outcomes were the proportion of ED visits with pneumonia diagnosis, co-diagnosis (>1 diagnosis of pneumonia, COPD, and HF), and co-treatment (treatment for >1 etiology). We included treatment in addition to diagnosis, as ED documentation of diagnoses is known to be incomplete and may not accurately represent whether the treating physician felt a condition was present. For admitted patients, we compared the agreement of ED pneumonia, COPD, and HF diagnosis with hospital discharge diagnosis.

ED and hospital diagnoses of pneumonia were defined as ICD-9-CM codes 480.xx, 481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.4x, 482.8x, 482.9, 483.xx, 485, 486, 487.0 and 488.11; COPD as codes 491.21, 491.22, 491.8, 491.9, 492.8, 493.2xx and 496; and HF as codes 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, and 428.xx. Dyspnea not otherwise specified (NOS) was defined as ICD-9-CM code 786.[1, 15]

Treatment for pneumonia, COPD, and HF were determined based on ED medications administered that were distinct for one of these conditions using the drug categories in NHAMCS and concordant with work by our group and others.[1, 15] Pneumonia treatment included penicillin, cephalosporin, fluoroquinolone, macrolide, vancomycin, tetracycline, aminoglycoside, or carbapenem antibiotics. Treatment for COPD included glucocorticoids. Treatment for HF included loop diuretics, vasodilators, or positive inotropes.[1, 14, 15] Inpatient diagnosis of pneumonia was used as the criterion standard to determine the rate of misdiagnosis by ED providers given the lack of culture and imaging results in the dataset.

**Data Analysis**

Descriptive statistics are reported. Confidence intervals and *P*-values are not reported, as statistical significance would not correlate with clinical significance given large weighted sample sizes in the dataset. We used NHAMCS weighting procedures as outlined in their documentation to obtain nationally representative estimates.[14] For strata with a single sampling unit, standard deviations calculated using both centered and certainty in STATA had similar results. We incorporated appropriate elements from published recommendations for NHAMCS analyses.[16] Data management was conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC) and data analysis using STATA 15 (StataCorp., College Station, TX).

This study was determined to be exempt from institutional review board review.

**RESULTS**

From 2012-2014, the NHAMCS contained 2464 visits representing 1,593,930 weighted ED visits by dyspneic adults with cancer. This population is described in Table 1 overall and stratified by disposition. Multiple etiologies of dyspnea exist. Table 2 reports the ED diagnosis and treatment frequency in this patient sample. Of all dyspneic cancer visits in the ED, 15.2% (95% CI, 11.1-20.5%) were diagnosed with pneumonia, 22.5% (95% CI, 16.7-29.7%) with COPD, and 7.4% (95% CI, 4.7-11.4%) with HF. Dyspnea NOS was diagnosed in 32.3% (95% CI, 25.7-39.7%) of visits and was the only diagnosis in 23.1% (95% CI, 16.3-31.6%). Co-diagnosis occurred in 4.0% (95% CI, 2.0-7.6%) of dyspneic adults with cancer and co-treatment in 12.1% (95% CI, 7.5-18.9%). Co-diagnosis of pneumonia with either COPD or HF was present in 2.6% (95% CI, 1.1-6.1%). We did not separately report co-diagnosis of all three diagnoses – pneumonia, COPD, and HF –due to too small sample size per NHAMCS guidelines.

Only 65.6% of all adult visits diagnosed with pneumonia received treatment with one of the antibiotics noted above; 61.2% of COPD visits received treatment; and 66.0% of HF visits received treatment. Imaging utilization was similar in the pneumonia subpopulation (radiograph: 88.8% [n = 215,131], chest computed tomography (CT): 15.4% [n = 37,261]) as in the total dyspneic population (radiograph: 79.3% [1,263,448], chest CT: 15.8% [n = 251,220]). Among hospitalized patients, hospital diagnosis agreement with ED diagnosis of pneumonia, COPD, and HF was low (Table 3). In admitted patients with an ED diagnosis of pneumonia, only 57.7% had a hospital discharge diagnosis of pneumonia. Rates were 45.9% for COPD and 50.3% for HF. In patients with an inpatient diagnosis of pneumonia, 74.6% had an ED diagnosis of pneumonia. Rates were 70.7% for COPD and 65.1% for HF. Among those admitted to the hospital, 168,717 (21.3%) had a length of stay of two days or less. Among those with pneumonia admitted to the hospital, 36,482 (17.9%) had a length of stay of two days or less.

**Table 1.** Weighted characteristics of adult dyspneic cancer patient visits by emergency department disposition in calendar years 2012-2014. Data presented as n rounded to nearest 1,000 (%).

| | All (n=1,594,000) | | Admitted (n=794,000) | | Not Admitted (n=800,000) | |
|---|---|---|---|---|---|---|
| Age, mean (SD) | 69.6 | (1.0) | 77.2 | (1.0) | 53.7 | (0.8) |
| Female | 711,000 | (44.6) | 353,000 | (44.4) | 359,000 | (44.8) |
| Race | | | | | | |
| White | 994,000 | (62.4) | 541,000 | (68.2) | 453,000 | (56.6) |
| Black | 117,000 | (7.3) | 79,000 | (9.9) | 38,000 | (4.7) |
| Other | 62,000 | (3.9) | 50,000 | (6.4) | 12,000 | (1.5) |
| Missing | 421,000 | (26.4) | 123,000 | (15.5) | 298,000 | (37.2) |
| Comorbidities | | | | | | |
| COPD | 583,000 | (36.6) | 299,000 | (37.7) | 284,000 | (35.4) |
| HF | 318,000 | (19.9) | 217,000 | (27.4) | 101,000 | (12.6) |
| Diabetes | 419,000 | (26.3) | 269,000 | (33.8) | 150,000 | (18.8) |
| Renal disease* | 112,000 | (7.0) | 95,000 | (11.9) | 17,000 | (2.2) |
| Residence | | | | | | |
| Private residence | 1,466,000 | (91.9) | 706,000 | (89.0) | 759,000 | (94.9) |
| Nursing home | 67,000 | (4.2) | 56,000 | (7.1) | 11,000 | (1.4) |
| Other/missing/unknown | 61,000 | (3.8) | 31,000 | (3.9) | 30,000 | (3.8) |
| Arrived by ambulance | 599,000 | (37.6) | 352,000 | (44.4) | 247,000 | (30.8) |

*Variable "EDDIAL" for calendar years 2012-2013; "chronic kidney disease" and "end-stage renal disease" for 2014.
*EDDIAL*, a condition requiring dialysis; *SD*, standard deviation; *COPD*, chronic obstructive pulmonary disease, *HF*, heart failure.

## DISCUSSION

Differentiating the etiologies of dyspnea is challenging and clinically critically important as ED diagnosis is known to affect the subsequent care of patients.[1, 17] Inappropriate treatment of dyspnea secondary to diagnostic uncertainty can result in multiple adverse patient outcomes. The diagnostic uncertainty is further complicated in this population by the natural history of cancer and the potential effects of cancer treatment. This is a significant issue in this population as the proportion with "Dyspnea NOS" as the only diagnosis listed was 23.1%. The rate of co-treatment (12.1%) when compared to co-diagnosis (4.0%) further demonstrates the challenge of diagnostic uncertainty in this population. This may suggest that providers may be ordering additional unnecessary treatment or not listing all relevant diagnoses when faced with diagnostic uncertainty. Alternatively, this may represent a choice to pick a general rather than specific code. Finally, these markers of uncertainty were higher in those admitted compared to discharged; this could reflect that the admitted patient population was more medically complex and/or more ill compared to those who were discharged and confound the results. The rates of co-diagnosis (6%), co-treatment (15%) and the proportion with "Dyspnea NOS" as the only diagnosis (23%) are similar to a population of all dyspneic, older adult ED patients.[1]

Pneumonia diagnosis among patients with cancer presenting to an ED for acute care is common.[10] In this population, pneumonia was the most common specific diagnosis (13.9%) and was commonly present in those admitted (23.1%). Our analysis reveals a concern for a high rate of pneumonia misdiagnosis and under- treatment. Among individuals hospitalized with pneumonia, only 57.7% were discharged with a diagnosis of pneumonia, suggesting a high rate of over-diagnosis of pneumonia similar to other high-risk subpopulations in the ED setting.[1] This proportion is lower

**Table 2.** Weighted diagnosis, co-diagnosis and co-treatment of adult dyspneic cancer patient visits by emergency department disposition in calendar years 2012-2014. Data presented as n rounded to the nearest 1,000 (%).

| | All (n=1,594,000) | | Admitted (n=794,000) | | Not Admitted (n=800,000) | | Admission Rate |
|---|---|---|---|---|---|---|---|
| Top 10 ICD-9 categories diagnosis* | | | | | | | |
| Symptoms involving respiratory system and other chest symptoms | 515,000 | (32.3) | 206,000 | (26.0) | 309,000 | (38.6) | (40.0) |
| Pneumonia, organism unspecified | 222,000 | (13.9) | 183,000 | (23.1) | 39,000 | (4.8) | (82.5) |
| Chronic bronchitis | 201,000 | (12.6) | 100,000 | (12.6) | 101,000 | (12.6) | (49.8) |
| Chronic airway obstruction | 153,000 | (9.6) | 51,000 | (6.4) | 102,000 | (12.7) | (33.4) |
| Heart failure (HF) | 118,000 | (7.4) | 74,000 | (9.4) | 43,000 | (5.4) | (63.2) |
| Cardiac dysrhythmias | 116,000 | (7.3) | 38,000 | (4.8) | 78,000 | (9.7) | (32.8) |
| Disorders of fluid, electrolyte and acid-base balance | 115,000 | (7.2) | 83,000 | (10.5) | 32,000 | (4.0) | (72.0) |
| Pleurisy | 115,000 | (7.2) | 82,000 | (10.3) | 33,000 | (4.2) | (71.2) |
| General symptoms | 100,000 | (6.3) | 50,000 | (6.3) | 49,000 | (6.2) | (50.5) |
| Malignant neoplasm of trachea, bronchus, lung | 90,000 | (5.7) | 29,000 | (3.6) | 62,000 | (7.7) | (31.5) |
| Diagnosed with: | | | | | | | |
| Pneumonia, all types | 242,000 | (15.2) | 203,000 | (25.6) | 39,000 | (4.8) | (84.0) |
| COPD | 359,000 | (22.5) | 151,000 | (19.0) | 208,000 | (26.0) | (42.0) |
| HF | 118,000 | (7.4) | 74,000 | (9.4) | 43,000 | (5.4) | (63.2) |
| ≥ 1 of pneumonia, COPD, HF | 654,000 | (41.1) | 382,000 | (48.1) | 273,000 | (34.1) | (58.3) |
| Pneumonia and COPD or HF | 42,000 | (2.6) | 37,000 | (4.7) | 5,000 | (0.6) | (88.8) |
| Pneumonia and COPD | 39,000 | (2.4) | 36,000 | (4.5) | 3,000 | (0.4) | (91.6) |
| Pneumonia and HF | 2,000 | (0.1) | 2,000 | (0.2) | 0 | (0.0) | (100.0) |
| Dyspnea NOS | 515,000 | (32.3) | 206,000 | (26.0) | 309,000 | (38.6) | (40.0) |
| Only dyspnea NOS | 368,000 | (23.1) | 111,000 | (14.0) | 257,000 | (32.1) | (30.2) |
| Co-diagnosis | 63,000 | (4.0) | 47,000 | (5.9) | 16,000 | (2.0) | (74.6) |
| Co-treatment | 193,000 | (12.1) | 165,000 | (20.8) | 28,000 | (3.5) | (85.4) |

*First 3 numerals of ICD-9 diagnosis code as recorded in NHAMCS variables DIAG1-DIAG3
*ICD*, International Classification of Diseases; *COPD*, chronic obstructive pulmonary disease; *NOS*, not otherwise specified.

than previously reported rates for agreement between ED and inpatient diagnosis for community-acquired pneumonia in the US (66.9%, 72%)[18, 19] but higher than a study performed in Israel (29%).[20] Additionally, among individuals diagnosed with pneumonia only 65.6% were treated with antibiotics, suggesting a high rate of under-treatment in this population. These findings are concerning as it has been demonstrated that inappropriate treatment of dyspnea in the ED and inappropriate treatment of infection in patients is associated with increased mortality.[21-23]

Using the inpatient diagnosis of pneumonia as a criterion standard, 25.4% of patients with dyspnea diagnosed as having pneumonia by the inpatient team were not identified by the ED. This is an alarmingly high rate of under-diagnosis and is increased when compared to the 20.4% reported for community-acquired pneumonia in a general ED patient population.[27] This finding may be attributed to the increased burden of comorbidities and malignancy-related changes (tumor burden, malignant effusions, treatment-related effect) in our cohort. Additionally, this proportion likely represents an overestimate of the problem in this population as a portion of patients likely developed pneumonia during their hospitalization. Under-diagnosis leads to delayed antibiotic initiation, resulting in increased mortality and morbidity. The rate noted in this study requires further investigation to determine the true rates of ED under-diagnosis of pneumonia.

Among those individuals admitted, a fifth experienced a length of stay of two days or less further emphasizing the concern that the initial ED decision to admit a patient with cancer and dyspnea could be modified in a significant number of patients. The high rate of short hospitalization suggests that improved diagnostics or care pathways may be beneficial to improving the care of these patients. This could lead to more appropriate management and disposition decisions for dyspneic patients with cancer, particularly given the high rates of admission once pneumonia is diagnosed.

One potential modality to increase diagnostic accuracy in the ED is CT imaging.[24, 25] In our study, only 15.8% of patients had a CT performed. A study of inpatients with pneumonia in a time period overlapping with our data set found a CT utilization rate of 33%.[26] It is not surprising there are higher rates of utilization in inpatients as this is likely a sicker population. Additional work would be needed to validate an early-CT strategy in the ED.

**Table 3a.** Diagnosis of pneumonia by emergency physician and inpatient providers in dyspneic cancer patients admitted to the hospital (n = 794,000). Data presented as n rounded to the nearest 1,000 (%).

| | Hospital Diagnosis | | | |
|---|---|---|---|---|
| ED diagnosis | Present | | Not present | |
| Present | 117,000 | (14.8) | 86,000 | (10.8) |
| Not Present | 40,000 | (5.1) | 550,000 | (69.3) |

*ED*, emergency department.

**Table 3b.** Diagnosis of chronic obstructive pulmonary disease (COPD) by emergency physician and inpatient providers in dyspneic cancer patients admitted to the hospital (n = 794,000). Data presented as n (%).

| | Hospital Diagnosis | | | |
|---|---|---|---|---|
| ED diagnosis | Present | | Not present | |
| Present | 69,000 | (8.7) | 82,000 | (10.3) |
| Not Present | 29,000 | (3.6) | 614,000 | (77.4) |

*ED*, emergency department.

**Table 3c.** Diagnosis of heart failure (HF) by emergency physician and inpatient providers in dyspneic cancer patients admitted to the hospital (n = 794,000). Data presented as n (%).

| | Hospital Diagnosis | | | |
|---|---|---|---|---|
| ED diagnosis | Present | | Not present | |
| Present | 37,000 | (4.7) | 37,000 | (4.7) |
| Not Present | 20,000 | (2.5) | 700,000 | (88.1) |

*ED*, emergency department.

## LIMITATIONS

Due to the retrospective nature of this study and the limitations associated with the dataset,[16, 28, 29] further characterization of diagnostic uncertainty in the ED of dyspneic patients is not possible. The uncertainty is due to multiple reasons; a prospective study would be required to further assess the outcomes and causes of dyspneic ED patients with cancer. The criterion standard for pneumonia was used as an inpatient diagnosis, but there is no ability to verify the accuracy of this diagnosis. Since we do not know whether inpatient physicians might be under-diagnosing, over-diagnosing, or both we cannot determine which direction bias arising from this problem would move our results. Further, an inpatient discharge diagnosis could reflect a problem that arose while the patient was hospitalized and thus not represent a missed diagnosis by the emergency physician. Future efforts should focus on identifying new diagnostic approaches such as biomarkers or risk stratification algorithms to improve the clinical outcomes of this patient population.

## CONCLUSION

Among patients with cancer presenting to the ED with dyspnea, diagnostic uncertainty remains a significant concern. Clinical uncertainty among dyspneic ED patients results in both misdiagnosis and under- treatment of patients with pneumonia and cancer in the ED setting. There is only moderate agreement between ED and inpatient diagnosis of pneumonia in this population. These results demonstrate a need for further research to accurately diagnose the etiologies of dyspnea in patients with cancer seeking acute care in the ED setting.

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# Effect of Blood Pressure Variability on Outcomes in Emergency Patients with Intracranial Hemorrhage

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**Introduction:** Patients with spontaneous intracranial hemorrhage (sICH) have high mortality and morbidity, which are associated with blood pressure variability. Additionally, blood pressure variability is associated with acute kidney injury (AKI) in critically ill patients, but its association with sICH patients in emergency departments (ED) is unclear. Our study investigated the association between blood pressure variability in the ED and the risk of developing AKI during sICH patients' hospital stay.

**Methods:** We retrospectively analyzed patients with sICH, including those with subarachnoid and intraparenchymal hemorrhage, who were admitted from any ED and who received an external ventricular drain at our academic center. Patients were identified by the International Classification of Diseases, Ninth Revision (ICD-9). Outcomes were the development of AKI, mortality, and being discharged home. We performed multivariable logistic regressions to measure the association of clinical factors and interventions with outcomes.

**Results:** We analyzed the records of 259 patients: 71 (27%) patients developed AKI, and 59 (23%) patients died. Mean age (± standard deviation [SD]) was 58 (14) years, and 150 (58%) were female. Patients with AKI had significantly higher blood pressure variability than patients without AKI. Each millimeter of mercury increment in one component of blood pressure variability, SD in systolic blood pressure ($SBP_{SD}$), was significantly associated with 2% increased likelihood of developing AKI (odds ratio [OR] 1.02, 95% confidence interval [CI], 1.005-1.03, p = 0.007). Initiating nicardipine infusion in the ED (OR 0.35, 95% CI, 0.15-0.77, p = 0.01) was associated with lower odds of in-hospital mortality. No ED interventions or blood pressure variability components were associated with patients' likelihood to be discharged home.

**Conclusion:** Our study suggests that greater $SBP_{SD}$ during patients' ED stay is associated with higher likelihood of AKI, while starting nicardipine infusion is associated with lower odds of in-hospital mortality. Further studies about interventions and outcomes of patients with sICH in the ED are needed to confirm our observations. [West J Emerg Med. 2021;22(2)177-185.]

## INTRODUCTION

Patients with spontaneous intracranial hemorrhage (sICH) have high mortality and morbidity rates. The 30-day mortality rate was estimated to be 35-52%.[1] Blood pressure variability (BPV) is an independent risk factor associated with outcomes among these critically ill patients, especially those suspected to have high intracranial pressure.[2-4] BPV is defined as the average of absolute differences between consecutive blood pressure measurements (successive variations in systolic blood pressure [$SBP_{SV}$]) or variations in SBP during a period of time (standard deviation [$SBP_{SD}$]).[3]

Emergency physicians (EP) are among the first clinicians to manage critically ill patients when they first present. Effective management by EPs has been associated with improved patient outcomes.[5,6] However, little is known about the association between EPs' management and sICH patients' outcomes once patients leave the emergency department (ED).

It has been shown that acute kidney injury (AKI) results in negative patient outcomes in critically ill patients, but AKI and outcomes among patients with sICH are not well described.[7,8] Furthermore, patients with sICH are at a high risk for developing AKI due to their existing hypertensive nephropathy, which in turn was associated with worse outcomes in patients with sICH.[9,10] However, the correlation between BPV during patients' ED stay and AKI has not been investigated. In our study, which included patients with either subarachnoid hemorrhage (SAH) or intraparenchymal hemorrhage (IPH), we aimed to elucidate the association of BPV during sICH patients' ED stay and the development of AKI during their hospitalization. We also studied how effectively EPs managed these critically ill patients' blood pressures according to guidelines, and whether EPs' interventions are associated with our primary outcome of in-hospital AKI and our secondary outcomes of discharge home and mortality. We hypothesized that BPV in the ED would be associated with AKI. Furthermore, EPs' interventions would also be associated with outcomes in these critically ill patients.

*Population Health Research Capsule*

What do we already know about this issue?
*Critically ill patients, including those with ischemic stroke, are at increased risk to develop acute kidney injury (AKI).*

What was the research question?
*Would blood pressure variability (BPV) in the emergency department (ED) be associated with AKI among spontaneous intracranial hemorrhage (sICH) patients?*

What was the major finding of the study?
*In sICH, standard deviation in systolic blood pressure was associated with developing AKI. Nicardipine in the ED was associated with lower odds of in-hospital mortality.*

How does this improve population health?
*Our findings provide evidence for clinicians to avoid BPV in the ED and to use nicardipine early for patients with sICH.*

## METHODS

### Study Setting and Patient Selection

After obtaining approval from our institutional review board, we retrospectively studied all adult patients who were admitted to our quaternary academic medical center for management of sICH. Patients who were admitted between January 1, 2011–September 30, 2015 and underwent external ventricular drain (EVD) placement at our medical center were eligible. We identified patients from the electronic health records (EHR) during the study period according to the International Classification of Diseases, Ninth Revision (ICD-9), for sICH: code 430.XX or 431.XX, and procedure code 02.21 for EVD placement.[11,12] Patients with SAH and IPH were included. We excluded patients with insufficient ED records or those with traumatic hemorrhage. We also excluded patients whose source of hemorrhage was secondary to tumor, arteriovenous malformations, ischemic stroke, etc, because these patients have different pathophysiology and outcomes from those with sICH.[13,14]

### Outcome Measures

Our primary outcome was the development of AKI during hospital stay. We used the serum creatinine criteria from the Kidney Disease Improving Global Outcomes scale to identify patients with AKI and their respective stage.[15] We defined stage 1 AKI as a rise in serum creatinine during hospitalization ≥ 0.3 milligrams per deciliter (mg/dL) or a 1.5-times to 1.9-times increase from level at ED presentation. AKI stage 2 occurred if patients' serum creatinine increased from 2-times to 2.9-times their serum creatinine level at ED presentation. AKI stage 3 occurred when the serum creatinine level increased to ≥ 3-times the level at ED presentation.[15] Patients with a history of end-stage renal disease (ESRD) were considered as not having AKI, but were still included in the study.

Our secondary outcomes included the percentage of patients achieving goal SBP at ED departure according to previous guidelines, in-hospital mortality, and being discharged home directly from the hospital.[16] The American Heart Association/American Stroke Association guidelines recommend that clinicians reduce sICH patients' SBP to ≤ 160 millimeters of mercury (mm Hg).[16] We also selected discharge home as an outcome because it has been shown to correlate with good functional independence, compared to

those patients who are discharged to a rehabilitation center or nursing home.[17]

**Data Collection and Management**

The principal investigator (PI) trained research team members, who were not blinded to the study hypothesis, to extract data. Research team members were trained by sets of 10 patients' charts until inter-raters' agreements achieved at least 90% with the PI's data. Data was extracted into a standardized Microsoft Excel spreadsheet (Microsoft Corp, Redmond, WA). Research team members also extracted data in sections to reduce bias. For example, investigators extracting blood pressure records did not have access to outcome data, and vice versa. Another investigator independently checked 20% of the data to maintain 90% inter-raters' agreements during the data collection phase. The team met every other month to adjudicate disagreements until the data collection was completed.

We collected ED clinical factors (eg, blood pressure, invasive mechanical ventilation, seizure, etc) from ED paper records that accompanied patients if they were transferred from other hospitals' EDs. From these ED records, we collected details regarding the managements performed by EPs. Only interventions that were completed were recorded. Interventions that were ordered but not performed were not recorded in our dataset. Patients' demographic data (eg, age, gender, referring facilities, etc), laboratory values during hospitalization, and dispositions were obtained from our medical center's EHR.

**Blood Pressure Variability (BPV)**

BPV was calculated as previously described.[2-4] Since there is no established standard regarding how frequently ED staff record blood pressures in EDs, we extracted four measurements that were most clinically relevant during patients' ED stay and available for all patients: at ED triage ($SBP_{Triage}$); at ED departure ($SBP_{Depart}$); the highest one ($SBP_{Max}$); and the lowest one ($SBP_{Min}$), according to their chronological order. The values for $SBP_{Max}$ and $SBP_{Min}$ were not the same as $SBP_{Triage}$ and $SBP_{Depart}$. Appendix 1 depicts BPV graphically using the mean $SBP_{Triage}$, $SBP_{Max}$, $SBP_{Min}$, and $SBP_{Depart}$ for all patients. Additionally, the formulas used to calculate successive variations in systolic blood pressure ($SBP_{SV}$) and standard deviation (SD) in systolic blood pressure ($SBP_{SD}$) are presented.

**Sample Size Calculation**

We performed a sample size calculation according to a previous study about BPV in critically ill patients who developed AKI.[19] Based on this study, we determined that we would need at least 124 patients, or 62 patients with acute AKI and 62 without AKI, to detect a difference of three units of $SBP_{SD}$ with $\alpha = 0.05$ and power of 80%.

**Data Analysis**

We reported descriptive analyses with mean (±SD) or median (interquartile range [IQR]). We analyzed continuous data with a Student's t-test or Mann-Whitney U test as appropriate. We compared categorical data by Pearson's chi-square test or Fisher's exact test as appropriate.

To assess association between BPV, clinical factors during patients' ED stay, and AKI during their hospital stays, we performed a backward stepwise multivariable logistic regression. Independent variables to be included in the multivariable logistic regression were selected a priori and are shown in Appendix 2. All of these independent variables were included in the backward stepwise logistic regression for the models with all patients and the outcomes of interest (AKI, mortality, and discharge home). To reduce the risk of overfitting the multivariable models, we specified the significance level to remove interaction terms from the model as 0.05, which was stricter than the recommended level of 0.10.[20] We assessed the goodness-of-fit of our models with the Hosmer-Lemeshow test. Models with $p > 0.05$ were considered a good fit.

Since patients with SAH and IPH have different pathologies and mortality according to their disease severity, we first performed a multivariable analysis for all patients, which contained both SAH and IPH patients without including their disease severity scores. We subsequently performed multivariable analyses for each subgroup and included appropriate disease severity. We used the Hunt and Hess scale for patients with SAH and the Intracerebral Hemorrhage score and Functional Outcome in Patients with Primary Intracerebral Hemorrhage score for patients with IPH.

Independent variables with two-tailed $p < 0.05$ were considered statistically significant. We performed statistical analyses with Minitab version 19 (Minitab LLC, State College, PA) and SigmaPlot version 13 (www.systatsoftware.com, San Jose, CA). The bar graph was generated using GraphPad Prism version 8.3.1 (GraphPad Software, San Diego, CA).

## RESULTS

**Patient Characteristics**

We identified 378 eligible patients electronically and analyzed 259 patients (Figure 1). In our patient population, 71 (27%) developed AKI during hospitalization. There were no patients with ESRD in our patient population. The total number of individuals with AKI also met the requirements of our sample size calculation.

Patients' mean age (± SD) was 58 (14) years, and 150 (58%) were female (Table 1). The majority of patients (69%) had SAH, while 31% had IPH. The mean intracranial opening pressure (± SD) for our patients was 22 (7) centimeters water. Patients who developed AKI during hospitalization had significantly higher mean serum creatinine levels at ED presentation, when compared to those who did not develop AKI [1.3 (1.3) vs 0.8 (0.5), $p = 0.002$]. The median time interval from admission to the development of AKI in days [IQR] was 23 [3-38] days (Table 1).

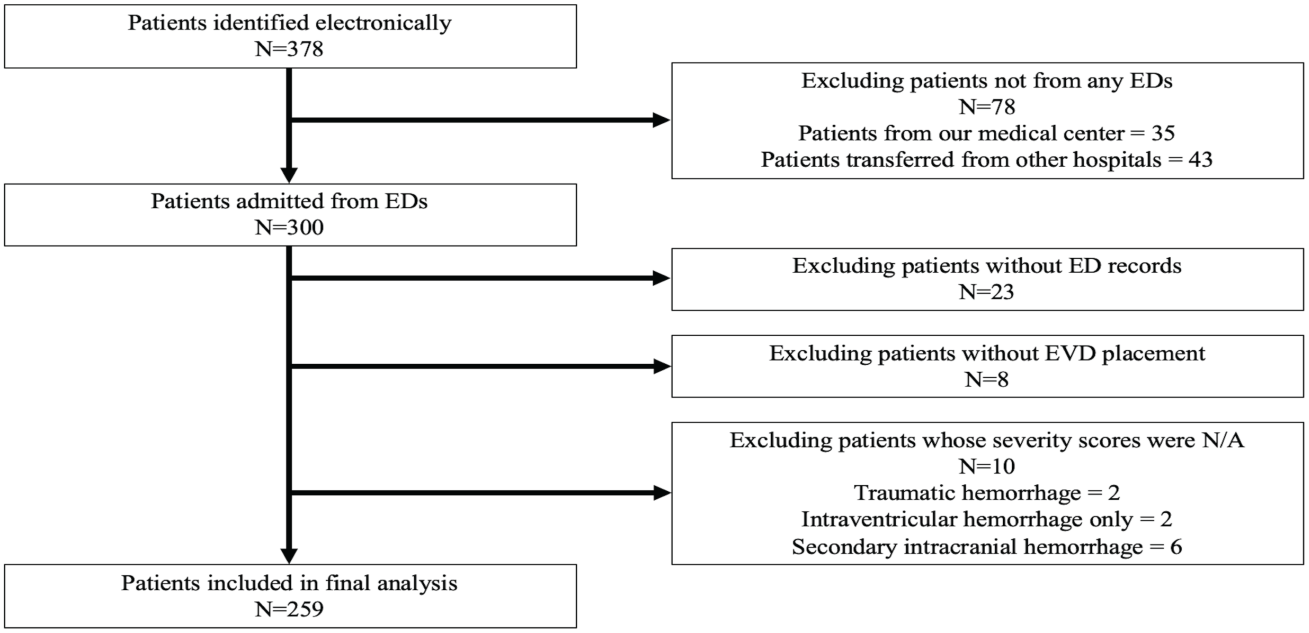



**Figure 1.** Patient selection diagram with patients included in final analysis.
*ED,* emergency department; *EVD,* external ventricular drain; *N/A,* not applicable.

**Managements in Emergency Departments**

Overall, the median [IQR] of the total number of ED interventions was similar between patients with or without AKI (3 [1-5] vs 3 [2-4], $p = 0.64$) (Table 2). Forty-two (59%) patients with AKI required invasive mechanical ventilation, compared to 101 (54%) patients without AKI. Both groups of patients received similar amounts of intravenous (IV) crystalloids in the ED. The percentage of patients receiving nicardipine infusion was also similar between groups (31% vs 26%, $p = 0.38$).

**Blood Pressure Variability and Patients' Outcomes**

Patients with AKI had significantly higher mean $SBP_{SD}$ than patients without AKI (48 [24] mm Hg vs 38 [20] mm Hg, $p = 0.002$) (Table 1). Similarly, patients with AKI also had higher $SBP_{SV}$ (36 [23] vs 28 [20] mm Hg, $p = 0.01$). While bivariate analyses showed that mortality and hospital length of stay (LOS) were similar between both groups (Table 1), only 8 (11%) patients with AKI were discharged home directly, compared with 49 (26%, $p = 0.01$) patients without AKI.

Our study showed that 94 (36%) patients had a SBP at ED triage ($SBP_{Triage}$) of ≤ 160 mm Hg, with 47 (18%) patients having a maximum SBP ($SBP_{Max}$) of ≤ 160 mm Hg during their ED stay (Figure 2). At ED departure, 165 (64%) patients had a SBP ($SBP_{Depart}$) ≤ 160 mm Hg. This increment in percentage of patients whose SBP at ED departure met the recommended guidelines was statistically significant ($p = <0.001$) (Figure 2).

Multivariable logistic regression showed that patients' increased presenting serum creatinine levels (OR 2.4, 95% confidence interval [CI] 1.4-4.2, $p = 0.002$) and higher $SBP_{SD}$ in EDs (OR 1.02, 95% CI, 1.005-1.03, $p = 0.007$) were significantly associated with increased likelihood of developing AKI during hospitalization (Table 3). Our result suggested that each unit increment of $SBP_{SD}$ in mm Hg is associated with 2% increased likelihood of developing AKI. The goodness-of-fit test with Hosmer-Lemeshow's *P*-value for this test was > 0.05.

For the secondary outcome of mortality (Table 4), more advanced age was consistently associated with higher odds of in-hospital death in all patients (OR 1.03, 95% CI, 1.005-1.05, $p = 0.017$) and the subgroup of patients with SAH (OR 1.05, 95% CI, 1.004-1.09, $p = 0.03$) (Appendix 3). Each increased year of age was associated with a 3% increased risk of mortality. Similarly, starting nicardipine infusion in EDs was associated with lower odds of death in all patients (OR 0.35, 95% CI, 0.15-0.77, $p = 0.01$) and subarachnoid subgroup (OR 0.19, 95% CI, 0.4-0.82, $p = 0.027$). Additionally, higher Hunt and Hess scale (OR 3.9, 95% CI, 1.5-10.3, $p = 0.006$) and higher ICH score (OR 2.1, 95% CI, 1.2-3.9, $p = 0.014$) were significantly associated with higher odds of death for subarachnoid and intraparenchymal subgroups, respectively (Appendix 3). All three models showed goodness-of-fit tests with $p > 0.05$.

For the secondary outcome of discharge home directly from the hospital (Table 4), increased age was associated with decreased odds of being discharged home in all patients (OR 0.96, 95% CI, 0.94-0.98, $p = 0.004$). Each increased year of age was associated with a 4% lower likelihood of being discharged home. Increased age (OR 0.97, 95%, CI 0.94-0.99, $p = 0.03$) and a higher Hunt and Hess scale (OR 0.51, 95% CI, 0.37-0.71, $p = 0.001$) were associated with lower likelihood of

**Table 1.** Characteristics of patients with spontaneous intracranial hemorrhage who were transferred from emergency departments (ED) to a tertiary care center.

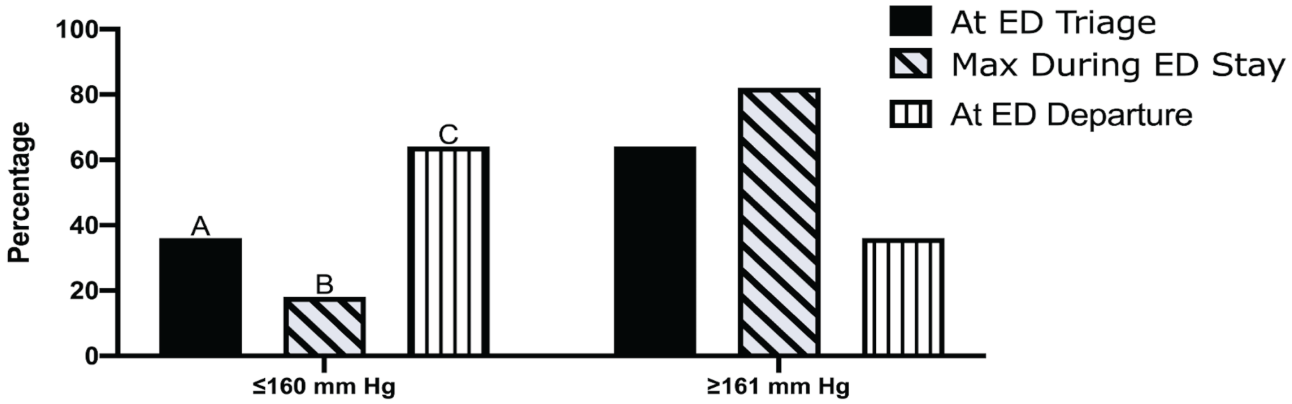
| Variables | All patients (N = 259) | AKI during hospital stay (N = 71) | No AKI (N = 188) | P-value† |
|---|---|---|---|---|
| Age (years), mean (Standad deviation [SD]) | 58 (14) | 57 (13) | 59 (14) | 0.15 |
| Gender, N (%) | | | | |
| Male | 109 (42) | 38 (54) | 71 (38) | **0.022** |
| Female | 150 (58) | 33 (46) | 117 (62) | |
| Transport type, N (%) | | | | |
| Ground | 175 (68) | 48 (68) | 127 (68) | 0.99 |
| Air | 84 (32) | 23 (32) | 61 (32) | |
| ESI, median [IQR][a] | 2 [1-3] | 2 [1-3] | 2 [1-3] | 0.80 |
| Ground distance (kilometers), mean (SD) | 29 (40) | 28 (37) | 30 (41) | 0.70 |
| ED LOS (minutes), mean (SD) | 222 (161) | 214 (139) | 225 (169) | 0.59 |
| Type of hemorrhage, N (%) | | | | |
| Subarachnoid hemorrhage (SAH) | 180 (69) | 42 (59) | 138 (73) | **0.026** |
| Intraparenchymal hemorrhage (IPH) | 79 (31) | 29 (41) | 50 (27) | |
| Disease severity for patients with SAH | | | | |
| Hunt & Hess scale*, median [IQR] | 3 [2-4] | 3 [2-4] | 3 [2-4] | 0.32 |
| Disease severity for patients with IPH | | | | |
| Intracerebral Hemorrhage score*, mean (SD) | 2 (1) | 2 (1) | 3 (1) | 0.84 |
| FUNC score#, mean (SD) | 7 (2) | 8 (2) | 7 (2) | 0.55 |
| Seizure, N (%) | 27 (10) | 10 (14) | 17 (9) | 0.24 |
| Serum sodium (mEq/L), mean (SD) | 141 (5) | 141 (4) | 141 (5) | 0.94 |
| Serum creatinine (mg/dL), mean (SD) | 1.0 (0.8) | 1.3 (1.3) | 0.8 (0.5) | **0.002** |
| Platelet (count/μL), mean (SD) | 235 (79) | 225 (81) | 239 (79) | 0.20 |
| International normalized ratio, mean (SD) | 1.1 (0.3) | 1.1 (0.3) | 1.1 (0.3) | 0.48 |
| Serum glucose (mg/dL), mean (SD) | 165 (62) | 169 (68) | 163 (59) | 0.56 |
| $SBP_{Max}$ (mm Hg), mean (SD) | 196 (37) | 211 (41) | 190 (35) | **<0.001** |
| $SBP_{Min}$ (mm Hg), mean (SD) | 136 (26) | 141 (29) | 135 (25) | 0.09 |
| $SBP_{Max-Min}$ (mm Hg), mean (SD) | 59 (36) | 70 (40) | 55 (34) | **0.01** |
| $SBP_{SV}$ (mm Hg), mean (SD) | 30 (21) | 36 (23) | 28 (20) | **0.01** |
| $SBP_{SD}$ (mm Hg), mean (SD) | 41 (21) | 48 (24) | 38 (20) | **0.002** |
| ICU SBP (mm Hg), mean (SD) | 147 (25) | 151 (26) | 145 (25) | 0.11 |
| ICU admission GCS, median [IQR] | 9 [6-14] | 9 [7-14] | 9 [6-14] | 0.66 |
| Intracranial opening pressure (cm $H_2O$), mean (SD) | 22 (7) | 22 (7) | 22 (7) | 0.76 |
| AKI within 24 hours of admission, N (%) | 26 (10) | 25 (35) | 1 (1) | **<0.001** |
| Time interval to AKI (days), median [IQR] | N/A | 23 [3-38] | N/A | N/A |
| Any AKI during hospitalization, N (%) | | | | |
| AKI-level 1 | 52 (20) | 52 (73) | N/A | N/A |
| AKI-level 2 and 3 | 19 (7) | 19 (27) | N/A | N/A |
| Mortality, N (%) | 59 (23) | 21 (30) | 38 (20) | 0.11 |
| Hospital length of stay (days), median [IQR] | 21[14-30] | 23 [12-33] | 20 [14-28] | 0.31 |
| Discharge home, N (%) | 57 (22) | 8 (11) | 49 (26) | **0.01** |

*Higher score, more severe disease.
#Higher score, better outcome.
[a] Emergency Severity Index (ESI) is ranked from 1 (most severe) to 5 (least severe). Patients who were assigned a lower score are associated with higher acuity and higher care intensity in the ED.
†Bold cells indicate statistically significant findings
*AKI,* acute kidney injury; *cm $H_2O$,* centimeters of water; *count/μL,* count per microliter; *$SBP_{Max-Min}$*, difference between maximum and minimum systolic blood pressure; *FUNC score,* Functional Outcome in Patients with Primary Intracerebral Hemorrhage score; *GCS,* Glasgow Coma Scale; *ICU,* intensive care unit; *IQR,* interquartile range; *$SBP_{Max}$*, maximum systolic blood pressure; *mEq/L,* milliequivalents per liter; *mg/dL,* milligrams per deciliter; *mm Hg,* millimeters of mercury; *$SBP_{Min}$*, minimum systolic blood pressure; *N/A,* not applicable; *$SBP_{SD}$*, standard deviation in systolic blood pressure; $SBP_{SV}$, successive variations in systolic blood pressure.

**Table 2.** Emergency department management of patients with spontaneous intracranial hemorrhage.

| Variables | All patients (N = 259) | AKI during hospital stay (N = 71) | No AKI (N = 188) | P-value |
|---|---|---|---|---|
| Total number of interventions, median [IQR] | 3 [1-4] | 3 [1-5] | 3 [2-4] | 0.64 |
| Total amount of IVF (mL), mean (SD) | 258 (549) | 266 (647) | 238 (485) | 0.74 |
| ED mechanical ventilation, N (%) | 143 (55) | 42 (59) | 101 (54) | 0.43 |
| Any sedation, N (%) | 102 (39) | 32 (45) | 70 (37) | 0.25 |
| Propofol infusion, N (%) | 66 (25) | 23 (32) | 43 (23) | 0.12 |
| IVP benzodiazepines, N (%) | 43 (17) | 15 (21) | 28 (15) | 0.23 |
| Any paralytics, N (%) | 55 (21) | 17 (24) | 38 (20) | 0.51 |
| Succinylcholine, N (%) | 23 (9) | 6 (8) | 17 (9) | 0.88 |
| Rocuronium, N (%) | 32 (12) | 11 (15) | 21 (11) | 0.35 |
| Any pain medication, N (%) | 82 (32) | 20 (28) | 62 (33) | 0.46 |
| Fentanyl infusion, N (%) | 5 (2) | 1 (1) | 4 (2) | 0.99 |
| IVP morphine equivalent (unit), mean (SD) | 3 (5) | 2 (4) | 3 (5) | 0.11 |
| Any hyperosmolarity therapy, N (%) | 41 (16) | 13 (18) | 28 (15) | 0.50 |
| Any antihypertensive medication, N (%) | 131 (51) | 40 (56) | 91 (48) | 0.26 |
| IVP labetalol, N (%) | 68 (26) | 22 (31) | 46 (24) | 0.29 |
| Nicardipine infusion, N (%) | 70 (27) | 22 (31) | 48 (26) | 0.38 |
| Any blood product, N (%) | 10 (4) | 5 (7) | 5 (3) | 0.14 |
| Platelet, N (%) | 2 (1) | 1 (1) | 1 (1) | 0.47 |
| Fresh frozen plasma, N (%) | 8 (3) | 4 (6) | 4 (2) | 0.22 |
| Packed RBCs, N (%) | 0 (0) | 0 (0) | 0 (0) | N/A |
| Any arterial line monitoring, N (%) | 5 (2) | 1 (1) | 4 (2) | 0.99 |

*AKI,* acute kidney injury; *ED*, emergency department; *IQR*, interquartile range; *IVF,* intravenous fluid; *IVP,* intravenous push; *mL,* milliliter; *N/A,* not applicable; *RBCs*, red blood cells; *SD,* standard deviation.




| Variables | SBP ≤160 mm Hg | | | SBP ≥161 mm Hg | | | *P* | |
|---|---|---|---|---|---|---|---|---|
| | At ED Triage | Max During ED Stay | At ED Departure | At ED Triage | Max During ED Stay | At ED Departure | A vs. B | A vs. C |
| **Total patients, N (%)** | 94 (36) | 47 (18) | 165 (64) | 165 (64) | 212 (82) | 94 (36) | **<0.001** | **<0.001** |
| **SBP (mm Hg), mean (SD)** | 139 (18) | 145 (12) | 134 (16) | 200 (28) | 207 (31) | 178 (16) | 0.08 | **0.02** |

**Figure 2.** Percentage of patients with systolic blood pressure measurements ≤160 millimeters mercury (mm Hg) or ≥161 mm Hg at different time intervals in the emergency department (ED): at ED triage; during ED stay; and at ED departure.
*ED,* emergency department; *mm Hg,* millimeters of mercury; *SD,* standard deviation; *SBP,* systolic blood pressure.

**Table 3.** Backward stepwise multivariable logistic regression to measure the association between clinical variables and primary outcome: acute kidney injury during hospitalization. All a priori selected variables were included, but only significant variables were reported.

| Variables | OR | 95% CI | P-value |
|---|---|---|---|
| Serum creatinine – each mg/dL | 2.4 | 1.4-4.2 | 0.002 |
| $SBP_{SD}$ – each mm Hg | 1.02 | 1.005-1.03 | 0.007 |

Hosmer-Lemeshow goodness-of-fit test: degrees of freedom = 8, χ2 value= 15.7, p > 0.05.
*CI,* confidence interval; *mg/dL,* milligrams per deciliter; *mm Hg,* millimeters of mercury; *OR,* odds ratio; $SBP_{SD}$, standard deviation in systolic blood pressure.

**Table 4.** Backward stepwise multivariable logistic regressions to measure associations between clinical variables and secondary outcomes: mortality and discharge home. All a priori selected variables were included but only significant variables were reported.

| | All patients | | |
|---|---|---|---|
| | OR | 95% CI | P-value |
| Outcome: mortality | | | |
| Age | 1.03 | 1.005-1.05 | 0.017 |
| ED MV | 5.6 | 2.7-11.6 | 0.001 |
| Nicardipine infusion | 0.35 | 0.15-0.77 | 0.01 |
| Outcome: discharge home | | | |
| Age | 0.96 | 0.94-0.98 | 0.004 |
| ED MV | 0.2 | 0.1-0.4 | 0.001 |

Mortality and all patients, Hosmer-Lemeshow test: degrees of freedom = 8, χ2= 7.76, P = 0.45.
Discharge home and all patients, Hosmer-Lemeshow test: degrees of freedom = 8, χ2= 10.1, P = 0.26.
*CI,* confidence interval; *ED,* emergency department; *MV,* invasive mechanical ventilation; *OR,* odds ratio.

being discharged home among the subgroup of patients with SAH (Appendix 3). Goodness-of-fit tests' *p*-values for both models were > 0.05. We could not perform subgroup analysis for patients with IPH and discharge home, as there were not enough outcome measures to perform reliable multivariable logistic regression analyses.

## DISCUSSION

Our study demonstrated that a 10-unit mm Hg increase of $SBP_{SD}$ during patients' ED stay was associated with a 2.7-fold likelihood of developing AKI. Patients' absolute level of blood pressure, specifically their $SBP_{Max}$ and $SBP_{Min}$, did not have a significant association with AKI. Furthermore, we did not demonstrate an association between BPV with mortality or discharge home. Factors associated with patients' secondary outcomes were related to their disease severity (eg, age, the need for mechanical ventilation in ED) but nicardipine infusion by EPs was associated with decreased likelihood of patients' in-hospital mortality.

The association between BPV and AKI has yet to be established for sICH patients. In critically ill patients with stroke, AKI has been associated with worse patient-centered outcomes by negatively impacting discharge disposition and mortality.[21-23] Blood pressure control has been highlighted in stroke patients to contribute to renal injury, but this association remains unclear in the sICH patient population, especially in the hyperacute phase. Moreover, renal insufficiency that goes unrecognized has been shown to be common in stroke patients and negatively impact their short-term outcomes.[24,25] Our study suggests that one component of BPV during patients' ED stay, the $SBP_{SD}$, was significantly associated with sICH patients developing AKI during their hospital stay.

Patients who experience a sudden elevation of blood pressure, such as those with hypertensive sICH, would experience a condition called pressure natriuresis.[26] Patients with this condition would experience a significant increase of urinary sodium excretion and volume diuresis causing them to be intravascularly depleted.[26] As a result, it is recommended that EPs' monitor these high-risk patients' volume statuses closely since hypovolemia may precipitously lower patients' blood pressure. Furthermore, EPs' should consider using nicardipine infusion early to smoothly reduce patients' blood pressure toward the goal of a SBP ≤ 160 mm Hg to comply with the American Heart Association's guidelines.[16] Nicardipine infusion has been shown to reduce blood pressure toward this goal more rapidly, while producing less BPV than intravenous push (IVP) antihypertensive medication.[27-29]

Although our study did not identify BPV as an independent risk factor for the outcome of mortality among patients with sICH, we identified one EPs' intervention that was associated with patients' in-hospital mortality. Starting nicardipine infusion in the ED was associated with 65% lower likelihood of death for patients. This observation was present in the all-patient group, and was confirmed in the SAH subgroup, after adjusting for their appropriate disease severity. However, this effect was not present in the IPH subgroup, likely due to its smaller sample size. Nicardipine infusion was shown to produce less BPV compared to other IVP antihypertensive medications (eg, labetalol, hydralazine).[28,29] Therefore, it is possible that patients in our study who received nicardipine infusion in the ED had less BPV and were less likely to develop hematoma expansion as well as neurological deterioration.[18,30,31] Further studies are needed to confirm our observations and to further investigate EPs' interventions and sICH patients' outcomes.

The percentage of patients who developed AKI in our sICH patient population agreed with a previous study's result.[10] From bivariate analyses, without adjusting for any other confounding factors, Ansaritoroghi et al reported that the causes of AKI were attributed to nephrotoxic antibiotics and contrast media.[10] Therefore, we could not exclude other causality between $SBP_{SD}$ and AKI in our study. Patients who had higher BPV could have been more critically ill

and thus may have had to undergo more imaging studies and interventions. These interventions in turn predisposed patients to even higher risks of developing AKI during their hospital stay.

## LIMITATIONS

Our study had several limitations. Due to its retrospective nature, we could not account for different factors affecting patients' clinical care. Our study also relied on paper ED records, which could have been inadequate in critically ill patients.[32] We only included four blood pressure measurements, which may have affected the overall values of BPV, as a previous study involving the hyperacute phase of patients with sICH used five blood pressure measurements.[2] However, a previous report in abstract format reported that the number of blood pressure measurements was not associated with different BPV among patients with ischemic stroke undergoing thrombectomy.[33] Additionally, a survey of hospitals reported that there is currently no established protocol for the management and frequency of blood pressure measurements in patients with sICH.[34] Therefore, we extracted blood pressure measurements available for all patients to ensure a more uniform analysis.

Since patients' baseline creatinine levels were unknown, we used serum creatinine as the criteria to determine AKI. This may have underestimated the incidence of AKI, as many at-risk patients have already developed higher serum creatinine levels when they present to EDs. Since the majority of our patient population was transferred from other hospitals, we could not follow up with them to determine whether AKI developed during hospitalization was permanent or if their creatinine function returned to baseline after discharge. Also, our study only included patients who required EVD after admission, which may limit our study's generalizability. We were unable to perform subgroup analysis for patients with IPH and the outcome of discharge home because this subgroup did not have enough patients who were discharged home. By using a stricter than usual criteria to enter and remove variables, our stepwise multivariable regressions may have eliminated otherwise eligible independent variables. The design of the Minitab (version 19) statistical software does not retain any information regarding non-significant variables in the stepwise multivariable logistic regressions. As a result, we cannot present the statistical information for these non-significant independent variables from our regressions.

Our study also possessed a few strengths. We demonstrated the association between BPV in the ED with a comorbidity for patients with sICH. Furthermore, we provided evidence that nicardipine infusion in EDs would be associated with lower odds of death for these critically ill patients, although further studies are necessary to confirm our observations.

## CONCLUSION

Our study suggests greater $SBP_{SD}$ during patients' ED stay is associated with development of AKI during hospital stay among patients with sICH. Furthermore, we identified that starting nicardipine infusion in the ED was significantly associated with a 65% reduction in patients' odds of in-hospital mortality. Further studies about managements in EDs and outcomes of patients with sICH are needed to confirm our observation.

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# Evidence-Based Heatstroke Management in the Emergency Department

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**Introduction:** Climate change is causing an increase in the frequency and intensity of extreme heat events, which disproportionately impact the health of vulnerable populations. Heatstroke, the most serious heat-related illness, is a medical emergency that causes multiorgan failure and death without intervention. Rapid recognition and aggressive early treatment are essential to reduce morbidity and mortality. The objective of this study was to evaluate current standards of care for the emergent management of heatstroke and propose an evidence-based algorithm to expedite care.

**Methods:** We systematically searched PubMed, Embase, and key journals, and reviewed bibliographies. Original research articles, including case studies, were selected if they specifically addressed the recognition and management of heatstroke in any prehospital, emergency department (ED), or intensive care unit population. Reviewers evaluated study quality and abstracted information regarding demographics, scenario, management, and outcome.

**Results:** In total, 63 articles met full inclusion criteria after full-text review and were included for analysis. Three key themes identified during the qualitative review process included recognition, rapid cooling, and supportive care. Rapid recognition and expedited external or internal cooling methods coupled with multidisciplinary management were associated with improved outcomes. Delays in care are associated with adverse outcomes. We found no current scalable ED alert process to expedite early goal-directed therapies.

**Conclusion:** Given the increased risk of exposure to heat waves and the time-sensitivity of the condition, EDs and healthcare systems should adopt processes for rapid recognition and management of heatstroke. This study proposes an evidence-based prehospital and ED heat alert pathway to improve early diagnosis and resource mobilization. We also provide an evidence-based treatment pathway to facilitate efficient patient cooling. It is hoped that this protocol will improve care and help healthcare systems adapt to changing environmental conditions. [West J Emerg Med. 2021;22(2)186–195.]

## INTRODUCTION

Climate change is causing a global increase in average temperatures as well as an increase in the frequency, duration, and intensity of extreme heat events,[1-3] resulting in unprecedented levels of exposure to heat. Between 2000 and 2016, an estimated 125 million additional adult Americans were exposed to heat waves, and in the year 2017 alone, the majority of Americans experienced temperatures that were the hottest

recorded.[4,5] The number of days with dangerously elevated temperatures are projected to increase in coming years.[6] This will create significant challenges for exposed populations, healthcare systems, and public health officials leading community prevention and response efforts.[7] Emergency departments (ED) are likely to treat increasing numbers of patients affected by extreme heat.[8] According to the Centers for Disease Control and Prevention, heat-related illnesses are the leading cause of weather-related death in the United States.[9]

Heatstroke, the most serious heat-related illness, is a medical emergency that requires rapid recognition and treatment to prevent permanent morbidity and mortality.[10] The hallmark of heatstroke is the combination of central nervous system dysfunction and elevated core body temperature, defined as over 40 degrees Celsius.[11] The presenting symptoms of heatstroke can mimic many other illnesses including sepsis, ischemic stroke, and toxicologic emergencies, particularly if a core body temperature is not obtained. On average, 618 deaths are reported per year in the US due to environmental heat[12]; however, this is likely a gross underestimate of the true extent of heat-related illness as comorbid diseases that are exacerbated by heat exposure are often erroneously reported as the primary diagnosis, thus concealing the role of heat as an inciting factor.[13]

Exposure to elevated ambient temperatures coupled with increased metabolic activity may result in heat illness if the individual has exhausted physiological compensatory mechanisms and is unable to take behavioral steps to cool down.[14] Heat stress initially leads to activation of compensatory mechanisms such as sweating, which help maintain stable core temperature, but eventually lead to consumption of fluid and electrolyte reserves. Once these internal and behavioral mechanisms are overwhelmed, core temperature can rise precipitously. Left unchecked, elevated core temperature can result in catastrophic multisystem illness characterized by renal injury, liver injury, vascular inflammation, coagulopathy, airway spasms, disruption of homeostatic thermoregulation, and central nervous system dysfunction and death.[15]

Any person exposed to high environmental temperatures is at risk of heatstroke, but specific populations are at a comparatively higher risk of experiencing adverse health outcomes. Heat poses serious risks for children, older adults, pregnant women, and those with chronic health conditions such as cardiovascular, respiratory, renal, or psychiatric disease. Heat illness is also a disease of socioeconomic vulnerability and occupational vulnerability.[8,16] Communities in rural areas as well as dense urban settlements (heat islands) are at higher risk as well as certain demographics of workers, which include outdoor workers employed in agriculture and construction, first responders, military personnel, and others.[5]

Medications that interfere with salt and water balance and circulatory function place individuals at even higher risk. These medications include but are not limited to diuretics, anticholinergic agents, and beta-blockers, as well as medications that interfere with centers of thermoregulation such as selective serotonin reuptake inhibitors and anti-dopaminergic medications.[17] Heatstroke can result from either environmental exposure (classic heatstroke) or intense physical activity (exertional heatstroke), but in both cases early identification and rapid intervention are critical to survival and neurologic outcome. Older adults are at risk for classic heatstroke while younger individuals tend to be affected by exertional heatstroke.

*Population Health Research Capsule*

What do we already know about this issue?
*Heatstroke is a life-threatening, time-sensitive condition that requires significant resources to treat.*

What was the research question?
*What are the processes and current standards of care in the literature for the acute management of heatstroke?*

What was the major finding of the study?
*Recognition, rapid cooling, and supportive care were key steps to treatment, yet no scalable process was found.*

How does this improve population health?
*Our proposed heatstroke treatment pathway may assist healthcare systems to adapt to a changing climate and protect populations at increased risk.*

Emergency departments have alert systems for other high-risk, time-sensitive conditions to appropriately allocate human and hospital resources in a timely manner to improve patient outcomes. For example, sepsis and cardiac alerts are a component of quality incentive metrics for many EDs and have been shown to improve mortality.[18-20] Stroke alerts expedite imaging and timely intervention.[21,22] With these time-sensitive conditions, emergency medical services (EMS) also participates in identifying and initiating treatment by alerting treatment teams prior to hospital arrival to prepare for rapid, aggressive treatment. The time sensitivity of heatstroke and the risk of severe complications warrants a similar approach. Currently, national EMS protocols exist for hyperthermia,[23] but there are no mandates for implementation and each state determines its own protocols (if any). Similarly, many EDs lack protocols and have variable guidelines for management of heat-related illness, which vary by institution.[24]

The current lack of standardization and deployment of evidence-based protocols presents an opportunity to save lives and improve patient outcomes by instituting system-based

approaches to healthcare delivery for heatstroke patients. Here, we review current standards of care for the emergent management of heatstroke and propose an evidence-based algorithm to expedite care and improve recognition and treatment of this condition.

## METHODS

### Study Eligibility

The primary topical focus for all articles included in the study was heatstroke, defined as the combination of elevated core body temperature and altered mental status due to either ambient temperature, exertion, or both. Secondary topical foci included acute management of heatstroke and/or early outcomes associated with management. Studies were excluded for the following reasons: 1) non-English language; 2) non-human subjects; 3) full text not available; 4) qualitative studies unless high-level consesus panel recommendations; and 5) topical focus only on prevention or physiology descriptions, rather than acute treatment.

We included all quantitative studies. In addition, we included qualitative studies published as a consensus recommendation from a major health body such as the World Health Organization, US Occupational Safety and Health Administration, EMS, or military. Quantitative articles included published articles and articles in press, conference papers, editorials, reviews, case reports, and case series. Included articles were written in English and had full text available.

### Study Identification

We performed searches for scientific articles addressing the acute management of heatstroke using PubMed and Embase databases without date restrictions. This review did not meet eligibility criteria for a PRISMA systematic review or meta-analysis as it included two databases.[25] Search terms are available in the Supplemental Methods. All English-language articles meeting the heatstroke topical and situational criteria were included. The search strategy was designed in collaboration with a health sciences medical librarian with the goal of identifying articles that addressed the rapid recognition and treatment of heatstroke in prehospital, ED, or critical care settings. Additional searches of the non-peer-reviewed medical literature were performed to capture prehospital protocols and expert opinion. Additional articles were added after independent review of the references of articles identified during the literature search.

### Study Selection

After articles were identified via the initial search strategy, duplicates were removed, and titles and abstracts were screened for relevance and consistency with the inclusion criteria. Each article was read and assessed by two independent, blinded physician reviewers (CR, CD, CG, CS). Any discrepancies were resolved by a third blinded physician-author reviewer. We tracked inter-rater reliability for inclusion and exclusion criteria and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) criteria. We used EndNote bibliographic manager to assist in the review. Additional articles were found from bibliographic review of selected studies for inclusion.

### Data Extraction

Reviewers extracted information on author, year, study design, study setting (prehospital, ED, intensive care unit [ICU]), population, topical focus (recognition, cooling, management, systems), classic vs exertional heatstroke, cooling method, prognosticators if measured, and outcome. Notable case complications were also recorded. Quantitative studies were assessed by reviewers using the GRADE criteria, which included very low, low, moderate, and high quality.[26]

### Data Synthesis

We performed a descriptive thematic analysis due to the heterogeneous nature of the articles and developed a management pathway based on evidence in the literature.

## RESULTS

### Overview

Of the 183 articles identified in the search, 25 duplicates were removed and 58 were excluded by title and abstract review (Figure 1). In total, 63 articles met full inclusion criteria after full-text review and were included for analysis (Supplemental Results Table S1). Studies were primarily excluded due to lack of topical focus on heatstroke or acute management. There was discrepancy between reviewers for

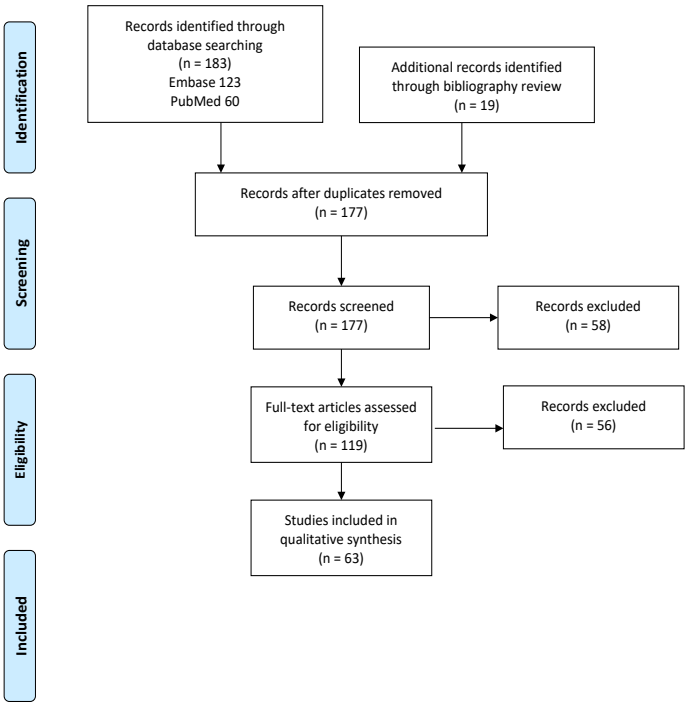


**Figure 1.** Flow chart for selected studies on heatstroke management.

14 studies from the database that required a third reviewer. Of those studies, nine were excluded and five were included. Studies included all years with relevant results, with publication dates ranging from 1956 to 2020.

Quality of studies varied. Of the included studies, 25 were assessed to be very low quality, 25 were low quality, and 13 were moderate quality. No studies were ranked as high quality. There was discrepancy in 17 of 63 studies (27%) between reviewers. All were one level of evidence off and resolved by a third blinded reviewer. The majority of moderate-quality studies were found through the search of references (10 of 13). Just over half of the included studies (34) were case reports or case series. Two case reports also included a review of current standards of care.[27,28] In total, 16 reviews, primarily unstructured, were identified, and 15 other studies ranged from opinion pieces to observational studies.

Exertional heatstroke was addressed in 38 studies, classic heatstroke in 12 studies, and both types in 13 studies. Patients in specific case reports and series were more frequently male than female.. More than half of studies (39 of 63) focused on a single care setting rather than across all three settings—prehospital, ED, and ICUs; management included prehospital care in 37 studies, EDs in 33 studies, and ICUs in 25 studies.

Numerous patient populations from infants[29] to older adults[30-32] were identified in this review of heatstroke. Pediatric athletes[27,33-35] and pediatric vehicular heatstroke cases were discussed.[36,37] Occupational heatstroke was described in construction workers,[38,39] a baker,[40] gold miners,[41] and an aluminum smelter pot room process-control operator.[42] Environmental circumstances including heat waves[29,31,40,43,44] and sunbathing[45] were identified as risks, as was non-endemic heat due to a dry sauna exposure.[46] Exertional heat stress was described in runners,[47-50] individuals along the US-Mexico border,[28] participants in the Hajj pilgrimage to Mecca,[51] and military personnel.[52-61] While many predisposing factors have previously been identified,[62] specific cases highlighted hypohydrosis disorder,[63] antipsychotic medications,[31] and social determinants of health such as poor housing[29] and lack of indoor cooling[43] as contributory to heatstroke.

Populations represented were from geographically diverse settings. Countries/regions included Pakistan,[64] China,[65] India,[55,66] Saudi Arabia,[51,63] Australia,[50] Puerto Rico,[53] the United Kingdom,[48] Japan,[34] Israel,[67] Nigeria[36] and other African countries,[41] France,[31] and the United States of America.[32,43,68,69]

**Key Steps in Heatstroke Management**

We identified three principle themes for clinical management: recognition, rapid cooling, and supportive care (Table).

*Recognition*

Heatstroke recognition was highlighted in 23 studies. Topical focus was cooling in almost all studies (55 of 63). Cooling methods included removal from the hot environment, fluid resuscitation, cold water or ice water immersion, application of cold packs, evaporative cooling with water and fans, internal cooling (gastric, bladder, and/or rectal), endovascular cooling,[28,40,54,70] and extracorporeal membrane oxygenation (ECMO)-based cooling.[71]

**Table.** Principle themes identified in literature review concerning heatstroke.

| Topic | Recommended action |
|---|---|
| Recognition | Maintain high clinical suspicion<br>Weather awareness<br>Measure core body temperature |
| Rapid cooling | Initiate immediate external cooling<br>Early decision regarding invasive cooling |
| Supportive care | Emphasis on airway, breathing, circulation<br>Monitor for and correct metabolic derangements |

*Rapid Cooling*

Preferred cooling treatments varied, with no clear prevailing recommendation. A previous systematic review (2007) showed no definitive data to guide specific cooling approaches.[24] In one study in which cooling rates were compared,[72] cold water immersion was considered the gold standard; this is consistent with the Wilderness Medicine Society Grade 1A recommendations for cold water immersion of heatstroke patients.[73,74] Other studies by the same author supported cold water immersion.[75,76] Earlier work found no statistically significant difference between ice water immersion and cold water immersion.[77] One study recommended ice water immersion.[78] Other than rate of cooling, a primary consideration was mental status and other monitoring required in these patients. In intubated, obtunded patients, a cooling catheter was placed[70] or evaporative cooling was preferred for patient safety.[49,60]

*Supportive Care*

Laboratory management was discussed in 23 studies with variation in values reported. One study found sodium >145 was an independent risk factor for death[44]; in contrast, low sodium was reported to be common in other cases.[42,65] A case series found both high and low values of potassium, sodium, calcium, and phosphorus.[65] Aspartate aminotransferase >1000 units was associated with death.[41] Elevated troponin T and creatine kinase were also noted in patients.[49] Lactate, troponin I, and creatinine were significantly elevated in non-survivors of classic heatstroke as compared with survivors, although time to cooling in the non-survivor group was significantly longer.[31] Resuscitation guidance was the focus of two studies,[51,65] which recommended Foley catheters to monitor urine output and avoidance of over-resuscitation due to risk of pulmonary edema.[51] Only four studies addressed systems-based approaches to heatstroke; all focused on exertional heatstroke.[50,57,60,79]

Many of the reported patient outcomes consisted of complete recovery followed by discharge from the hospital.[30,36,38,48,49,53-57,60,68,70,80-82] Several patients required a prolonged hospitalization up to 75 days.[39,63,83] Notable case sequelae were ventricular tachycardia,[39] aspiration,[40,60] cerebral edema,[53] seizures,[38,55] residual neurological deficits,[42,59,63,66] acute liver failure that required transplantation[46,83,84] or supportive care,[45] and death.[27,29,31,34,43,47,59,65,66,68] It was noted that many patients arrived via EMS, yet cooling was often delayed.[31,32,46,47,58,67] However, none of the articles or guidelines that were reviewed described a scalable system-based EMS and ED process, alert, pathway, or algorithm to expedite early identification and intervention.

## DISCUSSION

This literature review examined current available English-language literature on the recognition and management of acute heatstroke. This review did not identify any standardized, systematic approach for EMS or ED treatment of heatstroke. These results are consistent with findings of a previous review.[24] Available guidelines tend to emphasize "rapid cooling" without exploring the specific operational steps that are necessary to ensure this occurs efficiently and consistently in practice, despite the fact that most deaths are attributable to delays in prehospital or ED care. There is some evidence that identification of patients with heatstroke may be a limiting factor; consideration of elevated indoor and outdoor temperatures, membership in vulnerable groups, and recent or ongoing increased metabolic demand[37] were shown to improve detection, but currently are not applied in a systematic fashion.

The review supports the efficacy of standard emergency medicine (EM) management of heatstroke. However, it appears that the application of these techniques is variable, as is timely identification of at-risk patients. Here, we propose an ED heatstroke pathway to facilitate rapid identification and timely intervention for these critically ill patients.

### Treatment Approach

Rapid identification and initiation of treatment in patients with heatstroke is a core component of EM training yet remains difficult to implement in many settings. Heatstroke is an uncommon diagnosis that is time and resource intensive; early diagnosis is both challenging and essential. Published literature demonstrates reduced morbidity and mortality with prompt action and provides evidence for key clinical actions in heatstroke management.

*Early Recognition and Core Temperature*

Early recognition is consistently emphasized in the published literature. Military events and athletic events frequently have protocols in place during warm weather days. Other variables of heat stress beyond temperature were inconsistently incorporated, such as wet-bulb globe temperature.[69] Heat index (temperature and humidity) was used in the algorithm similar to previous work.[85] Time of the year and active heat advisories were also considered to address exposure risks.

Elevated core body temperature is a crucial cue to responders to initiate cooling. Thus, early rectal temperature measurement[35,54,68,86] was emphasized in the algorithm; empiric treatment is also an option if high suspicion exists and it is not possible to obtain a core temperature.[77] Failure to recognize heatstroke was life-threatening.[46,58,67] In contrast, patients who were rapidly cooled frequently had rapid reversal of mental status changes[30,49] and in some cases were discharged from the ED. In one study of 274 cases of exertional heatstroke, there was 100% survival with on-site immersion in cold water.[81]

*Treat or Transport? Advantages of Cooling Prior to Transport or Transfer*

Cooling was recommended prior to transfer in several publications, with recommendations to continue cooling during transport if possible.[35,49,50,79] Time was the main driver of this recommendation, with a goal of less than 30 minutes[69] or less than 60 minutes to cooling.[86] Delays in cooling contributed to adverse outcomes.[47,31,32,67]

On-site cooling is important in rural settings; the literature favors continued attempts at cooling prior to transport until temperature is controlled or until all means of cooling are exhausted. Urban populations were more represented in the literature[32,43,68] than rural populations, but some of the methods of cooling described in the literature may be most applicable in remote settings. For example, sites with air transport can use the downdraft of a helicopter as a fan to evaporate cool water.[82]

*Allocation of Human and Medical Resources*

Unique and specialized resources such as cooling devices as well as multiple specialties and staff resources are required to manage heatstroke. A target goal of 39°C was chosen as other studies demonstrate safety between 38.3-39°C.[24,74] Early initiation of the heat response algorithm is expected to facilitate appropriate care early in the treatment timeline. We believe a protocol encourages discussion of resources available at individual EDs before the first patient arrives, as many methods are available for effective cooling: body bag,[30] tarp,[80] helicopter downdraft,[82] endovascular,[70] and ECMO.[71,87] Other more robust responses such as a dedicated heatstroke unit[55] or an on-site, field-deployed body cooling unit[49] may apply in certain settings.

A proportion of patients required intubation and definitive airway management. In one study, non-survivors were more likely to have been intubated in the ED than survivors.[32] When mentioned, rocuronium[39] and succinylcholine[27] were both used in patients with no discussion on preference of one over the other. While there is a theoretical basis to support the use of a nondepolarizing agent such as rocuronium, which avoids possible heat generation during fasciculations and results in longer duration neuromuscular blockade that may reduce

metabolic heat generation, no clear evidence supports the recommendation of rocuronium in favor of succinylcholine.

Transfer to a liver transplant center was included in the algorithm as a consideration due to several cases of acute liver failure secondary to heatstroke.[46,83,84] There was one case of a teenager who died secondary to acute liver failure and disseminated intravascular coagulation (DIC) with no transplant.[27] Of the three cases identified in the review in which patients underwent transplant, two athletes with exertional heatstroke required transplant on day three of admission[83,84] and one required transfer to a transplant center on day three followed by transplant on day six.[46]

*At-risk Populations*

Certain populations appear to be at elevated risk. The populations identified in this review include older adults, who tended to present with classic heatstroke, and athletes and military personnel, who tended to present with exertional heatstroke. Identification of at-risk populations can help educators inform the general public, public health agencies, occupational health agencies, and first responders with regard to identification of potential heatstroke patients.

Classic heatstroke was predominantly described in urban environments; patients tended to be older and suffer worse outcomes[32] than those described for exertional heatstroke.[81] The 1959 heat wave in Melbourne,[29] the 1995 heat wave in Chicago,[43] and the 2003 heat wave in France,[31,40,44] exposed large numbers of urban dwellers to sustained high temperatures with tragic consequences. Hypernatremia was an independent risk factor for death in the heat wave in France, which was associated with advanced age.[44] Patients with classic heatstroke tended to have underlying comorbidities that placed them at elevated risk, although mortality rates varied widely from 17%[68] to 63.6%.[31]

Most descriptions of exertional heatstroke involved athletes and military personnel. Among runners, intermediate-skill runners were more often described as suffering from heatstroke as compared to novice or elite runners.[48,50] Hyperkalemia (9 milliequivalents per liter), elevated creatinine, rhabdomyolysis, acidosis, and elecrocardiogram changes were associated with one runner fatality.[69] Two publications described non-athletic, nonmilitary cases of exertional heatstroke. One case report highlighted a male along the US border who had been walking for 24 hours.[55] A second publication described a male construction worker who had persistent ventricular tachycardia until he was cooled.[39]

Men were more represented than women in the literature. Larger body mass may contribute, although males do not appear to be at higher physiologic risk once cooling is initiated. A study of exertional heatstroke in runners found no statistical difference in cooling rate based on initial temperature, age, or gender.[81] The discrepancy in publication volume may be a function of historical gender patterns in outdoor work and military activities; it should be noted that women are also at risk in similar situations, as described in a case report of an 18-year-old female military recruit who suffered rhabdomyolysis and a two-week hospitalization before being discharged neurologically intact.[61]

*A Community-based Approach to Heatstroke*

Heatstroke is a preventable yet under-recognized medical emergency. Only four studies clearly addressed system-based changes[50,57,60,79] despite previous calls for systemic approaches to address heat-related illness, particularly in EM.[88] None of these studies addressed classic heatstroke or the impact of heat waves, despite the fact that these patients are often more vulnerable, present later, and suffer worse outcomes, and the fact that heat wave frequency and intensity is projected to increase as a result of climate change. This situation represents a significant opportunity for communities to reduce health harms and direct and indirect healthcare costs associated with extreme heat from lost productivity, worker absenteeism, medications, and healthcare utilization.[89]

While the present study did not address prevention, the results are useful for stakeholders working to expand syndromic surveillance and warning systems. Real-time surveillance has already demonstrated success for monitoring deaths and public health interventions during a heat wave.[90] Heat early warning systems have reduced heat exposure risks in communities by evaluating healthcare data and heat index values for heat alert processes.[85] Multidisciplinary teams with representatives from athletics, public health, climate sciences, emergency management, energy, city planning, and meteorology have had meetings using the National Integrated Heat Health Information System to better prepare and adapt to heat.[91] Furthermore, these efforts demonstrate an active commitment to addressing climate change and to improving social and environmental determinants of health,[29,43] and resultant health inequities. Thus, final recommendations focus on an integrated approach both in the ED and in the community to facilitate heat-related illness education, recognition, and treatment.

**Heat Alert Algorithm**

We developed an alert process and treatment algorithm to facilitate critical care delivery in EDs (Figure 2). The algorithm is based on available evidence from the published literature regarding presentation, critical interventions, and time-dependence of interventions. Seasonal timing is appropriate for use in the Northern hemisphere temperate zone for peak heat illness.[92] Details should be adjusted to match local conditions.

In Step 1 of the algorithm, a heat alert flag integrates information on current environmental conditions, body temperature, and patient complaints and prompts triage staff to consider whether the patient has heatstroke. In Step 2, the heat alert expedites clinical evaluation by a trained health

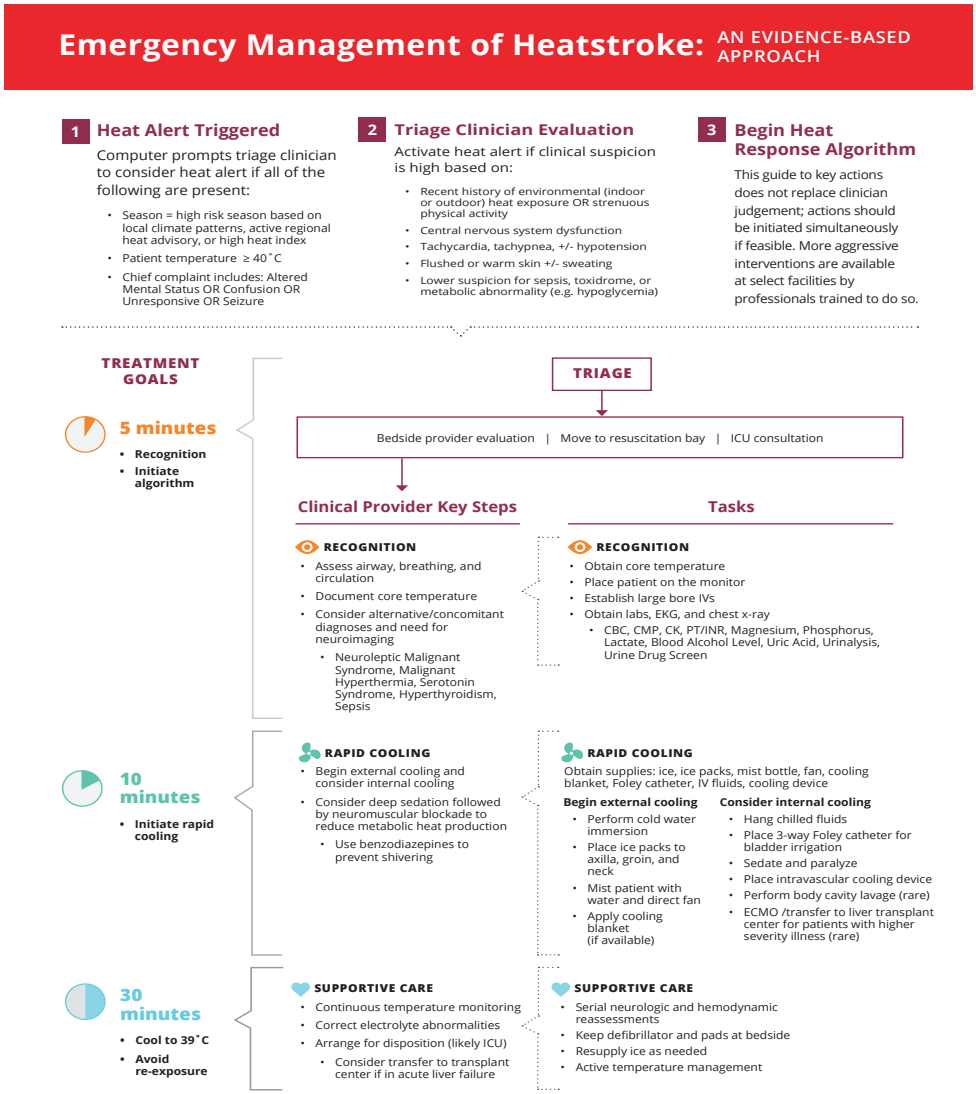


**Figure 2.** Management of heatstroke in the emergency department.
*CBC,* complete blood count; *CMP,* comprehensive metabolic panel; *CK,* creatine kinase; *PT/INR,* prothrombin time/international normalized ratio; *ECMO,* extracorporeal membrane oxygenation; *ICU,* intensive care unit.

professional to assess for other underlying etiologies and ultimately triggers or ceases the continuation of the algorithm. Step 3 is the heat response guide for members of the healthcare team to perform within 30 minutes of evaluation.

**Recommendations**

- Health systems need to implement heat alert systems and train relevant staff members
- Include prehospital providers and EMS networks in early identification, early communication, and treatment of heat illness
- Increase public health messaging around risks of endemic and acquired heat illness especially among vulnerable populations
- Increase syndromic surveillance and improve heat warning systems

## STRENGTHS AND LIMITATIONS

This study has a few strengths. A rigorous search strategy was developed in partnership with a research librarian across two large databases. Next, the literature included in the review spanned 64 years with results that represented populations from infants to older adults and incorporated a spectrum of occupational as well as endemic and acquired heatstroke cases across a wide range of geographic areas. The mix of study settings also incorporated the expertise of prehospital, emergency care and critical care providers, which strengthened the management approach.

Several limitations remain. The majority of studies were of low-quality evidence as case reports or case series. This may limit validity and allows for confounding factors for management suggestions. For example, time to cooling rather than specific laboratory prognosticators may influence patient

outcomes the most. While many populations were represented, missing vulnerable populations, such as prisoners, were not included. These populations may benefit from systemic changes and protocols the most and will be important to include in further implementation of scientific research on efficacy and outcomes of protocols.

## CONCLUSION

Rapid recognition and management of heatstroke is critical for the healthcare system to successfully adapt to the increases in frequency, intensity and duration of heat waves as a result of climate change. The proposed heat alert algorithm is intended to help ED and prehospital teams identify heatstroke patients, implement critical treatments, and allocate resources in a timely fashion. The process presented here is a template for evidence-based clinical practice and may help institutions meet the standard of care for patients with life-threatening heat-related illnesses. Improved recognition and treatment of heatstroke has the potential to reduce mortality and neurological complications and support vulnerable patients in a rapidly warming world.

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# Norepinephrine in Septic Shock: A Systematic Review and Meta-analysis

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**Introduction:** Most experts recommend norepinephrine as the first-line agent in septic shock. Our objective was to determine the effectiveness and safety of norepinephrine in patients with septic shock.

**Methods:** We searched the Cochrane Central Register of Controlled Trials and Epistemonikos, as well as MEDLINE from 1966 till August 2019. Screening of full texts, evaluation for eligibility, and data extraction were done by four independent reviewers. We estimated risk ratios (RR) and mean differences (MD) using a random-effects model with 95% confidence intervals (CI). The primary outcomes included the number of participants who achieved the target mean arterial pressure (MAP), time to achieve the target MAP, and number of participants with all-cause 28-day mortality. The secondary outcomes included the length of stay in the intensive care unit, length of hospital stay, incidence of arrhythmia and myocardial infarction, vasopressor-free days, and number of participants with all-cause 90-day mortality.

**Results:** We identified 11 randomized controlled trials with a total of 4,803 participants. There was no difference in the number of participants who achieved the target MAP between those patients receiving norepinephrine and other vasopressors (RR 1.44; 95% CI, 0.32 to 6.54; P = 0.640; $I^2$ = 94%; two trials, 116 participants). There was no significant difference in time to achieve the target MAP (MD -0.05; 95%, CI, -0.32 to 0.21; P = 0.690; $I^2$ = 26%; two trials, 1763 participants) and all-cause 28-day mortality (RR 0.95; 95% CI, 0.89 to 1.02; P = 0.160; $I^2$ = 0%; seven trials, 4,139 participants). Regarding the secondary outcome, norepinephrine may significantly reduce the incidence of arrhythmia as compared to other vasopressors (RR 0.64; 95% CI, 0.42 to 0.97; P = 0.030; $I^2$ = 64%; six trials, 3974 participants). There was no difference in the incidence of myocardial infarction (RR 1.28; 95% CI, 0.79 to 2.09), vasopressor-free day (RR 0.46; 95% CI, -1.82 to 2.74) and all-cause 90-day mortality (RR 1.08; 95% CI, 0.96 to 1.21) between norepinephrine and vasopressors.

**Conclusion:** In minimizing the occurrence of an arrhythmia, norepinephrine is superior to other vasopressors, making it safe to be used in septic shock. However, there was insufficient evidence concerning mortality and achievement of the target MAP outcomes. [West J Emerg Med. 2021;22(2):196-203.]

## INTRODUCTION

Sepsis remains one of the significant causes of morbidity and mortality in critically ill patients worldwide despite the use of broad-spectrum antibiotics, advanced intensive care unit (ICU) management, and resuscitation strategies and protocols.[1] More than 19 million sepsis cases and 5 million

sepsis-related deaths are reported to occur annually, especially in low- and middle-income countries.[2] According to the most recent report from the US Centers for Disease Control and Prevention, sepsis affects approximately 1.5 million people in the United States annually, resulting in 250,000 deaths, or one of every three hospital deaths.[3] The incidence is increasing, mostly influenced by an aging population with multiple comorbidities, increased use of immunosuppressive therapy, and high-risk interventions.[4]

Definitions of sepsis and septic shock were revised in 2001 to incorporate the threshold values for organ damage. In 2016 there was a dramatic change in the definitions of sepsis and septic shock.[5] Sepsis is now defined as life-threatening organ dysfunction caused by a dysregulated host response to infection. Organ dysfunction is characterized by an increase in the Sequential Organ Failure Assessment score of two points or more, which is associated with an in-hospital mortality greater than 10%. Patients with septic shock require vasopressor to maintain a mean arterial pressure (MAP) of 65 millimeters mercury (mm Hg) or greater and serum lactate level greater than 2 millimoles per liter (>18 milligrams per deciliter) in the absence of hypovolemia. This combination is associated with hospital mortality rates greater than 40%.[6]

The therapeutic goals in the management of sepsis are to improve tissue oxygenation and perfusion and to provide antimicrobial therapy with appropriate cover against the causative organism. The recent 2016 key recommendations include the following: 1) Intravenous (IV) antibiotics should be started within one hour of sepsis recognition; 2) patients with hypoperfusion should receive at least 30 milliliters per kilogram (mL/kg) of IV crystalloid within three hours and should be reassessed frequently; 3) for patients who require vasopressors, the initial target MAP should be 65 mm Hg; and 4) norepinephrine is the first choice for patients who need vasopressors, followed by vasopressin or epinephrine.[4]

The main pharmacological effect of norepinephrine is to increase organ perfusion by increasing vascular tone. Several studies comparing norepinephrine with dopamine favored the former in terms of overall improvements in oxygen delivery, organ perfusion, oxygen consumption, and less risk of arrhythmic effect.[7] In this regard, norepinephrine is used primarily as a vasopressor to manage low systemic vascular resistance caused by vasodilation, which occurs in septic shock.[8]

A previous meta-analysis, which included trials up to January 2017, assessed outcomes such as mortality, oxygen delivery, oxygen consumption, cardiac index, heart ratio, MAP, mean pulmonary arterial pressure, central venous pressure, and systemic vascular resistance index.[9] The current review evaluates other important outcomes and includes the latest trials, which may affect the findings of previous reviews. We performed a systematic review and meta-analysis to assess the effectiveness and safety of norepinephrine compared with other vasoactive agents and placebo in patients with septic shock. The primary outcomes included the number of participants who achieved the target MAP, time to achieve the target MAP, and all-cause 28-day mortality.

## METHODS

This systematic review was executed according to the protocol formerly published in the PROSPERO register. The methodology and reporting were constructed grounded on references from the Cochrane collaboration,[10] and the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement.[11] The appraisal was done according to the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.[12]

### Literature Search and Selection of Studies

We searched the Cochrane Central Register of Controlled Trials (Issue 8 of 12, August 2019), Epistemonikos, and MEDLINE (1966 to August 2019), using the text words "norepinephrine" and "septic shock" as well as Boolean operators such as "AND," "OR," truncation, and wildcards for variations in words. We restricted our search to English language publications. The reference list of identified randomized controlled trials (RCT) and articles were examined to find any unpublished or unidentified trials. Ongoing trials were also searched through the World Health Organization International Clinical Trials Registry Platform and ClinicalTrials.gov.

Four authors (MAR, MBY, AR, AY) selected the RCTs for inclusion, using these search strategies. Titles and abstracts were screened, and full-text copies of those that appeared relevant were obtained to determine whether they met the inclusion criteria. We contacted authors of trials, if necessary, to clarify study eligibility. Any disagreements between the review authors were resolved by discussion. We included RCTs comparing norepinephrine with other inotropes and vasopressors (dopamine, epinephrine, vasopressin, phenylephrine, terlipressin) or placebo administered intravenously. We excluded cross-over studies and those that did not report the outcomes of interest. The population of interest was comprised of patients, regardless of age, who were diagnosed with septic shock by clinicians.

### Data Extraction

Using a data extraction form, the review authors (MAR, MBY, AR, AY) independently extracted data on characteristics of the trials, participants' characteristics, methodology, intervention, and outcomes. We attempted to contact the corresponding authors of trials if the information was missing or inadequately reported. Discordances at all stages were resolved through discussion.

### Outcome Measures

The primary outcomes of interest included the number of participants who achieved the target MAP, time to achieve the target MAP, and number of participants with all-cause 28-

day mortality. Length of stay in the intensive care unit (ICU), length of hospital stay, incidence of arrhythmia, incidence of myocardial infarction, vasopressor-free days, and number of participants with all-cause 90-day mortality were considered as secondary outcomes.

**Assessment of Risk of Bias in Included Studies**

We assessed the risk of bias based on random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors, completeness of outcome data, the selectivity of outcome reporting, and other bias. The Cochrane Collaboration tool for assessing the risk of bias was used to appraise the trials and is reported in the risk of bias table.[10] We categorized risk of bias as low, high, or unclear. Any disagreements between the review authors were resolved by discussion.

**Primary Data Analysis**

Review Manager (RevMan) version 5.3.5 (Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark) was used to perform the statistical analyses. For all the included trials with categorical outcomes, we calculated the risk ratios (RR) and 95% confidence intervals (CI). For numerical outcomes, the mean differences (MD), standardized mean differences (SMD), and 95% CIs were calculated. If data from two or more trials were included in an analysis of an outcome, we reported the results of the random-effects model. We pooled these measures in meta-analyses and drew forest plots.

The presence of heterogeneity was assessed via two steps. First, we evaluated obvious heterogeneity at face value by comparing populations, settings, interventions, and outcomes. Second, we assessed statistical heterogeneity using the $I^2$ statistic.[10] We used the following guide to interpret heterogeneity: 0–40% may not be important; 30–60% may represent moderate heterogeneity; 50–90% may represent substantial heterogeneity; and 75–100% would represent considerable heterogeneity.[10] Our goal was to conduct subgroup analyses based on time intervals for the primary outcomes if there were adequate trials present for each group.

**Grading Quality of Evidence**

We used the principles of the GRADE approach for evaluating the quality of evidence in this review.[12,13] For each outcome, four review authors independently assessed the quality of evidence. This approach detailed four levels of quality – high, moderate, low, and very low – depending on the existence of the following five parameters: 1) risk of bias of included trials; 2) indirectness of evidence; 3) unexplained heterogeneity; 4) imprecision of results; and 5) study design. The GRADEpro GDT software (Evidence Prime, Inc., Hamilton, Ontario, Canada) was used to reflect the quality of evidence for each outcome.

## RESULTS

The preliminary search yielded 613 trials from the electronic databases according to the search strategy (Supplementary file, Figure 1). From these, 45 records were removed due to duplication. A total of 549 trials were excluded because their abstracts did not meet the inclusion criteria. We reviewed 19 full texts for eligibility, and excluded eight publications because one of them was a cross-over study[14] and the remaining did not report the outcome of interest.[15-21] Therefore, 11 trials with a total of 4,803 participants were included for systematic review and meta-analysis (Figure 1).[22-32] Five trials were single-center studies,[23,27,28,30,31] while six were multicenter studies.[22,24-26,32]

From a total of 4,803 participants, 2,368 were in the intervention group while 2,435 were in the control group. The study with the largest sample size had 1679 participants.[24] All

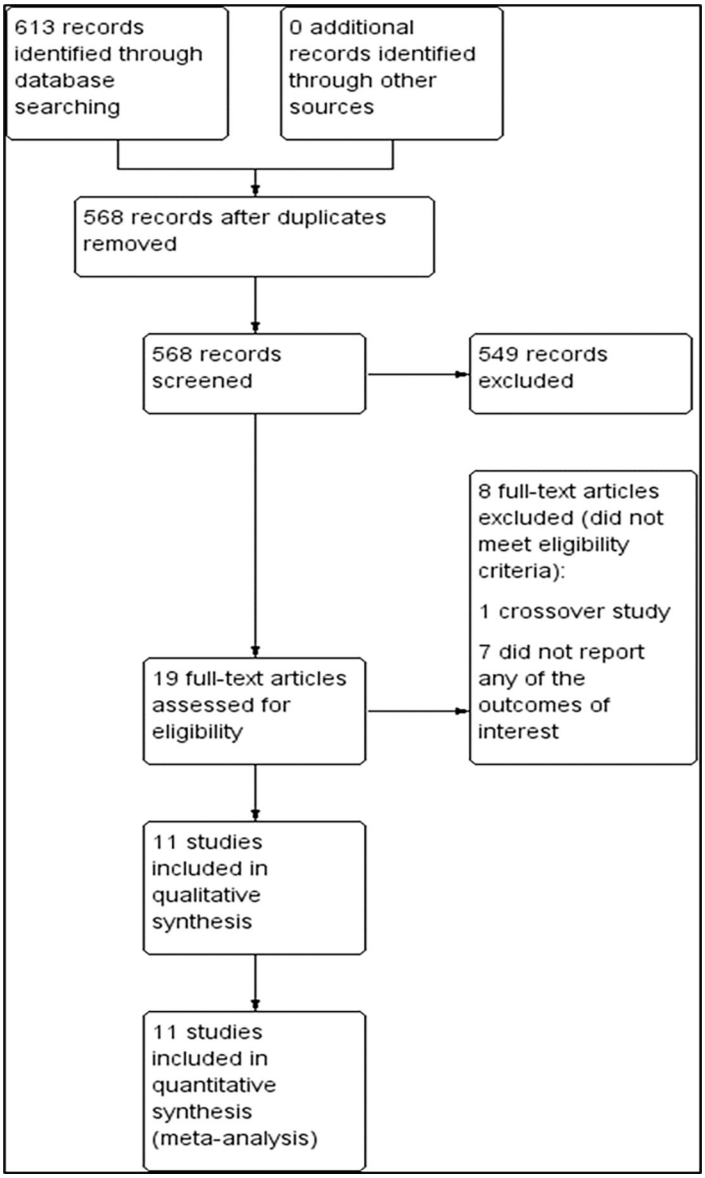


**Figure 1.** PRISMA flow chart of study selection for metanalysis of norepinephrine use in septic shock.

trials included participants older than 16 years of age. The diagnostic criteria for septic shock varied among the studies with the majority of trials using MAP less than 65-70 mm Hg after adequate fluid resuscitation as reference. All studies recruited participants from the ICU, except for one study that recruited from the emergency department.[31] All trials used IV norepinephrine comparing with other agents such as dopamine, epinephrine, vasopressin, phenylephrine, terlipressin, and placebo, except for one study that used either norepinephrine alone or in combination with dobutamine.[22] Three trials compared norepinephrine with dopamine,[24,27,30] two trials compared norepinephrine with epinephrine,[22,29] two trials compared norepinephrine with vasopressin,[25,32] and two trials compared norepinephrine with terlipressin.[23,26] Only one trial used placebo as a control.[31] The dosage of drugs for both intervention and control groups varied among studies. Characteristics of the

**Table.** Summary of included studies.

| Study ID | Setting | Country | Total randomized (n) | Mean age (years) | Intervention | Control | Primary outcome |
|---|---|---|---|---|---|---|---|
| Martin 1993 | Single center, ICU | France | 32 | 52.5 | Norepinephrine (0.5 mcg/kg/min) | Norepinephrine (0.5 mcg/kg/min) | Systemic and regional haemodynamic achievement |
| Annane 2007 | Multi-center, 19 ICU | France | 330 | 63 | Norepinephrine (0·2 mcg/kg/min min) ± dobutamine (5 mcg/kg/min) | Epinephrine (0·2 mcg/kg/min) ± placebo | 28-day all-cause mortality |
| Morelli 2008 | Single center, ICU | Italy | 32 | 70 | Norepinephrine | Phenylephrine | Study drugs requirement, systemic and regional haemodynamic achievement |
| Myburgh 2008 | Multi-center, 4 ICU | Australia | 280 | 59.9 | Norepinephrine | Epinephrine | Achievement of MAP goal >24 h without vasopressors |
| Russell 2008 | Multi-center, 27 centers | Canada, Australia, and USA | 778 | 60.5 | Norepinephrine (5 to 15 mcg/min) | Vasopressin (0.01 to 0.03 U/min) | 28-day mortality of any cause |
| De Backer 2010 | Multi-center, 8 ICU | Belgium, Austria, and Spain | 1,679 | 67.5 | Norepinephrine | Dopamine | Rate of death at 28 days |
| Patel 2010 | Single center, ICU | USA | 252 | Not stated | Norepinephrine (maximum of 20 mcg/min) | Dopamine (maximum of 20 mcg/kg/min) | 28-day all-cause mortality |
| Choudhury 2016 | Single center, ICU | India | 84 | 47.5 | Norepinephrine (7.5 mcg/min to 60 mcg/min) | Terlipressin (1.3 to 5.2 mcg/min) | Achievement of MAP of >65 mm Hg and maintenance of the same for the initial 48 hours |
| Gordon 2016 | Multi-center, 18 ICU | United Kingdom | 409 | 66 | Norepinephrine (maximum of 12mcg/min) | Vasopressin (maximum of 0.06 U/min) | Kidney failure-free days during the 28 days after randomization |
| Liu 2018 | Multi-center, 21 ICU | China | 617 | 61 | Norepinephrine (4 to 30mcg/min) | Terlipressin (20 to 160 mcg/h) | 28-day all-cause mortality |
| Permpikul 2019 | Single-center, ED | Thailand | 310 | Not stated | Norepinephrine (0.05 mcg/kg/min) | Placebo (Dextrose 5% in water) | Shock control rate by 6 hours |

*ICU,* intensive care unit; *mcg,* microgram; *kg,* kilogram; *min,* minute; *U,* unit; *h,* hour; *MAP,* mean arterial pressure; *ED,* emergency department.

included trials are summarized in the Table. In this review, we formed two comparisons between 1) norepinephrine and vasopressors and 2) norepinephrine and placebo. We evaluated included studies as having low, high, or unclear risk of bias for each domain (Supplementary file, Figure 2). Generally, the risk of bias in each domain was reported to be low or unclear among the included studies. Risk of bias for individual studies is described in Supplementary file, Figure 3. All trials reported methods of randomization used. Eight trials used computer-generated randomization, and one trial used quasi-randomization based on odd or even day of the month.[30] Two trials used block randomization.[23,26] Three trials did not describe methods of allocation concealment used.[27,28,30] All trials reported blinding of participants, personnel, and outcome assessor except in two trials, which were open-label studies.[23,30] Nine trials carried out an intention-to-treat analysis.[22-26,29-32] Ten trials reported the outcomes as specified in their protocols.[22-26,28-32] Only one trial did not report any protocol.[27]

**Primary Outcomes**

For comparison between norepinephrine and vasopressors, the outcome for the number of participants who achieve the target MAP was reported in two trials.[23,27] There was no significant difference in the number of participants who achieved the target MAP between those patients receiving norepinephrine and vasopressors (RR 1.44; 95% CI, 0.32 to 6.54; $P = 0.640$; $I^2 = 94\%$; two trials, 116 participants: low quality of evidence) (Figure 2). Two studies that reported time to achieve the target MAP [23,24] were analysed and revealed no significant difference between both groups (MD -0.05; 95% CI, -0.32 to 0.21; $P = 0.690$; $I^2 = 26\%$; two trials, 1,763 participants: high quality of evidence) (Supplementary file, Figure 4). For outcome of all-cause 28-day mortality, there was no significant difference between the norepinephrine and vasopressors groups (RR 0.95; 95% CI, 0.89 to 1.02; $P = 0.160$; $I^2 = 0\%$; seven trials, 4,139 participants: high quality of evidence) (Figure 3). For comparison between norepinephrine and placebo, the outcomes for the number of participants who achieved the target MAP and all-cause 28-day mortality were reported in one trial.[31] Norepinephrine was superior to placebo in the number of participants who achieved the target MAP (RR 1.57;95% CI, 1.31 to 1.89; $P < 0.001$; one trial, 310 participants). There was no significant difference in the number of patients with all-cause 28-day-mortality between both groups (RR 0.71; 95% CI, 0.44 to 1.13; $P = 0.150$; one trial, 310 participants).

**Secondary Outcomes**

We included all secondary outcomes in the meta-analysis except for length of ICU and hospital stay. Only one study reported length of hospital stay in mean number of days[30] while the remaining reported in median.

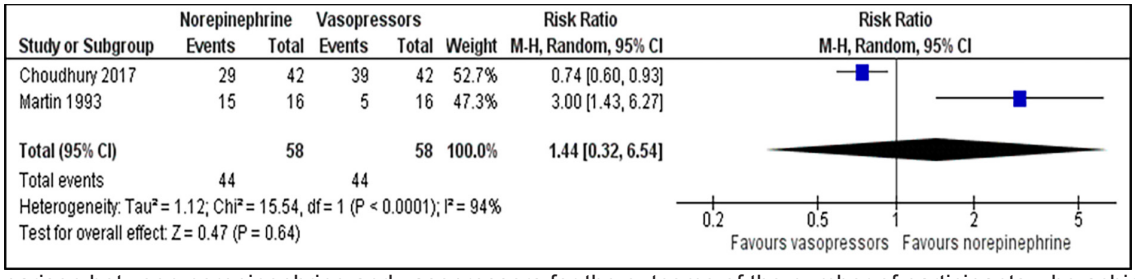


**Figure 2.** Comparison between norepinephrine and vasopressors for the outcome of the number of participants who achieved the target mean arterial pressure.
*M-H,* Mantel-Haenszel method; *CI,* confidence interval.

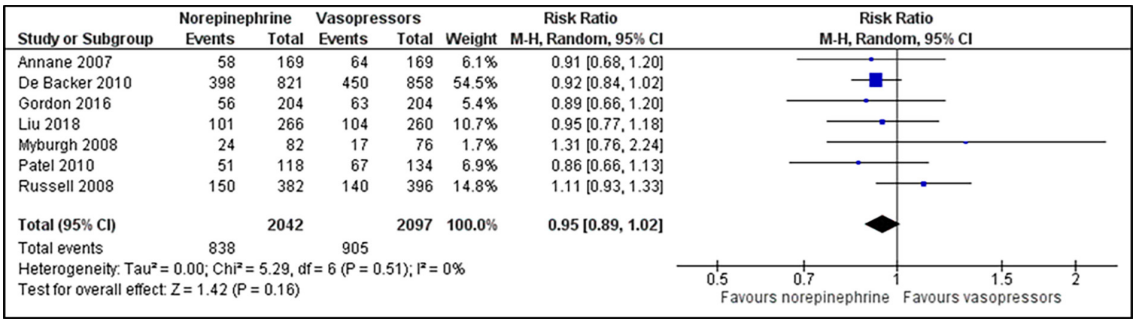


**Figure 3.** Comparison between norepinephrine and vasopressors for the outcome of the number of participants with all-cause 28-day mortality.
*M-H,* Mantel-Haenszel method; *CI,* confidence interval.

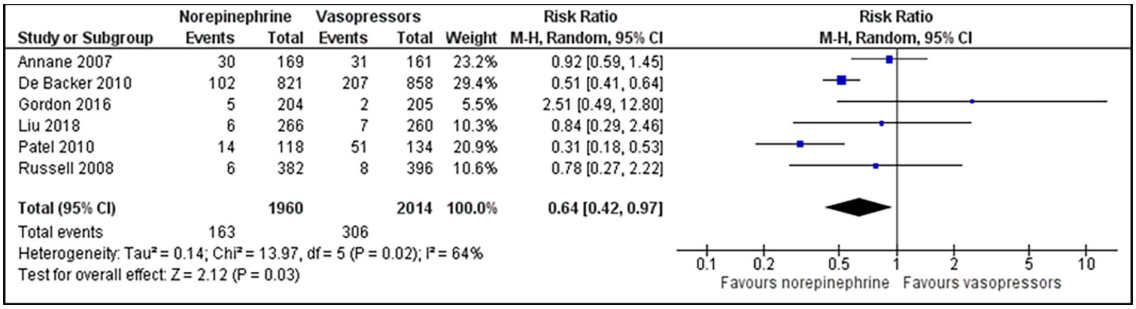


**Figure 4**. Comparison between norepinephrine and vasopressors for the outcome of the incidence of arrhythmia. *M-H,* Mantel-Haenszel method; *CI,* confidence interval.

Norepinephrine was superior to other vasopressors in reducing the incidence of arrhythmia (RR 0.64; 95% CI, 0.42 to 0.97; $P = 0.030$; $I^2 = 64\%$; six trials, 3,974 participants: moderate quality of evidence) (Figure 4). There was a non-significant difference in incidence of myocardial infarction (RR 1.28; 95% CI, 0.79 to 2.09; $P = 0.310$; $I^2 = 0\%$; three trials, 2983 participants: high quality of evidence) (Supplementary file, Figure 5), vasopressor-free day (RR 0.46; 95% CI, 1.82 to 2.74; $P = 0.690$; $I^2 = 76\%$; two trials, 2,205 participants: moderate quality of evidence) (Supplementary file, Figure 6) and all-cause 90-day mortality (RR 1.08; 95% CI ,0.96 to 1.21; $P = 0.440$; $I^2 = 0\%$; three trials, 1,257 participants: high quality of evidence) (Supplementary file, Figure 7) between norepinephrine and vasopressors groups. For comparisons between norepinephrine and placebo, one trial[31] reported the outcome of the incidence of arrhythmia, which revealed the significant advantage of norepinephrine over placebo (RR 0.55; 95% CI, 0.32 to 0.95; $P = 0.030$; one trial, 310 participants). Length of ICU stay was reported in eight trials, while the length of hospital stay was described in five trials.

## DISCUSSION

The 2018 Surviving Sepsis Campaign bundle introduced "hour-1 bundle," which outlined five essential key elements to be considered within the first hour of recognition of sepsis patients in healthcare facilities. These elements include measuring lactate level, obtaining blood cultures, administering broad-spectrum antibiotics, and instituting 30 mL/kg IV crystalloid for the hypotensive patient, as well as administration of vasopressor to maintain a MAP of 65 mm Hg.[33] It clearly shows the importance of early vasopressor use to maintain adequate tissue perfusion in septic shock patients, thus reducing mortality.

Using the GRADE approach, the quality of evidence among the measured outcomes ranged from moderate to high (Supplementary file, Table 1). Generally, the risk of bias in each domain for most trials was reported to be low or unclear. Only two trials showed a high risk of performance bias since both were open-label studies.[23,30] All trials were classified as low risk in random sequence generation except for one study, which used randomization based on odd or even day of the month.[30] The risk of reporting bias was present in one trial since there was no protocol provided.[27]

Evaluation of all three primary outcomes – namely, the number of participants who achieved the target MAP, time to achieve the target MAP, as well as all-cause 28-day mortality – revealed no significant difference between norepinephrine and other vasopressors. This is consistent with two previous meta-analyses, which had shown no mortality benefit of norepinephrine over other vasopressors such as dopamine, epinephrine, phenylephrine, and vasopressin.[9,34] However, two reviews[35,36] reported that norepinephrine was superior to dopamine for the outcome of 28-day mortality. Comparison between norepinephrine and placebo for the number of patients who achieved the target MAP showed significant benefit of norepinephrine over placebo. There was substantial heterogeneity (94%) in the outcome of the number of participants who achieved target MAP, possibly as a result of the differences in the definition of target MAP and the dosage of the drugs used among studies.

We chose two life-threatening adverse effects to be assessed as secondary outcomes: the incidence of cardiac arrhythmia; and myocardial infarction. Interestingly, the use of norepinephrine in septic shock is associated with a 36% and 45% reduction of incidence of arrhythmia, respectively, compared to other vasopressors and placebo. This may be explained by the beta-1 effect of norepinephrine, which increases cardiac contractility, thus increasing blood flow to the heart. A previous systematic review had also shown the superiority of norepinephrine over dopamine in reducing the risk of arrhythmia in septic shock patients.[36] This review also indicates that the incidence of myocardial infarction was not different between the groups. Other adverse effects were not included as they were reported in variable ways. Additionally, we discovered no significant difference between both groups in terms of vasopressor-free day and all-cause 90-day mortality. We were unable to proceed with meta-analysis for outcomes of length of hospital and ICU stay since all trials reported the number of days in median rather than mean, except in one study.

This review has several strengths. We used a systematic search strategy and included only relevant RCTs. Four authors independently conducted trial screening and data extraction. We used Cochrane's risk of bias tool to assess the quality of all studies and GRADE to evaluate the quality of evidence for important outcomes in this systematic review. We have updated this review with the addition of two recent trials.[26,31] Two comparisons were made comparing norepinephrine and other vasopressors as well as with placebo, which had not been addressed in previous reviews. It is intended to demonstrate the strength of norepinephrine alone as opposed to other vasopressors or placebo, if any.

## LIMITATIONS

We acknowledge a few limitations in this review. Firstly, only 11 trials met the inclusion criteria. Therefore more clinical studies are required to confirm the findings. Pediatric age group was not included because of limited trials available. The largest contribution of the review is from a trial[24] with the highest number of sample size (n = 1,679) and may have influenced the overall findings of this review. There were a few outcomes with moderate to substantial heterogeneity. These variable outcomes were most probably due to the variation of characteristics of populations and different dosages of vasopressors used in different studies, as well as different definitions of outcomes used among studies. We could not perform subgroup analysis due to inadequate information available. A funnel plot was not constructed due to insufficient studies contributing to each outcome. Our review included only English language publications. However, there is no evidence of a systematic bias in the use of language restrictions in systematic, review-based meta-analyses in conventional medicine.[37] While we believe that all relevant trials have been included, we cannot rule out the possibility that additional trials may be unpublished or published in sources not accessible to our search.

## CONCLUSION

In summary, there is no sufficient evidence to prove that norepinephrine is superior to other vasopressors in terms of mortality and achievement of the target MAP. However, this meta-analysis demonstrated the superiority of norepinephrine in reducing the incidence of arrhythmia, making it the safest vasopressor to be used in septic shock. Larger RCTs should be conducted to prove the efficacy and safety of norepinephrine over other vasopressors. We recommend future trials to perform proper allocation concealment and blinding of participants and personnel to reduce the risk of bias. The trials should also emphasize outcomes related to parameters of end-organ perfusion, monitoring of the participants, and effects of norepinephrine on other internal organs.

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



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# Prevalence and Temporal Characteristics of Housing Needs in an Urban Emergency Department

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**Introduction:** Our objective was to determine the proportion of patients in our emergency department (ED) who are unhoused or marginally housed and when they typically present to the ED.

**Methods:** We surveyed patients in an urban, safety-net ED from June–August 2018, using a sampling strategy that met them at all times of day, every day of the week. Patients used two social needs screening tools with additional questions on housing during sampling shifts representing two full weeks. Housing status was determined using items validated for housing stability, including PRAPARE, the Accountable Health Communities Survey, and items from the United States Department of Health and Human Services. Propensity scores estimated differences among respondents and non-respondents.

**Results:** Of those surveyed, 35% (95% confidence interval [CI], 31-38) identified as homeless and 28% (95% CI, 25-31) as unstably housed. Respondents and non-respondents were similar by propensity score. The average cumulative number of homeless and unstably housed patients arriving per daily 8-hour window peaks at 7 AM, with 46% (95% CI, 29-64) of the daily aggregate of those reporting homelessness and 44% (95% CI, 24-64) with unstable housing presenting over the next eight hours.

**Conclusion:** The ED represents a low-barrier contact point for reaching individuals experiencing housing challenges, who may interact rarely with other institutions. The current prevalence of homelessness and housing instability among urban ED patients may be substantially higher than reported in historical and national-level statistics. Housing services offered within normal business hours would reach a meaningful number of those who are unhoused or marginally housed [West J Emerg Med. 2021;22(2)204–212.]

## INTRODUCTION

### Background

Homelessness, housing, and health are deeply intertwined. Data suggest the annualized risk of death in homeless individuals to be 7.2%, 1.6 times that of housed individuals after adjustment.[1] The experience of homelessness is also related to significantly elevated rates of chronic disease, disability, and infection, making homelessness an issue of profound concern in public health and for health systems.[2-4] From a health systems standpoint, individuals experiencing homelessness have higher rates of emergency department (ED) utilization compared to those who are housed.[5-7] Previous data suggest that

ED utilization rates correlate with changes in housing status, suggesting that a history of homelessness may increase the risk for higher ED use.[5,8] National data on ED visits by homeless individuals show that they are more likely to have arrived by ambulance, to lack insurance, and to have had a recent ED visit or hospitalization.[9,10]

**Significance**

A natural, if somewhat revolutionary, response to the health risks of homelessness has been a national movement toward "housing as healthcare." As described in a 2013 paper in the *New England Journal of Medicine*, this movement embraces the deployment of resources typically reserved only for the provision of medical care toward housing, where these resources could potentially have a more substantial and lasting impact on health.[11] Because of the role that the ED plays in providing medical care to people experiencing homelessness, the ED may represent a natural site to practice a housing-as-healthcare model. In addition, because the ED is so frequent a source of care for chronically ill individuals experiencing homelessness, those who have started on the road to permanent supportive housing but are lost to the system could be reconnected during their ED visit.

Despite this area of opportunity, little is known about the true prevalence of homelessness and housing instability in urban EDs, in particular in safety-net EDs, which the Institute of Medicine defines as those that "care for a proportionately greater share of poor and uninsured people."[12] There is also little research on the temporal pattern of ED usage by individuals experiencing homelessness or housing instability. A recent systematic review on homelessness in the ED found that it is likely under-recognized, and prescribed more research on its prevalence and characteristics.[13]

Such a view acknowledges that historical and national-level data on homelessness may be poor indicators of current urban ED housing needs, especially with many major metropolitan areas experiencing significant housing crises in recent years. Furthermore, few studies have looked at the prevalence of housing challenges overall within the ED, examining both homelessness and unstable housing. Housing instability may present a significant area of opportunity for homelessness prevention linkage services in EDs. Finally, temporal findings could have important practical implications for co-locating housing linkage services within the ED, as has been done for human immunodeficiency virus, hepatitis C, and medication for opioid use disorder.[14-16] The workflow of the typical ED is poorly synchronized with most employment norms, and how to staff such a position in a way to best capture the need has been a conundrum within the field of social emergency medicine.

**Study Aim**

Our study was dually aimed to determine the proportion of visitors to a safety-net ED who are unhoused or marginally housed and to determine whether a greater number of such patients present to the ED at certain times of the day or the week. As housing needs are only one area of health-related social needs, we also gathered information on other social needs of our study population.

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency departments (ED) serve many patients experiencing homelessness or unstable housing. These needs can profoundly affect health and disease.*

What was the research question?
*To best target services, we asked what proportion of ED patients have housing needs and when are they visiting the ED?*

What was the major finding of the study?
*Nearly 2 of 3 patients in our ED were homeless or unstably housed. Almost half arrived between 7 AM–3 PM.*

How does this improve population health?
*Unstable housing is a public health crisis broadly affecting ED patients. EDs could be accessible linkage points offering housing services during daytime hours.*

## METHODS

**Study Design**

We assessed housing status and social needs of our patients at Highland Hospital ED, an urban safety-net ED with 68,000 annual visits, through a combination of surveys and chart review. To evaluate as representative a sample of the ED population as possible, we sampled at all times of day, every day of the week, covering a period equivalent to two full weeks for a total of 336 hours (14 days * 24 hours/day) from June 2018–August 2018. All patients at Highland ED during study hours were considered for eligibility. Patients completing the survey section were 18 years of age or older and spoke English or Spanish. Patients who were medically unstable, unresponsive, or had altered mental status were not surveyed, nor were those who had already participated. The work was reviewed and approved by the institutional review board at Highland Hospital.

The survey instrument included two social needs screening tools: 1) PRAPARE: Protocol for Responding to and Assessing Patient Assets, Risks, and Experiences,

developed by the National Association of Community Health Centers, Inc., and its partners[17]; and 2) the Accountable Health Communities (AHC) Health-Related Social Needs Screening Tool, developed by the Centers for Medicare & Medicaid Services.[18] In addition, we developed an item set of questions specifically focused on housing to better understand our patients' housing situations. These questions are largely sourced from the US Department of Health and Human Services (DHHS).[19]

Trained research assistants (RAs) approached patients during gaps in care and obtained verbal consent using a standard approach script. RAs approached available patients in order of arrival time, circling back to patients who were unavailable at the time of their initial approach when possible. Survey responses from participants were input directly into a secure electronic data capture system, REDCap, on a password-protected tablet.[20,21] RAs read the questions aloud, or participants completed the survey directly on the tablet if preferred. Arrival and discharge times, disposition, medical history, prior ED utilization, and past admissions were abstracted from the electronic health record (EHR) (Wellsoft Corporation, Somerset, NJ) ) during a standardized chart review. An aggregate measure of housing status was determined using items validated for housing stability, including PRAPARE, the AHC screening tool, and items from DHHS. We categorized subjects as homeless or unstably housed based on the criteria specified in Table 1. Any patients who did not meet the criteria for the categories of homeless or unstably housed, we categorized as stably housed.

To identify whether there were any substantive differences between patients who completed the survey and potentially eligible patients who did not, we performed an analysis of non-respondents using data from the EHR. We defined non-respondents as those who were approached but declined to respond as well as potentially eligible patients who were not approached. We excluded patients who were found to be ineligible when approached and those with medical records clearly indicating that they did not speak English or Spanish. Respondents were compared 1:1 to randomly selected non-respondent ED patients with visits during the study time period, matched by hour of arrival. We created a propensity score using the following covariates between the two groups: age; gender; acuity; language; race; insurance type (including "other public," which includes county-pay, workers' compensation, and others); disposition; past medical history; whether the patient was in custody or on a psychiatric hold; whether there were any indicators of homelessness documented in the clinicians' chart; past 12-month ED usage; and past 12-month inpatient hospitalizations.

**Statistical Analysis**

For each of the three groups, homeless, unstably housed, and stably housed, we calculated standard descriptive statistics such as mean, standard deviation, range, and proportions. We then tested for differences between the groups for each variable using analysis of variance for continuous variables and chi-square tests for categorical variables. Patient arrivals for a given time of day were tabulated and compared for unstably housed and homeless patients. To address any temporal non-randomization in our sample, results were scaled and weighted based on average arrival times of the ED population as a whole as well as the proportion of the available patients that we were able to approach. We calculated the cumulative number of patients who presented within a moving eight-hour window, stratified by homeless and unstably housed as well as cumulative, and then calculated confidence intervals assuming a binomial distribution with the observed probability of an individual's arrival time falling within the given eight-hour window. To compare our respondent to our non-respondent populations, we calculated propensity scores for each individual based on covariates available for both sets.

**Table 1.** Study flow showing adult patients approached for survey participation on homelessness and housing instability in Oakland, California.

| Homeless | Unstably housed |
|---|---|
| "Yes" to any of the following: | Does not meet the criteria for Homeless and "Yes" to any of the following: |
| 1. "I do not have housing" (PRAPARE)<br>2. "I do not have a steady place to live" (AHC)<br>3. "Last night, I stayed at...<br>• An emergency shelter, hotel, or motel (whether or not paid for with a voucher)"<br>• Transitional housing for homeless persons"<br>• A place not meant for human habitation"<br>• A friend or family member's room or apartment" (DHHS)<br>4. "I am currently homeless" in response to ability to stay in last night's place for more than 90 days (DHHS) | 1. Yes, I am worried about losing my housing" (PRAPARE)<br>2. I have a place to live today, but I am worried about losing it in the future" (AHC)<br>3. Moved 3 or more times in the past 12 months<br>4. Has had to move in with other people in the past 12 months because of financial problems<br>5. Unable to stay in current place for more than 90 days (DHHS) |

*PRAPARE,* Protocol for Responding to and Assessing Patients' Assets, Risks, and Experiences; *AHC,* Accountable Health Communities; *DHHS,* US Department of Health and Human Services.

## RESULTS

During the survey times, 2573 ED visits by 2357 unique adults occurred. Among these, we approached 1522. Of those approached, 758 patients completed the survey, 27 started but did not complete the survey, 478 declined to participate, and 259 were discovered to be ineligible after approach (Figure 1). The primary reasons for ineligibility were that the patient 1) could not complete the survey in English or Spanish (51%), or 2) lacked capacity due to altered mental status or critical illness (47%).

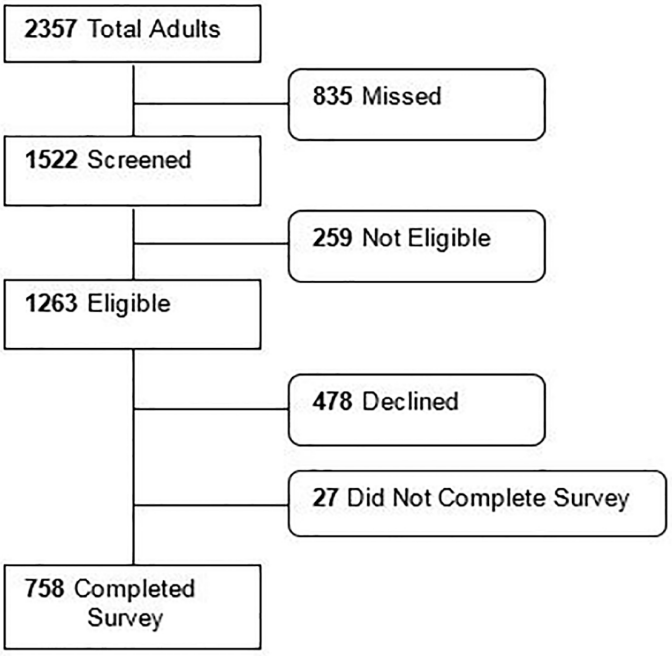


**Figure 1.** Study flow showing adult patients approached for survey participation.

Among respondents, 40% identified as Latinx, 39% Black, 15% White, 5% Asian, and 8% other races/ethnicities. Median age was 42 (IQR 29-57) and 54% were male. By our aggregate measure, 35% (95% CI, 31-38) were found to be homeless and 28% (95% CI, 25-31) reported being unstably housed (Table 2).

The rates of homelessness indicated by each survey individually were 26% (PRAPARE), 24% (AHC), and 29% (modified DHHS). (Table 3)

Participants reporting homelessness were more likely to be Black and to report a physical or mental disability. Participants reporting being unstably housed were more likely to be Latinx and to speak a primary language other than English. Stable housing was associated with more than a high school education and with advanced age. All groups reported high levels of Medicaid and uninsurance, typical of our hospital and others in the safety net.

The adjusted average number of patients arriving per hour who reported being homeless or unstably housed clustered in the hours between 7 AM–8 PM (not shown). The average cumulative number of homeless and unstably housed patients arriving per each eight-hour window of the day peaked at 7 AM, with 46% (95% CI, 29-64) of the daily aggregate of those reporting homelessness and 44% (95% CI, 24-64) with unstable housing presenting over the next eight hours (Figure 2).

To investigate whether our respondents were similar to non-respondents, we calculated propensity scores, which indicate the probability that a given patient responded to the survey given their covariates. The distribution of the scores with the mass appearing toward the middle suggests that respondents and non-respondents were relatively similar with respect to baseline covariates (Figure 3). Given the high-dimensional nature of the covariates, it is not surprising to see blips towards the tails.

## DISCUSSION

### Prevalence of Homelessness

In our study, 35% of respondents indicated that they were experiencing homelessness and 28% indicated that they were experiencing housing instability, a substantially higher prevalence than was reported in most previous studies.[5,22-24] Indeed, taken together, patients with housing challenges represented the majority of all visits to this urban safety-net ED. Although studies of data from the National Hospital Ambulatory Medical Care Survey (NHAMCS) consistently show rates of homelessness under 1% of all visits,[13] focused, survey-driven results from more recent studies indicate the prevalence of homelessness to be significantly higher, with wide variability across hospital types. A study of a public ED in New York City using data from 2016–2017 found 21.4% of patients screening positively for homelessness.[24] Similarly, a survey-based study in Pennsylvania from 2015–2016 reported homelessness rates varying from 7.5% of all visits at a suburban ED to 18.8% at an urban ED.[5,22] A similar order of magnitude was uncovered by Doran et al, who found that 14% of patients in their urban ED were living in shelters or on the streets.[23]

While it is unsurprising that our homelessness rates were higher than NHAMCS data, it is remarkable that they were considerably higher than rates reported in other studies. One possible explanation for the high prevalence we found is that we asked participants about their housing situation in more than one way and classified them as homeless if they met any of the homeless screening criteria from our three surveys. We chose this broader definition of homelessness in an attempt to capture all patients likely to be experiencing homelessness, under the logic that even a patient on the brink of homelessness could benefit from housing services in the ED. Yet even using only the narrower definitions of the established surveys (PRAPARE, AHC) individually, our rates were somewhat higher than those previously reported, with PRAPARE at 26% and AHC at 24%.

**Table 2.** Baseline characteristics of all respondents by housing status.

| | Housed N = 281 (37.1%) | | Unstably housed N = 213 (28.1%) | | Homeless N = 264 (34.8%) | |
|---|---|---|---|---|---|---|
| Sociodemographic characteristics | n | % | n | % | n | % |
| Age group | | | | | | |
| 18 - 24 years | 44 | 15.7 | 20 | 9.4 | 36 | 13.6 |
| 25 - 54 years | 139 | 49.5 | 145 | 68.1 | 155 | 58.7 |
| 55 - 64 years | 55 | 19.6 | 32 | 15.0 | 51 | 19.3 |
| > 64 years | 43 | 15.3 | 16 | 7.5 | 22 | 8.3 |
| Male** | 130 | 46.3 | 113 | 53.1 | 167 | 63.3 |
| Race/Ethnicity*** | | | | | | |
| Black/African American | 97 | 34.5 | 54 | 25.4 | 143 | 54.2 |
| Latinx/Hispanic | 119 | 42.3 | 121 | 56.8 | 65 | 24.6 |
| White | 44 | 15.7 | 29 | 13.6 | 39 | 14.8 |
| Asian | 18 | 6.4 | 7 | 3.3 | 14 | 5.3 |
| Other | 23 | 8.2 | 10 | 4.7 | 26 | 9.8 |
| Education* | | | | | | |
| Less than a high school degree | 61 | 21.7 | 83 | 39.0 | 66 | 25.0 |
| High school diploma or General Education Diploma | 97 | 34.5 | 55 | 25.8 | 108 | 40.9 |
| More than high school | 122 | 43.4 | 73 | 34.3 | 86 | 32.6 |
| Primary Language*** | | | | | | |
| English | 197 | 70.1 | 100 | 46.9 | 221 | 83.7 |
| Spanish | 76 | 27.0 | 105 | 49.3 | 35 | 13.3 |
| Other | 8 | 2.8 | 7 | 3.3 | 7 | 2.7 |
| English speaking proficiency*** | | | | | | |
| Well/very well | 225 | 80.1 | 124 | 58.2 | 237 | 89.8 |
| Not well/not at all | 54 | 19.2 | 89 | 41.8 | 25 | 9.5 |
| Veteran | 8 | 2.8 | 7 | 3.3 | 11 | 4.2 |
| Main Insurance*** | | | | | | |
| None | 26 | 9.3 | 20 | 9.4 | 12 | 4.5 |
| Medi-Cal | 104 | 37.0 | 95 | 44.6 | 152 | 57.6 |
| Medicare | 56 | 19.9 | 19 | 8.9 | 39 | 14.8 |
| Private | 64 | 22.8 | 65 | 30.5 | 47 | 17.8 |
| Other public insurance | 31 | 11.0 | 14 | 6.6 | 14 | 5.3 |
| Physical or mental disability affecting activities of daily living*** | 34 | 12.1 | 47 | 22.1 | 12 | 4.5 |
| HIV positive | 5 | 1.8 | 3 | 1.4 | 7 | 2.7 |

Statistically significant differences between housing status are indicated as follows: *p< 0.05, **P< 0.001, ***P<0.0001.
*HIV,* human immunodeficiency virus.

In addition to our broader definition of homelessness, our higher rates may be partially explained by our setting: an urban safety-net ED in the San Francisco Bay Area. The Bay Area region has the third highest number nationally of people experiencing homelessness, after New York and Los Angeles.[25] Our region in 2019 was experiencing a severe housing crisis. A comparison of American Community Survey (ACS) data from 2009 and 2017 shows the average median rental price increasing by 33% in Alameda County where our survey was conducted.[26] As of 2017, the most recent published year of results for the ACS, 86% of the county's renter households earning less than $50,000 spend over 30% of their household income on housing.[26] In addition, urban public EDs likely serve a higher proportion

**Table 3.** Prevalence of homelessness and housing instability.

| | PRAPARE | AHC | Modified DHHS | Aggregate measure |
|---|---|---|---|---|
| Homeless | 26% | 24% | 29% | 35% (95% CI, 31-38) |
| Unstably Housed | 25% | 22% | 13% | 28% (95% CI, 25-31) |

*PRAPARE,* Protocol for Responding to and Assessing Patients' Assets, Risks, and Experiences; *AHC,* Accountable Health Communities; *DHHS,* Department of Health and Human Services; *CI,* confidence interval.

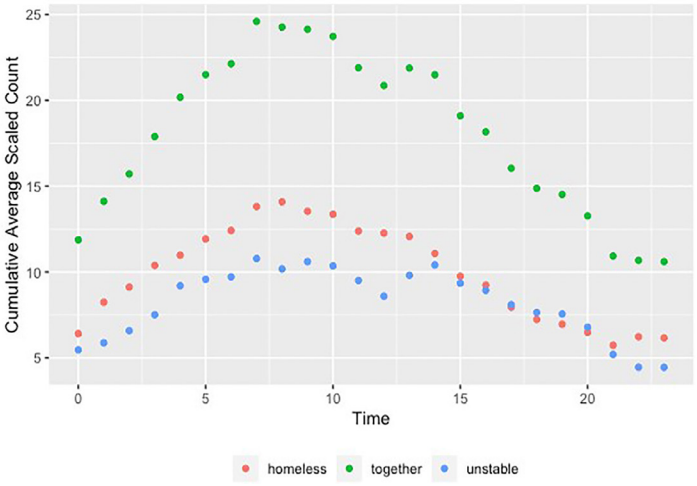


**Figure 2.** Cumulative average scaled count of homeless and unstably housed in emergency department arrivals 8-hour window. Each hour marking on the x-axis represents the start time of the 8-hour time windows, with the corresponding y value showing the cumulative number of patients who arrived during that 8-hour window by group. 0 = midnight, otherwise numbers denote military time hours.

of homeless and lower income patients than private or rural hospitals, factors that might contribute to higher reported rates of housing instability and homelessness than EDs on average nationwide. Nonetheless, given that more than half of those experiencing homelessness live in cities, our results may be relevant to the institutions and communities where those experiencing homelessness and housing instability are most likely to receive their emergency care.[26] As of publication, our study protocol is being expanded to other hospitals in other regions of the US.

**Housing Instability**

While many studies have focused on patients in the ED who are experiencing homelessness, far fewer have studied the prevalence of housing instability among ED patients. Individuals experiencing housing instability have been shown to have higher rates of ED and acute care utilization than stably housed individuals.[27,28] Unaffordable housing has also been associated with increased odds of hypertension and cost-related healthcare non-adherence, as well as worse self-rated health compared to controls using propensity score analyses.[29] In our study, 28% of ED patients reported having unstable housing, suggesting that the ED may offer significant opportunities for homelessness prevention through linkage to legal and social services. The ED as a touchpoint may be of particular import to patients who have limited interaction with other public institutions.

Of note, our results indicate that those reporting housing instability, as opposed to homelessness or stable housing, were significantly more likely to speak a primary language other than English and to report lower rates of English proficiency. Families with limited English proficiency may be particularly vulnerable to predatory or discriminatory housing practices and face higher risks and greater challenges advocating for their rights as tenants.[30] Given these findings, a more inclusive study on the interplay between housing stability, language access, and the particular challenges faced by low-income immigrant communities may be warranted. Additionally, these findings may be relevant to designing housing assistance programs within the ED that meet the language access needs of potential participants.

**Temporal Patterns of Homelessness and Housing Instability in the ED**

Our findings also suggest that the majority of both homeless and unstably housed patients present during daytime hours, with almost half arriving between 7 AM – 3 PM. Our temporal trend for homeless and unstably housed patients aligns with previous studies of the general adult ED population showing patient flow to be highest during daytime hours.[31] One implication of our temporal finding is that its congruence with employment norms could help facilitate the provision of housing services by community agencies in the ED. The 7 AM – 3 PM window captured nearly half of all homeless and unstably housed patient arrivals and represented the highest incidence eight-hour interval, followed closely by the slightly more conventional 8 AM to 4 PM period. The practical implications may be of particular interest to hospitals in light of California's newly enacted Senate Bill-1152, a so-called "safe discharge" law, which mandates a coordinated discharge plan for homeless patients including referrals to community agencies.[32]

**Public Health Implications**

Taking a step back, our finding that a majority of visits to this urban safety-net ED were made by patients experiencing housing challenges supports the view that lack of affordable, stable housing has become a public health crisis. The deeply intertwined relationship between housing instability, healthcare utilization, and poor health is both intuitive and widely documented in the literature.[33-35] It is our view that if the majority of patients coming to an ED had a particular

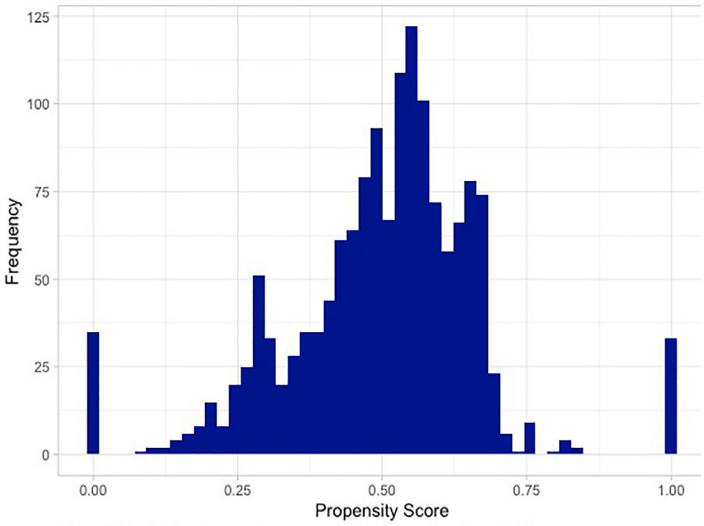


**Figure 3.** Distribution of propensity scores, which correspond to the probability of an individual having received and completed the survey given their particular combination of covariates.

diagnosis, say kidney disease, vast efforts would be mobilized to better understand and treat that condition. We believe that such efforts are needed in addressing homelessness and housing insecurity.

Our data support the view that the ED presents a unique linkage point in building systems that redefine housing as healthcare. A housing specialist centered in the ED, like other consulting specialists, would diagnose the acuity of a housing emergency—is the health threat of this person's housing status measured in hours, days, or months?—and leverage resources appropriately. Due to its accessibility, the ED represents a low-barrier contact point for high-cost and hard-to-reach users. The ED may provide particular value in reaching individuals experiencing housing instability and homelessness who interact less frequently with other government systems, whether as a result of historical marginalization, distrust of government actors, language barriers, or other obstacles.[36-38] A longitudinal study of newly homeless persons found that over a third had made a visit to the ED in the year prior to becoming homeless.[39] Given the high prevalence of housing instability reported by ED patients in our study, the prevention of homelessness through access to legal advocacy, eviction prevention, rent assistance, and other proactive supports arising from the ED may be a significant area of opportunity.

## LIMITATIONS

There are several limitations to this study. First, the study was conducted solely during summer months, which intuitively may impact rates of ED utilization by those facing housing challenges, even though recent studies suggest that seasonal variation may be limited.[32,40] Second, we missed a considerable proportion of our sampling target. Due to resource constraints, only 65% of the patients presenting in our sampling time period were approached for inclusion in the study, and 31% of the patients who were approached then declined to take the survey. Patients were approached in order of their arrival time, but some number of eligible patients did not complete the survey because they were receiving care at the time of the initial approach or were missed due to personnel limitations. Therefore, our study best represents a convenience sampling and a non-consecutive sampling of ED patients. Consecutive sampling would have increased the significance of the study.

Given this issue, a primary concern is that it is possible that a higher proportion of homeless patients were approached or chose to participate in the survey than the general ED population. We attempted to address this limitation by conducting a propensity score analysis comparing the surveyed group with potentially eligible non-respondents who were either never approached or who declined to complete the survey. Our analysis suggests that these groups would have responded similarly. However, this does not replace the value of having a larger and/or consecutive sample, and subject selection remains an important limitation.

An additional limitation involves the patients who were ineligible to participate. Our study did not include patients who could not complete the survey in English or Spanish and patients who could not complete the survey due to critical illness. Out of the 259 patients deemed ineligible after being approached (17% of screened patients), over half were ineligible because they spoke languages other than English or Spanish, and nearly half were ineligible because of critical illness. Finally, before more widespread confirmation, our results should be generalized with some caution, as housing challenges and associated service provision can vary widely geographically.

## CONCLUSION

We found that nearly two-thirds of patients seeking care in our ED faced housing challenges, with 35% homeless and 28% unstably housed. We also found that almost half such patients arrive between 7 AM and 3 PM, when they would be accessible to a housing specialist for counseling, referral, and management. All hands on deck are needed to address this crisis, and given the immense health impacts of housing challenges and the substantial financial resources of the healthcare sector, it is becoming increasingly compelling for health systems to be involved. Emergency departments may offer a unique linkage point in filling the "housing as healthcare" prescription.

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# A Model Partnership: Mentoring Underrepresented Students in Medicine (URiM) in Emergency Medicine

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**Introduction:** Creating a racially and ethnically diverse workforce remains a challenge for medical specialties, including emergency medicine (EM). One area to examine is a partnership between a predominantly white institution (PWI) with a historically black college and university (HBCU) to determine whether this partnership would increase the number of underrepresented in medicine (URiM) in EM who are from a HBCU.

**Methods:** Twenty years ago Emory Department of Emergency Medicine began its collaboration with Morehouse School of Medicine (MSM) to provide guidance to MSM students who were interested in EM. Since its inception, our engagement and intervention has evolved over time to include mentorship and guidance from the EM clerkship director, program director, and key faculty.

**Results:** Since the beginning of the MSM-Emory EM partnership, 115 MSM students have completed an EM clerkship at Emory. Seventy-two of those students (62.6%) have successfully matched into an EM residency program. Of those who matched into EM, 22 (32%) have joined the Emory EM residency program with the remaining 50 students matching at 40 other EM programs across the nation.

**Conclusion:** Based on our experience and outcomes with the Emory-MSM partnership, we are confident that a partnership with an HBCU school without an EM residency should be considered by residency programs to increase the number of URiM students in EM, which could perhaps translate to other specialties. [West J Emerg Med. 2021;22(2)213–217.]

## INTRODUCTION

Creating a racially and ethnically diverse workforce remains a challenge for medical specialties, including emergency medicine (EM).[1-3] In 2008 a set of recommendations designed to augment physician diversity in EM was published;[4] however, a recent study suggested that these best practices have not been widely implemented.[5] The pilot intervention in this study included three strategies focusing on a scholarship-based externship, a funded second-look event, and increased involvement of underrepresented in medicine (URiM) faculty in the interview and recruitment process. In response to these findings, a workgroup of emergency physicians with a focus on and expertise in diversity and inclusion reconvened in 2018. The workgroup identified several strategies to recruit diverse

applicants into EM. Among the most commonly discussed strategies was visiting elective clerkships for URiM students. These programs have proliferated in the last decade, with over 30 such programs in EM identified in 2018. However, as of this writing there has been limited data to suggest that the extent of impact of these URiM dedicated programs.[6]

The challenge faced by EM residency directors in recruiting diverse applicants is in large part a reflection of the number of URiM within undergraduate medical education (UME).[7] In a recent survey, 35% of program directors reported that the small pool of URiM applicants was the greatest barrier to recruiting a diverse class of residents.[5,6,8,9] However, there are a small number of medical schools with a higher representation of URiM students; most prominent of these are the historically black colleges and universities (HBCU). Based on a recent Association of American Medical Colleges (AAMC) data set, there are only three HBCU medical schools: Howard University College of Medicine; Meharry School of Medicine; and Morehouse School of Medicine.

These institutions represent 2.4% of United States medical schools yet have 14% of all Black medical students in the US.[10] Further, the mission and culture of these institutions generally emphasize care for the underserved and other principles of equity and justice that are considered to be core values of EM. The challenge, however, is that none of these institutions has an academic EM department or EM residency training program. This poses a significant barrier in recruiting students at HBCU medical schools who are interested in EM. In addition to not having easy access to EM advisors or mentors during the critical stages of the application process, students at HBCU medical schools may not have the same exposure to EM during the foundational early years of medical school, when a student's choice of residency training/specialty is often considered and in some cases, solidified.

Morehouse School of Medicine (MSM), a HBCU school in the city of Atlanta, does not have an academic EM department or residency training program and has more students that are URiM than the average US medical school. Founded in 1975, MSM has a student population that currently identifies as approximately 70% URiM. Another medical school in Atlanta, Emory University School of Medicine, has a large academic EM department and residency training program. Emory EM has had a nationally recognized history of supporting diversity and inclusion in EM with key URiM faculty publishing one of the first papers on how to improve diversity in EMt.[11] For the past 20 years there has been a meaningful partnership between MSM and the Emory Department of Emergency Medicine. Begun initially as an informal interaction, over the course of 20 years this relationship has flourished and become a more structured partnership that has resulted in significant outcomes with regard to matching HBCU students into EM residencies around the country.

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency medicine (EM) continues to have difficulty creating a racially and ethnically diverse workforce.*

What was the research question?
*Does a structured partnership between an EM residency and a historically black college and university (HBCU) medical school result in more underrepresented medical students in EM?*

What was the major finding of the study?
*A partnership between an EM residency and a HBCU medical school can help to increase the number of underrepresented in the field of EM.*

How does this improve population health?
*Partnerships like this can help to improve patient health outcomes, address healthcare disparities, and advance health equity.*

## METHODS

In 1999 the Emory Department of Emergency Medicine began its collaboration with MSM to provide guidance to MSM students who were interested in EM. At the onset of this collaboration, it was primarily the EM clerkship director who provided the bulk of mentorship and group activities. Since then, the program has expanded to include engagement of more Emory EM faculty and residents. Every MSM student who expresses interest in EM can meet with the faculty leadership in Emory EM. This includes the clerkship director, assistant clerkship director, program director, and associate/assistant program director, as well as other EM faculty. In addition, there continues to be an increased effort to engage UriM faculty as mentors and role models for URiM students. These relationships incorporate shadowing opportunities, assistance with career decisions, guidance for planning away rotations, fourth-year scheduling, application assistance, interview guidance, and when requested by the student, help with their rank list decisions.

In addition, an Emory EM faculty member serves as the faculty advisor for the MSM EM interest group, and the interest group is also assigned a senior Emory EM resident liaison. One key component of this partnership is the equitable treatment within Emory EM of MSM and Emory medical students regarding opportunities and exposure. This includes the guarantee that MSM students, like Emory students, are given priority to the Emory EM rotation in high-yield months. To evaluate the proportion of matches before and after the partnership, we submitted data to a regression using a beta

distribution and a logit link. The change following 1999 was analyzed using a linear spline with a single knot at 1999. We conducted analyses using R v 3.5.1, R Core Team (R Foundation for Statistical Computing, Vienna, Austria)

## RESULTS

MSM had its first student match into EM in 1985. Since the beginning of the MSM-Emory EM partnership in 1999, 115 MSM students have completed an EM clerkship at Emory. Seventy-two of those students (62.6%) have successfully matched into an EM residency program. Of those who matched into EM, 22 (32%) have joined the Emory EM residency program with the remaining 50 students matching at 40 other EM programs across the nation. To compare the proportion of MSM students who matched into an EM residency before vs after the MSM-Emory EM partnership, we conducted a linear spline in a beta regression. The significance level was assigned to alpha of 0.05. The spline in the regression was significant (odds ratio [1.10], 95% confidence interval, 1.01 – 1.20, $P = .03$). This finding indicates that the proportion of EM matches began to increase following the 1999 partnership.

MSM has undergone a period of rapid expansion in terms of class size. To control for this expansion, we also assessed the MSM-Emory EM partnership with regard to the percentage of total MSM students who matched into EM each year. Before the partnership, the average percent of the total MSM class matching into EM was 3.01%. Since the inception of the partnership, the total percent of the class matching into EM is 6.65%, which represents an increase of 121.20%. We performed descriptive analyses to further assess the match outcomes of the partnership as it progressed. Specifically, in the last six years (2012-2018), the mean candidates matching per year increased from 2.07 to 5.67. In the most recent two years of the partnership to date (2017-2018), the average number of EM matches was 9.0, which represented 15.79% and 11.84% of the total MSM senior class, respectively. This two-year period coincided with the period during which an Emory EM faculty member became adjunct faculty at MSM, and the EM rotation was certified as a senior elective, thus allowing this rotation to count toward required graduation credits. Further, over the last 10 years, MSM has matched at least one student to EM every year, which represents a notable increase over the 10 years prior.

## DISCUSSION

Over the past two decades, a successful partnership has developed and matured between the Emory Department of Emergency Medicine and MSM, resulting in a significant increase in the number of MSM students matching into EM. An increase in the diversity of residents and emergency physicians has been a goal for the Academy for Diversity and Inclusion in the Society for Academic Emergency Medicine, the premier organization for academic EM.[12]

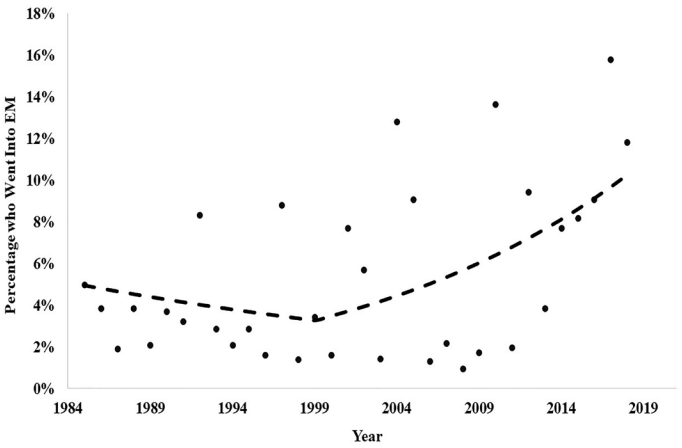


**Figure.** Percentage of Morehouse School of Medicine students matching into emergency medicine 1984-2018.

Emergency physicians are at the forefront of patient care, and increasing the number of emergency physicians to align with the population we serve is a desired goal.[13-15] For example, in 2017 there were 83,968 residents in US and Canadian allopathic medical schools, of whom only 13.67% classified as URiM.[16] During the same period, out of 7136 EM residents only 4.42% of these identified as Black. This is clearly a significant disparity given that in the 2017 Census, 13.4% of the US population identified as Black.[17]

This level of disparity is especially problematic in a racially diverse city such as Atlanta, since previous literature consistently indicates that patient outcomes and satisfaction are improved when a patient and his or her physician share a racial and/or ethnic background.[6,13,18-20] From its inception the MSM-Emory EM partnership has been intentional about closing this gap and has seen positive results. Since the partnership began, MSM has seen over twice as many students matched into EM as a percent of the overall class. Our analyses revealed that this was a significant difference, suggesting that the partnership has had a positive impact. The number of MSM students matching into EM has continued to rise as the MSM-Emory EM partnership grew and became more formalized.

In addition to continuing mentorship, application preparation, and previously noted activities, in 2017 an Emory emergency physician, who was the MSM EM faculty advisor, officially became adjunct faculty at MSM. Also, in that same year, MSM certified the Emory EM subinternship/clerkship as a senior selective, thus ensuring that it became part of the core curriculum for EM-bound and/or interested students who elected to take the rotation. Notably, in this same year, 15.79% of the MSM graduating class matched into EM, which is above the national average of the percent of US medical graduates matching into EM that year (9.16%).[21]

In our study there were 43 students enrolled in our EM

elective who did not match in EM. We do not have details regarding their confidential rank list order or subsequent career choices. This missing data only strengthens our conclusion that our partnership was successful since we likely underestimated the number of students impacted by our mentorship who either ranked EM but matched in other specialties, or within several years were able to switch into EM.

This type of partnership requires a culture, climate, and commitment in diversity and inclusion for all students who have an interest in EM. Based on the success of the MSM-Emory EM partnership, we propose a multilayered approach to successful matching in EM residency programs for HBCU schools without an EM residency. Mentorship has been demonstrated to be a significant factor in URiM applicants being able to identify with a residency program; as such, mentorship has been maintained as the cornerstone of this partnership.[8] Specifically, key aspects of this partnership include a dedicated group of Emory EM faculty and staff who provide the needed advising, mentoring, administrative support, and teaching throughout the MSM student's years in medical school. From the perspective of a non-HBCU medical school, partnering with HBCU schools without a residency program in EM is an opportunity to increase URiM in EM and advance diversity and inclusion in the field.

Initiatives to increase URiMs in EM, including a paid elective, a funded second look and URiM involvement in recruitment, focus on later stages of a student's decision-making process. Our focus is on a close relationship between an academic EM department and URiM students from a partner school to nurture an early interest in EM. As this relationship, mentoring, and advising continues throughout their medical education the opportunity of matching in EM is improved. Our holistic approach to EM mentorship for the MSM students has resulted in positive match outcomes exceeding national norms. We hope that the MSM-Emory EM partnership can serve as a model for other residency programs that value diversity and desire to increase the diversity of their residency classes in other specialties in medicine.

## LIMITATIONS AND FUTURE DIRECTIONS

The program we describe has some identified areas for growth. First, although we discussed the many benefits of increasing URiMs in EM residency programs, we do not specifically describe the racial or ethnic demographics of the MSM students matching into EM. Over the course of the Emory-MSM relationship, specific racial and ethnic data was not collected, and doing so retrospectively would have been complex. It should be noted that although on average 70% of MSM students identify as URiM, MSM also accepts and trains non-URiM students who have benefitted from the Emory-MSM partnership. Future analyses on this partnership would benefit from additional information specific to race/ethnicity and also socioeconomic status.

Additionally, as this is a single institutional program, the statistics are limited by sample size and meant to be descriptive only. With the increasing numbers of students contemplating EM as a career and ultimately applying for residency, as well as the increasing complexity of the application process, we recognized the need to better formalize our partnership and provide a structure for interested medical students throughout all years of medical school. In the last two years, for example, structured "EM bootcamp" sessions which include simulations, application discussion, and rotation preparation, have been instituted prior to the start of fourth-year subinternship rotations.

## CONCLUSION

The Emory-MSM partnership has shown success in increasing the presence of underrespresented students in EM with targeted intervention/involvement/efforts in the early stages of a medical student's specialty selection process. This type of program, which mentors URiM students early and engages them in multiple aspects of the specialty and its application process, should be adopted by other HBCU medical schools and all US medical schools. Given the limited published data, previous attempts to increase URiM student interest in EM, while likely beneficial, were less effective than our broad-based approach, or at this juncture, are unknown. Based on our 20-year experience with the Emory-MSM partnership and our outcomes, we are confident that our approach is effective and that partnership with an HBCU school should be considered by residency programs to increase the number of URiM students in residency programs.

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# Geographically Indexed Referral Databases to Address Social Needs in the Emergency Department

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**Introduction:** Unmet health-related social needs (HRSN) are among the drivers of disparities in morbidity and mortality during public health emergencies such as the novel coronavirus 2019 (Covid-19) pandemic. Although emergency departments (ED) see a high volume of patients with HRSN, ED providers have limited time to complete detailed assessments of patients' HRSN and are not always able to provide up-to-date and comprehensive information to patients on available community resources. Electronic, geographically indexed resource database systems have the potential to provide an efficient way for emergency physicians to rapidly identify community resources in settings where immediate social work consultation is not accessible.

**Methods:** We conducted a systematic review of papers examining the use of geographically indexed resource database systems in healthcare to better understand how these services can be used in emergency care. We then conducted simulated, standardized searches using two nationally available databases (211 and Aunt Bertha), applied to a single metropolitan area (Boston).

**Results:** Our systematic review found that most public health and screening interventions using nationally available databases have focused on chronic care needs. A small subset of publications demonstrated that these databases were mobilized during disasters to successfully aid vulnerable populations during Hurricanes Katrina and Rita. A total of 408 standardized searches were conducted to identify community resources related to four domains of social needs (food, transportation, housing, and utilities). Although 99% of the resources identified by both databases were relevant to the search domains queried, a significant proportion of the resources identified by each database were restricted to a specific demographic (eg, veterans).

**Conclusion:** Our findings demonstrate that geographically indexed referral databases may be an effective tool to help ED providers connect patients to nearby community resources during public health emergencies. We recommend that EDs select a referral database based on the greatest number of resources that are not demographically restricted. [West J Emerg Med. 2021;22(2)218-224.]

## INTRODUCTION

Public health emergencies, such as the novel coronavirus 2019 (COVID-19) pandemic, have the potential to disproportionately harm vulnerable populations.[1-3] Socially vulnerable populations face a greater likelihood of mortality during public health emergencies.[4-5] For example, during the 2009 H1N1 influenza pandemic, there were higher hospitalization and mortality rates among people who were categorized as low income and those living in low-income communities.[6,7]

Unmet health-related social needs (HRSN) are among

the primary drivers of disparities in morbidity and mortality during public health emergencies.[1,2] Limited access to healthy food options often result in higher incidence of heart disease, diabetes, and lung disease, which have been linked to increased risk of mortality from the current COVID-19 pandemic.[8] Patients with unmet HRSN face unique challenges to following emergency preparedness recommendations, such as self-isolation precautions and social distancing. These challenges include cohabitation with multiple family members or friends, unstable housing, inability to stockpile food, limited access to private transportation, limited social networks, lack of childcare, and reliance on income from jobs with limited benefits that pose additional health risks in the setting of an infectious pandemic.[9,10] Additionally, vulnerable patients may have more barriers to accessing care when they or someone in their household become ill enough to require an evaluation, and, therefore, may present increased risk for community spread. For COVID-19, this is particularly concerning given that household contacts have six times higher odds of infection.[11,12]

Emergency department (ED) providers often see a high proportion of patients with HRSN.[13-15] Although ED providers are often interested in addressing HRSN and recognize the high rate of unmet social needs affecting their patients, most report they do not feel adequately prepared to solve these problems.[13-15] ED providers have limited time to complete detailed assessments of patients' HRSN and are not practically able to provide up-to-date and comprehensive information to patients on resources available in their communities. Resources can cover a variety of needs, including help paying the utility bill, finding food pantries or subsidized groceries, and coordinating transportation to medical appointments. Although some EDs have care coordinators and social work services, availability of services is largely limited to daytime hours and some care coordination services may be restricted to certain payer groups (eg, Medicaid).

Geographically indexed resource databases represent a promising strategy for ED providers to efficiently link patients to accessible community resources. These software databases provide an electronic directory of community resources and have the capacity to facilitate e-referrals to social service agencies. Several resource databases are available, but no standardized comparison of their utility in the ED exists. We conducted a systematic review of papers examining the use of the geographically indexed resource database systems in healthcare to better understand how these services can be used in emergency care. We then conducted simulated, standardized searches using two nationally available databases (211 and Aunt Bertha), applied to a single metropolitan area (Boston). The goal of this work was to provide guidance to ED providers looking to develop a local resource directory for their community, specifically about how those databases have been used in the past and the advantages and disadvantages of standard, commercially available databases.

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency department providers see a high proportion of patients with unmet social needs who are at highest risk of morbidity and mortality during public health emergencies.*

What was the research question?
*How can geographically indexed resource referral databases be used to address the health-related social needs of patients in the emergency department setting?*

What was the major finding of the study?
*Geographically indexed resource referral databases can accurately identify local community resources to meet the common domains of social needs; however, identified resources are oftentimes restricted to a particular patient demographic group.*

How does this improve population health?
*Geographically indexed referral databases may be an effective tool to help ED providers connect patients to nearby community resources during public health emergencies.*

## METHODS

### Scoping Review

We performed a scoping review of published articles discussing geographically indexed databases (eg, 211 system, NowPow, and Aunt Bertha).[17-19] Articles were found via Google, Google Scholar, Ovid Medline, PubMed, and a modified snowball sampling using the cited sources of the primary articles for relevant studies. Search terms included the following: "United Way," "press/call/dial 211," "helpline," "hotline," "call center," "caller," "telephone," "information services," "community services," "crisis intervention," "hotline services," "referral," "consultation" and "professional referral," "Aunt Bertha," "CommunityRx," "NowPow," "social determinants of health," "referrals," "e-prescribing," "HealtheRx," and "community services," "social and medical care," and "medical informatics." Inclusion criteria were articles available in English that discussed the social resource database in any capacity. Three team members reviewed articles for eligibility. After duplicates were removed, 41 sources were identified by web-based and database searches.

### Resource Database Usability

We selected two nationally available social resource databases to demonstrate the functionality of new referral technologies when used from the perspective of the ED setting.

We chose 211 because it is freely available throughout the United States. We chose Aunt Bertha because it is now the largest database for social services nationally and the basic search functions are freely available despite being a privately run service.[18] The 211 system began on July 21, 2000, when the Federal Communications Commission (FCC) ruled in favor of assigning the three digit "211" number to social services.[20] The goal of 211 is to serve a function analogous to 911, but for community referral needs rather than acute medical emergencies; 211 services are available to about 95% of people in the United States as of 2019.[17] In 2018 alone, 211 centers assisted with 12.8 million requests for community resources.[17]

Aunt Bertha was started in 2010. It is a public benefit corporation that offers an open access, free search engine for public users as well as for-cost features designed for health organizations. Additional features include a social determinants of health screening tool, a closed-loop referral system that provides updates on the status of referrals that are made on a patient's behalf, and analytical reports for healthcare organizations to measure use.[18]

We simulated the application of the two databases within the large metropolitan area of Boston. We selected 51 ZIP codes to apply to our search comparison to encompass neighborhoods within or surrounding Boston. Searches were conducted between March 2–November 6, 2019 by trained research assistants. For each ZIP code, we ran standardized searches for community resources that related to four domains of social needs (food, transportation, housing, and utilities) across the 211 and Aunt Bertha databases. Search terms for Aunt Bertha included the following: "emergency food," "food pantry," "help pay for food," "meals," "help pay for housing," "help pay for utilities," "transportation for healthcare," "help pay for transportation," "help pay for gas," "help find housing," and "temporary shelter." Search terms for 211 included the following: "emergency food," "food pantries," "help paying for food," "hot meals," "SNAP/ food stamps," "help paying for electricity," "help paying for gas," "help paying for home heating," "bus passes," "discounted public transportation," "free rides," "emergency shelters," "help paying for housing," "homeless," and "housing vouchers and subsidized housing" (Appendix A).

For each domain, we recorded the total number of resources (n) identified by Aunt Bertha vs 211 for each searched ZIP code. We then mapped the number of resources available in both housing and food domains within each ZIP code to the relative need using ArcGIS 10.1 (Environmental Systems Research Institute, Redlands, CA). Relative need was represented as percent of households in poverty, as identified in the 2018 American Community Survey 5-year estimates (B17017 table) and displayed at the Zip Code Tabulation Areas (ZCTA) level using the 2010 Census ZCTAs. We calculated the mean number of resources across all 51 ZIP codes for each domain. Each resource identified from searches was verified through review of the resource's website. Resources identified in searches were categorized as correct or incorrect based on whether the resource was related to the domain queried (eg, search under food domain that yielded payment assistance for utility bills was deemed incorrect). Resources were also categorized based on whether eligibility for that resource was demographic-restricted (e g, resource restricted to women, veterans, or children). Given that ZIP codes are in close proximity to one another in this urban area, we did not deem a resource incorrect if it was located outside the specific ZIP code queried.

The number and percentage of resources identified that were correct vs incorrect based on the search domain were recorded and calculated for each ZIP code. To examine how useful resource search results would be in a time-limited ED setting where confirmation around patient eligibility criteria would be challenging, we then calculated the number and percentage of resources correct by domain that were also demographic-restricted. In this way we were able to compare how useful each database would be in an ED setting that may have incomplete information about demographic eligibility (eg, veteran status).

## RESULTS

We identified 30 studies discussing the 211 system, of which 26 were included. Of the four that were excluded upon full-text review, two analyzed the fiscal aspect for the implementation and viability of 211 infrastructure in a state.[21] One examined data storage variations in 211 centers,[22] and another described the benefit of using a public library as a 211 center.[23] The included studies addressed the history and background of the 211 system and role of 211 centers in disaster response and HRSN linkage. We identified 11 articles for review through the NowPow and CommunityRx search. Of these, five were included in final analysis. Six were excluded because they were abstracts only. An extensive search for articles related to Aunt Bertha yielded no results.

### Health Related Social Needs

Reports on the 211 system demonstrated both clinical and research implications. Most people who use 211 are typically a population that is difficult to reach and at high risk of poor health outcomes.[24,25] A Healthcare Navigation Program trial concluded that 211 centers can successfully connect people to resources, particularly in healthcare access.[26,27] The 211 system serves the public by "encouraging healthy behaviors, by raising awareness of preventive services, and by breaking down barriers that prevent access."[28] The 211 systems have databases that can inform targeted interventions.[29] The database combines "anecdotal" details gathered from the personal conversations callers have with 211 staff and "systematic" statistics that are collected for each call in a standard format.[29]

### Disaster Response

A subset of studies focused on the ability of 211 centers to assist communities recovering from disasters. For example, a retrospective study focused on unmet needs in the setting of Hurricanes Katrina and Rita to understand which populations

were most vulnerable to resource exhaustion and found that large, metropolitan cities struggled to absorb mass amounts of evacuees even though these areas had extensive community resources.[30] Additionally, the calls during this time were categorized by the caller's requested resource to determine the most acutely needed resource.[30] These authors suggested a similar spatial analysis could be productive to examine the health needs of a given community.[30]

Another study examined 211 centers' roles during the severe acute respiratory syndrome epidemic and the Great Northeastern Blackout in Toronto, Canada. One lesson extrapolated from these disasters advocated that 211 centers successfully served as a connector for callers and healthcare providers, and thus potentially reduced unnecessary 911 calls and presentations to EDs by connecting callers to services and calming anxieties.[31] There were no studies identified that assessed the accuracy of the resource databases.

**Results: Resource Database Usability Simulation**

We conducted a total of 408 standardized searches across both 211 and Aunt Bertha (Figure 1).

*Total Number of Resources Identified for Each Domain*

Across both databases, the highest average number of resources were identified within the food domain: 211 identified an average of 41 resources per ZIP code for the same simulated search while Aunt Bertha identified an average of 76 resources related to food insecurity per ZIP code. Searches related to transportation needs yielded the fewest average number of resources per ZIP code with 211 identifying 24 resources per ZIP code and Aunt Bertha identifying an average of 22 resources per ZIP code.

*Geographic Distribution of Resources*

Across all domains and both databases, the total number of social resources identified varied by ZIP code (Figure 2). The greatest geographical variation in the number of resources per ZIP code was observed under the food domain for both 211 (range = 27-122) and Aunt Bertha (range = 52-108). The least geographic variation in number of resources across ZIP codes occurred within the utilities domain for 211 (range = 38-40) and the transportation domain for Aunt Bertha (range = 19-30) (Figure 2).

*Accuracy and Applicability Social Resource Referral Databases*

Nearly all of the resources identified by both 211 and Aunt Bertha were correct based on the search domain. Averaging across all ZIP codes, both databases had greater than 99% accuracy for each of the four domains assessed. However, a significant proportion of the resources identified by both databases were restricted to a specific demographic. Resources related to housing were most often demographic-restricted; averaging across all ZIP codes and both databases, 54% of resources identified for this domain were found to be demographic-restricted. Conversely, resources related to utilities were the least often demographic-restricted; averaging across both databases, 39% of resources identified for this domain were found to be demographic-restricted.

*Comparing Across Referral Databases*

Averaging across all 51 ZIP codes, 211 identified a fewer number of resources that addressed food insecurity (n = 41) compared to Aunt Bertha (n = 76). However, a higher proportion of the food insecurity resources identified by Aunt Bertha were demographic-restricted relative to 211 (57% vs 32%, respectively). Similarly, under the housing domain, 211 identified only half as many resources on average across ZIP codes relative to Aunt Bertha (n =36 vs n = 68, respectively) but, again, the more resources identified by Aunt Bertha were demographic-restricted (62%) compared to 211 (46%).

Under the transportation domain, 211 identified a greater number of resources compared to Aunt Bertha (n = 24 vs n = 22, respectively); a higher proportion of the resources identified by Aunt Bertha were demographic-restricted relative to 211 (68% vs 17%, respectively). Similarly, 211 identified twice as many resources related to home utilities on

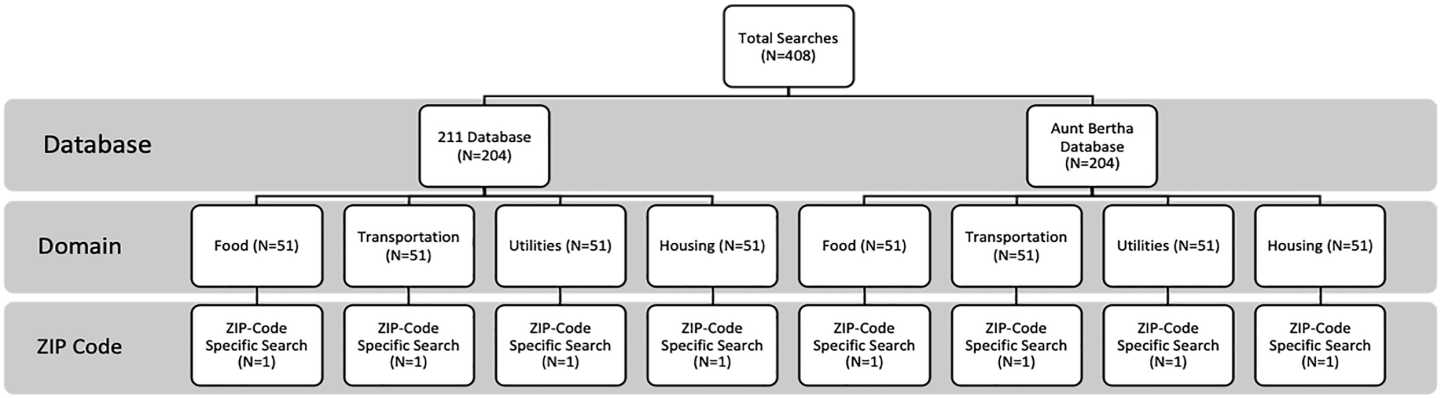


**Figure 1.** Number of platform searches conducted by database, domain, and ZIP code to identify social needs resources in the emergency department.

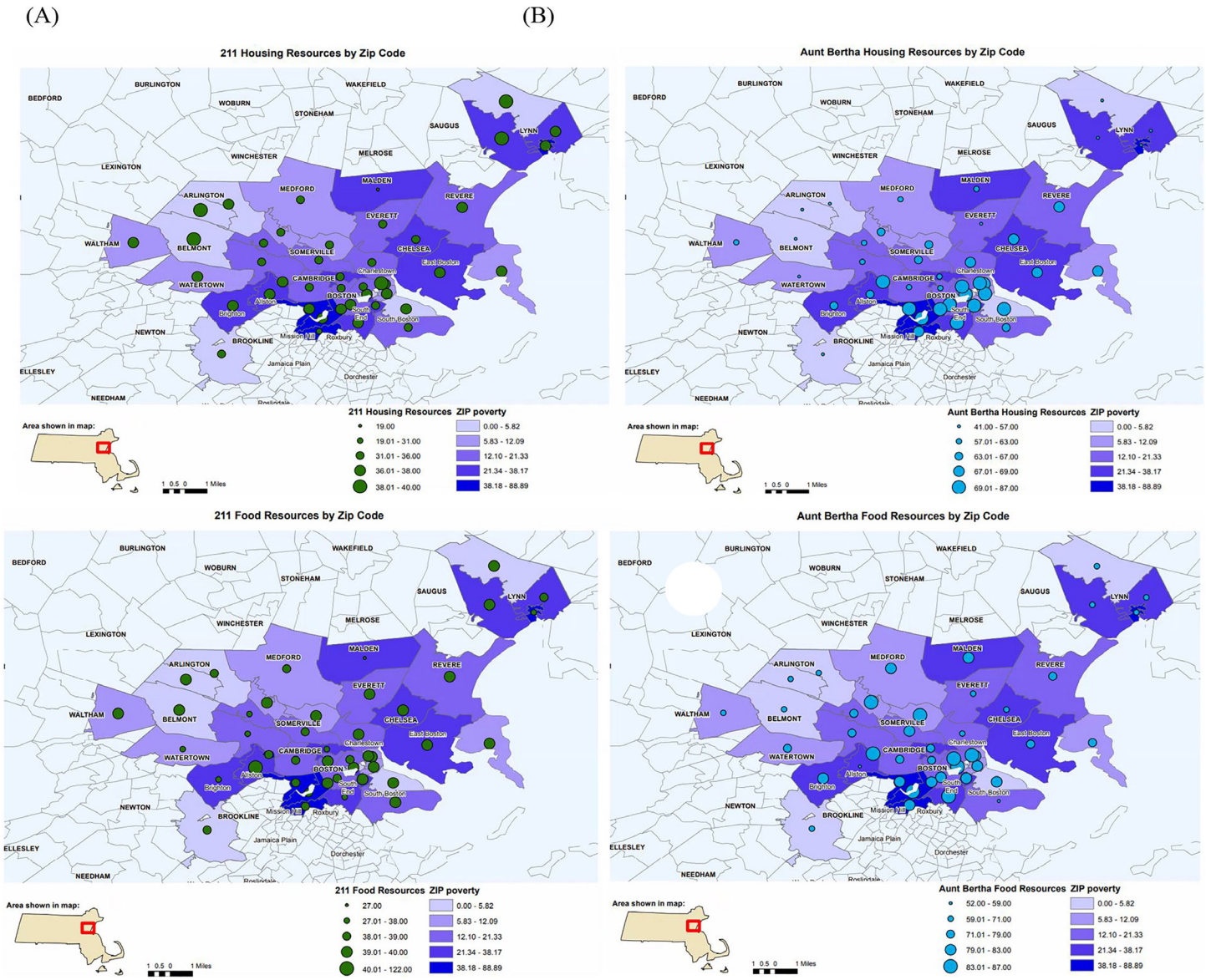


**Figure 2.** Geographic distribution of resources (n) for each ZIP code relative to poverty index for database housing domain using 211 database (A), housing domain using Aunt Bertha database (B), food domain using 211 database (C), food domain using Aunt Bertha (D). Green circles display 211 resources and blue circles display Aunt Bertha resources. Size of circles represents the number of resources within each ZIP code; larger circles indicate a greater number of resources. Purple scale represents percent of households in poverty within each ZIP code; darker shades of purple indicate greater percentages of poverty.

average compared to Aunt Bertha (n = 40 vs n = 21); a higher proportion of the resources identified by Aunt Bertha were demographic-restricted relative to 211 (65% vs 13%).

## DISCUSSION

Unmet HRSN are important drivers of disparities in morbidity and mortality during public health emergencies.[2] Emergency departments need to establish an efficient mechanism to refer patients to community health resources that address their unmet social needs. Geographically indexed database referral systems may represent an effective strategy for quickly and accurately identifying community resources that are within patients' reach. These resources are available in real time and only require an Internet connection, which is manageable in most EDs. Patients could access the websites or applications by using the hospital's WiFi and their own device, or the hospital could invest in communal devices located in spaces such as waiting rooms.

Although most public health and screening interventions using geographically indexed community resource referral systems have focused on chronic care needs, these databases have been mobilized during disasters to successfully aid vulnerable populations.[30,31] Additionally, referral systems can be used during disasters to disseminate crucial information to

the population and can, in turn, inform EDs of active issues. When recovering from a disaster, collaboration between community resource referral systems and EDs can inform preparation for a similar event in the future.[31] In addition to connecting patients to resources, data from referral systems can parse out opinions and beliefs held by certain populations. Knowledge of these opinions allows for targeted education efforts designed to increase health efficacy and accessibility for vulnerable populations.

The success of community resource databases in connecting patients with community resources is of importance for EDs attempting to address patients' HRSN in a time-limited setting with multiple, competing obligations. The ability to access geographically proximate resources for patients in need, and refer them to a free, multilingual hotline for further assistance in accessing resources, has significant potential to improve ED discharge processes, particularly for centers with limited social resources.

An inherent limitation of geographically indexed resource databases is the difficulty ensuring that the referral information is up to date and not specific to certain demographics (eg, veterans). Our standardized searches demonstrated that 39% and 54% of the resources identified by 211 and Aunt Bertha, respectively, were demographic-restricted. In the ED setting, it may not always be feasible for providers to elicit whether a patient meets eligibility criteria for community resources. Therefore, we recommend that ED providers selecting a referral database evaluate the following: ensure that the databases focus on identifying non-demographic-restricted resources and have options to clearly sort by demographic eligibility criteria. Programs should also be clear on the frequency of updates to ensure that patients are successfully referred to operating community resources.

## LIMITATIONS

Our study is subject to a number of limitations. We only simulated use of databases for a single metropolitan area; given geographic variability in availability of community resources, our findings on the relative usability of the two databases we simulated may not be generalizable to other settings, particularly more rural settings. Additionally, relevance of resources to the queried search domain was gleaned from review of the resource's website and not through direct contact with resource staff, so it is possible that we overestimated the accuracy of some platform search outcomes. Future research should focus on identifying the best strategies for using these resources to address the needs of ED patients. Additionally, future research should also examine the application of these resources to other metropolitan areas and geographic regions.

## CONCLUSION

Health-related social needs are associated with high-frequency utilization of the ED,[4,5] but existing ED systems and resources to address the non-medical, but health-impacting, needs of our patient population are limited. Geographically indexed resources databases have the potential to assist ED providers with identifying appropriate and geographically proximate community resources for patients. Even when applied to the same geographic area, resource databases vary in the total number of resources and the proportion of resources that are not restricted to a particular demographic. Before investing, safety-net organizations should carefully appraise databases to assess their usefulness in meeting their population's health-related social needs.

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# Language Barriers and Timely Analgesia for Long Bone Fractures in a Pediatric Emergency Department

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**Introduction:** Long bone fractures are common painful conditions often managed in the pediatric emergency department (PED). Delay to providing effective pediatric pain management is multifactorial. There is limited information regarding how the issue of language spoken impacts the provision of adequate and timely institution of analgesia. We sought to determine whether there is a difference between English-speaking and non-English speaking patients with respect to time to pain management for long bone fractures in a multi-ethnic urban PED.

**Methods:** We conducted a retrospective cohort study of consecutive cases over 29 months of children <18 years old who presented to the PED with a first-time long bone fracture. A correlation of multiple clinical variables with timeliness to providing analgesia as a primary outcome was determined. We performed regression analysis to eliminate confounding and to determine the magnitude of each variable's effect on the outcome.

**Results:** We analyzed a total of 753 patient cases (power 0.95). Regression analysis showed that the variable of English vs non-English language spoken was the most significant predictor of timeliness to pain management ($p < 0.001$). There was a significant difference in median time to triage measurement of pain score (1 minute vs 4 minutes for English vs non-English speakers [$p < 0.001$]); median time to initial analgesia (4 minutes vs 13 minutes for English vs non-English speakers ($p < 0.001$]); and median time to opioid analgesia (32 minutes vs 115 minutes for English vs non-English speakers ($p < 0.001$]), respectively. All measurements of time were from the creation of a patient's electronic health record. Just 30% of all patients received an opioid analgesic for treatment of long bone fractures, including only 37% with moderate triage pain scores.

**Conclusion:** Delay to receiving analgesic medications in pediatric patients with long bone fractures can be augmented by language barriers. Time to providing analgesia for long bone fractures is significantly delayed in non-English speaking families, contributing to disproportionate care in the PED. Furthermore, use of opioid analgesia for fractures in children remains poor. [West J Emerg Med. 2021;22(2):225-231.]

## INTRODUCTION

Pain is one of the most common complaints encountered in the emergency department (ED).[1] Prior studies indicate that ED pain intensity is higher than in other healthcare settings, due to the higher acuity and complexity of conditions generally encountered.[2] Despite mandatory pain assessment and safe, appropriate pain control becoming the standard of care for patients, oligoanalgesia remains a common

occurrence in the ED.[3-6] This problem is especially prevalent in children, even among providers who work solely in a pediatric emergency department (PED).[7]

Extremity injury is one of the more common painful conditions for which appropriate and timely management of pain is important. However, a prior study of long bone injuries in children reported that just 29% of patients received analgesia and the mean time to receiving analgesia was two hours.[8] Despite availability of opiates and procedural sedation for ED management of long bone fractures, ED providers still underutilize and delay pain medications in children.[2,6,8] Challenges in pediatric pain management include difficulty in assessing pediatric pain; underuse of pain assessment tools; a tendency to dismiss children's pain as fear; time and staff constraints in the busy ED environment; and concern for adverse effects or addiction to opioid analgesia.[1-2,6]

Pain is a subjective, self-reported process, which can often vary in its manifestation among children of different cultural and ethnic backgrounds.[9-11] Ethnic minorities in the United States have been shown to be at higher risk of oligoanalgesia in the ED.[12] Prior studies demonstrated that Black, Hispanic, and Asian patients of all ages receive reduced quantity and quality of analgesia and sedation care.[13-18] Minority groups have similar perception of pain to others, but differences in provider assessment of their pain negatively affect their pain management.[19] These differences exist despite cross-cultural validity existing for multiple pediatric visual pain scales.[20] With increasing populations of families with limited English proficiency, children with significant injuries will be placed at high risk of oligoanalgesia.

To our knowledge, only one prior published study has documented an association between limited parental English proficiency and oligoanalgesia in hospitalized children. In postoperative patients, children from limited English proficiency households were less likely to receive opioid analgesia compared to children from English-proficient households with comparable pain scores.[21, 22] There are currently no published studies that correlate English proficiency with time to administering ED analgesia in children. Our objective was to assess whether a difference in timeliness to receipt of pain assessment and analgesia exists among children with long bone fractures based on the patient/family's primary language.

*Population Health Research Capsule*

What do we already know about this issue?
*Oligoanalgesia remains a common occurrence in the emergency department (ED), especially in children, with ethnic minorities at highest risk.*

What was the research question?
*Does language play a role in timeliness of pain assessment and analgesia in a pediatric ED?*

What was the major finding of the study?
*Children from non-English speaking families were more likely to experience a delay in analgesia for fractures.*

How does this improve population health?
*Greater knowledge about healthcare disparities can inform future work in settings providing care for families with limited English proficiency.*

## METHODS

### Study Design and Setting

We conducted a retrospective cohort study, reviewing electronic health record (EHR) charts from January 2011–May 2013. This time period was chosen due a change in the PED's triage system that was initiated on June 1, 2013. Long bone fractures were selected for study due to the common nature of this complaint, potential for inducing significant pain, and the need for rapid analgesia and general care for these conditions.

This study was conducted in an urban PED in Brooklyn, NY, with an annual patient volume of 37,500, approximately 1400 long bone fractures per year, and a high volume of families not proficient in English. Per protocol, patients were initially triaged by a nurse, who recorded vital signs and initial pain score. Triage pain score was attained via patient self-report, using the Wong-Baker FACES scale or the Numeric Pain Rating Scale for patients aged ≥6 years. For younger patients, the FLACC (face, legs, activity, crying and consolability) behavior scale was recorded. Initial analgesia, typically acetaminophen at 15 milligrams per kilogram (mg/kg) or ibuprofen at 10 mg/kg, could be given by the nurse at that time by standing order. If no analgesia was administered at triage, the treating physician in the PED could order either one of these or an opiate medication in place of or in addition to acetaminophen or ibuprofen.

The opiate generally favored by our PED staff was intravenous morphine at 0.05-0.1mg/kg. On-site hospital interpreters are available by request for Spanish, Mandarin, Cantonese, and Russian-speaking families. The EHR was created, with vital signs and pain score documented by the triage nurse, only once an interpreter was present to assist non-English speaking families. If on-site interpretation was unavailable, phone-based interpretation was accessible for all other languages typically encountered in our PED, with language phone lines present for use both in triage and within the PED. This study was approved and conducted in accordance with guidelines from the hospital's institutional review board.

### Data Collection and Processing

We initially screened charts for *International Classification of Diseases*, 9th revision, codes corresponding to long bone fractures of both upper and lower extremities, excluding

injuries to the clavicle, hands, feet, fingers and toes as these were determined as less likely to need urgent intervention for pain. We also excluded other orthopedic conditions of torus or avulsion fractures, nursemaid's elbow and patella dislocations, as they are not typically treated with analgesia on the same sustained basis as performed with long bone fractures. Diagnosis of long bone fracture was confirmed by a positive radiograph report in the health record as read by an attending-level radiologist. We further excluded any cases for which patients had prior history of chronic medical conditions that predisposed to limb pain (sickle cell disease and osteogenesis imperfecta) and those patients with conditions who may alter pain perception or accurate communicability (developmental delay, autism). Patients who received pain medications for their acute injury prior to hospital arrival were excluded, as were patients who indicated routine use of pain medication (defined as at least weekly use of acetaminophen or an nonsteroidal anti-inflammatory drug). In addition, we excluded patients with abnormal mental status, hypotension for age, multi-organ trauma or triage status of "resuscitation," as their serious medical conditions could potentially have precluded pain management as a primary goal. Finally, any patient who arrived without a parent or legal guardian present was excluded because of the natural delay in care that would result while attempting to obtain consent for treatment.

Data collected included information on clinical variables that could possibly affect timely ED pain management: patient demographics (patient age, gender, ethnicity, type of health insurance); and clinical or circumstantial data relevant to treatment of their extremity injury and pain (initial pain score, triage acuity level, mode of travel to ED, patient disposition, and provision of procedural sedation). Spoken language was determined as a routine part of the triage process on all patients; interpreter usage was noted where available.

The primary outcomes measured were time intervals from creation of a patient's EHR to each of the following pain management endpoints: time to measuring initial pain score; time to administration of initial pain medication (generally, acetaminophen or ibuprofen); and time to administration of opiate pain medication. Baseline time zero was the timestamp for the creation of the EHR; each endpoint measurement of pain management was compared to this baseline. Thus, the times to administration of pain medications already included the time to measurement of the initial pain score in triage and were not sequential time periods. Timely administration of analgesic agents was the focus of study due to the importance of rapid care for long bone fractures. Secondary outcomes analyzed related to quality of ED pain management for fractures.

### Data Analysis

We conducted a retrospective health record review in accordance with criteria set forth by prior articles.[23] Three abstractors initially reviewed the chart data and recorded information into a templated paper data recording sheet; all abstractors underwent a training process with the primary investigator, including a mutual review of 10-15 charts, to help locate both typical and alternate portions of the health record where each data point could be found. Missing data was given a unique numerical code and accounted for in the final statistical calculations. These were then transcribed into Microsoft Excel (Microsoft Corporation, Redmond, WA) by the primary author, in order to control for any inconsistencies between reviewers and create uniformity in the data. Thus, no inter-rater reliability statistics were used. None of the abstractors or primary author were blinded to the hypothesis of the study.

We performed statistical tests using Microsoft Excel and SPSS 19.0 (SPSS Inc., Chicago, IL). Analysis included descriptive statistics and chi-square test for categorical variables. Since the variable of time would likely not follow a normal distribution curve, univariate analysis of factors (age, gender, insurance type, race/ethnicity, language spoken) related to timing of analgesia used non-parametric statistics, specifically Mann-Whitney and Kruskal-Wallis tests. Finally, we performed a regression analysis to control for potential confounders.

Statistical significance was set at $p < 0.05$. To maximize accuracy, we determined a sample size allowing a power of 95% to detect a minimal difference of five minutes to pain assessment and analgesic provision (750 patients). We set a higher standard than the traditionally used 80% limit in order to capture even the slightest difference possible between the two groups; if such a small difference was present at this level of statistical significance and power, then it would certainly be present in any larger time difference that would be more clinically relevant in the ED.

## RESULTS

We screened a total of 3426 charts for the child's first fracture-related visit, and 753 met inclusion criteria (Figure 1). Characteristics of study subjects are detailed in Table 1. Compared to English-speaking families, patients from non-English speaking families were more likely to have Medicaid as their primary insurance. In our study population, non-English speaking families were more likely to be Hispanic or Asian, and English-speaking families were more likely to be White or Black. We initially sought to divide out each individual language spoken in our patient population: Spanish, Russian, Chinese – Mandarin and Cantonese, Urdu, Bangladeshi, Vietnamese, Yiddish, Other/Mixed. However, the variable frequencies of languages and the small number of patients who spoke each individual language were too small to analyze separately. Thus, we simplified into English and non-English groups.

The median times to initial triage measurement of pain scores, initial administration of analgesia, and opioid medication are depicted in Table 2, with each interval beginning at the creation of the patient chart in the EHR. Median time to triage measurement of pain score was 1 minute vs 4 minutes for English vs non-English speakers ($p < 0.001$); median time to initial analgesia was 4 minutes vs 13 minutes for English vs non-English speakers ($p < 0.001$); and median time to

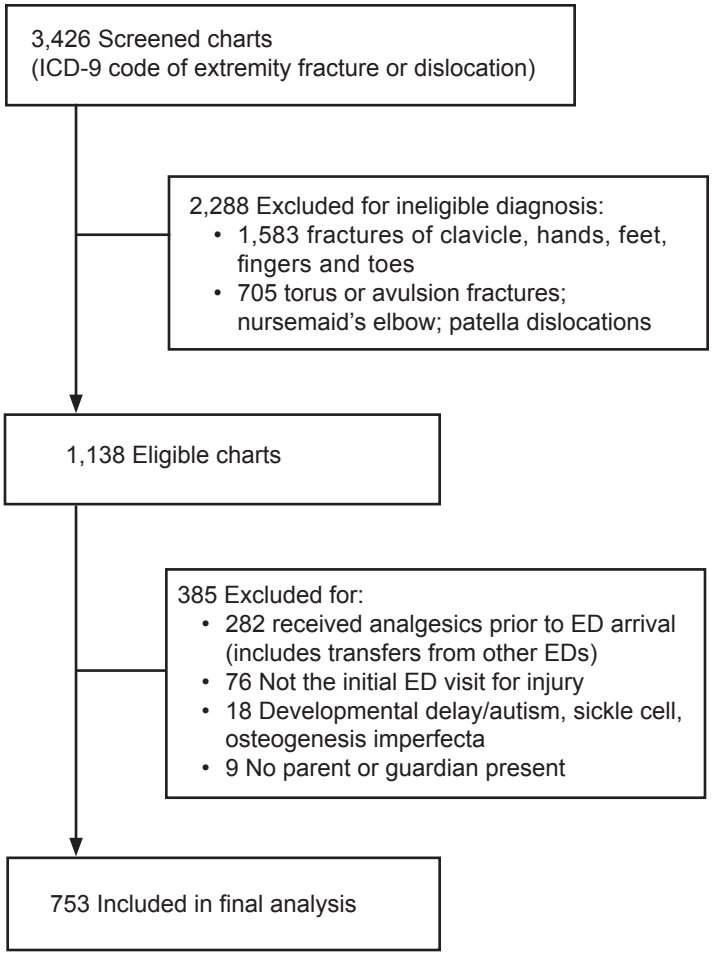


**Figure 1.** Inclusion of cases in study of pain administration to children with long bone fractures.
*ED,* emergency department, *ICD-9,* Intenational Classification of Diseases, 9th revision.

opioid analgesia was 32 minutes vs 115 minutes for English vs non-English speakers ($p < 0.001$), respectively. There was a significant difference between English vs non-English speaking patients/families in median time to triage measurement of pain score and median time to administering analgesia medications.

Secondary measures related to quality are summarized in Table 3. There was no overall difference between English and non-English speakers with respect to receipt of pain score, receipt of initial analgesia, receipt of opioid analgesia, or rate of providing procedural sedation for fracture reduction. Although there was no significant difference in opiate analgesia received between English vs non-English speaking groups, there was a significantly greater rate of an opiate administered as the initial pain mediation in the English-speaking group. In addition, among all patients who received a pain score > 0, 40 of 513 patients (8%) did not receive any pain medication; for patients with a pain score of $\geq 4$, just 151 of 405 patients (37%) received an opiate medication. Overall, 198 of 661 patients (30%) who received analgesia were given opiates for long bone injuries.

Factors independently associated with enhanced timeliness to pain management included having commercial insurance, non-Asian ethnicity, non-Hispanic ethnicity, and race identified as White. The results of the linear regression show that English-speaking language was ultimately the most significant predictor of timeliness to pain management [$R^2$: 0.054-0.178, $p < 0.001$].

## DISCUSSION

Providing analgesia for children is important to help relieve suffering, decrease anxiety, facilitate success in examination and diagnosis, increase patient satisfaction, and to avoid long-term neuro-psychological sequelae to painful stimuli.[21] This study advances current general knowledge about cultural disparities in delivery of healthcare. Specifically, prior studies have outlined differences attributed to racial and socioeconomic differences, with minority children overwhelmingly more likely to receive less timely and appropriate analgesia overall in the ED.[8] While the single-site location of this study somewhat limits its generalizability to the rest of the United States, this PED is located in one of the most diverse communities in New York City, allowing some generalizability to similar urban areas. Also, non-English speaking families seek care in many PEDs throughout the United States.

This is the first known study to address language-related barriers causing delays to analgesia administration in the PED. Among non-English speakers, there was an additional nine minutes of median wait times for initial analgesia in our ED and an additional 83 minutes of median wait times for opioid analgesia. This disparity existed despite a lack of significant difference between the two groups in terms of actual receipt of pain scores, initial analgesia, opioid analgesia, or procedural sedation for fracture or dislocation reduction. This difference was present despite the baseline time being the creation of the EHR, which would not be done for non-English speakers until there was an interpreter available to assist the patient or their family. Hence, our study design would not capture any additional delay in first obtaining an interpreter to start the registration process.

Interestingly, the one disparity in quality of pain management that existed in our study was that English speakers were more likely to receive an opiate as their first-line pain medication. It is possible that language barriers between patient and providers make it more likely that English-speaking patients would more effectively communicate degree of pain to ED providers. Also, at the time of this study, there was no intranasal formulation for rapid-onset opioid pain relief available in this institution. The extra step of explaining placement of an intravenous line for medication administration to non-English patients' families may have been perceived as an additional barrier for staff, especially if the interpreter would need to be recalled to the ED to explain this procedure. We found no correlation between higher level of triage acuity, older patient age, or higher initial pain score with respect to timing to pain score, analgesia, or opioid analgesia.

There were some demographic differences between the two groups, with non-English speaking families more likely to have

**Table 1.** Characteristics of study subjects.

| | English speaking (N = 369) | Non-English speaking (N = 384) | *p*-value |
|---|---|---|---|
| Median age, years | 7 (4-11.5)* | 6 (3-11)* | 0.111 |
| Male gender | 252 (68.3%) | 277 (72.1%) | 0.265 |
| Type of insurance: | | | |
| Medicaid | 201 (54.9%) | 299 (78.3%) | <0.001 |
| Self-pay | 22 (6.0%) | 32 (8.4%) | 0.258 |
| Commercial | 143 (39.1%) | 51 (13.4%) | <0.001 |
| Ethnicity/Race: | | | |
| White | 214 (58.8%) | 118 (31.0%) | <0.001 |
| Hispanic | 45 (12.4%) | 98 (25.7%) | <0.001 |
| Asian | 29 (8.0%) | 117 (30.7%) | <0.001 |
| Middle Eastern/Indian | 32 (8.8%) | 21 (5.5%) | 0.088 |
| Middle Eastern (other) | 29 (8.0%) | 27 (7.1%) | 0.678 |
| Black | 15 (4.1%) | 0 (0.0%) | <0.001 |
| Median initial pain score | 5 (2-8)* | 5 (2-7)* | 0.023 |
| Pain scale Used | | | |
| FACES/Numeric | 203 (64.4%) | 179 (55.4%) | 0.024 |
| FLACC | 112 (35.6%) | 144 (44.6%) | |
| Admitted | 38 (10.4%) | 51 (13.4%) | 0.216 |
| Median triage level | 3 (2-4)* | 3 (2-4)* | 0.849 |
| Ambulance arrival | 91 (24.7%) | 90 (23.4%) | 0.733 |

**IQR,* interquartile range.
*FACES,* Wong-Baker FACES pain scale; *FLACC,* behavioral pain scale with face, legs, activity, cry, consolability.

Medicaid insurance and be of Hispanic or Asian ethnicity. These differences were also independently associated with delays in pain management, which support prior studies that demonstrate minority ethnicity and Medicaid patients have less optimal pain management compared to their White and commercially-insured counterparts.[13-18] However, our linear regression analysis demonstrated language spoken as the key factor in delays to pain management. With the rapid increase in diversity of the United States population and the expected increase of households with limited English proficiency, delay to analgesia may continue to compromise healthcare in these children.[21]

Overall, 92.4% of our patient population received a pain score, which parallels a prior study of long bone fractures in children and is evidence of our hospital's standardized practice of pain assessment as mandated by the Joint Commission.[3,25] Our patient population had an 87.8% rate of receipt of some form of analgesia for long bone fractures. This is a large improvement for pain management compared to prior studies that demonstrated rates of overall analgesia to be in the 30% range.[8,25] We attribute this to our hospital's protocol that allows our triage nurse to administer medications such as acetaminophen and ibuprofen to children in triage. This also allows patients to receive pain medications faster as opposed to waiting for a physician order for initial analgesia. In general, recommendations from prior pediatric studies support pain assessment along with initial triage vital signs with additional protocols to facilitate administration of acetaminophen, ibuprofen, and opiates as appropriate.[6,26]

One area for quality improvement in pain management is short-term acute use of opiates for long bone fractures. We found that our overall rate of opiate administration (30%) to be just as sub-par as previously documented.[8,16,25] Attempts to educate healthcare staff about the importance of treating acute pain, the creation of national and hospital-based standards for pain management, and establishing physician-reminders to prompt analgesia order-entry have not improved rates of analgesia in children seen in the ED for painful conditions.[4,15] Furthermore, in patients who received a pain score measurement of ≥ 4, just 37% received an opiate for pain control. This reflects poor compliance with guidelines and policies to use opiate medications for pain scores of ≥ 4 that other institutions follow for acute pain management.[2,8]

**Table 2.** Timeliness of pain management in pediatric patients.

| | English speaking (IQR) | Non-English speaking (IQR) | *p*-value |
|---|---|---|---|
| Median time to pain score | 1 minute (0-94) | 4 minutes (0-155) | < 0.001 |
| Median time to initial analgesia | 4 minutes (0-91) | 13 minutes (0-891) | < 0.001 |
| Median time to opioid analgesia | 32 minutes (0-221) | 115 minutes (12-423) | < 0.001 |

*IQR,* interquartile range.

**Table 3.** Quality of pain management variables related to language barriers.

| | English speaking (N = 369) | Non-English speaking (N = 384) | *p*-value |
|---|---|---|---|
| Pain score performed in triage | 335 (90.8%) | 361 (94.0%) | 0.100 |
| Initial analgesia administered in triage | 317 (85.9%) | 344 (89.6%) | 0.148 |
| Opioid analgesia administered | 87 (23.6%) | 111 (28.9%) | 0.099 |
| Need for sedation | 65 (17.6%) | 52 (13.5%) | 0.132 |
| Opiate as initially administered analgesic | 35 (40.7%) | 27 (24.3%) | 0.020 |

The ongoing opioid crisis in the US and concern that even legitimate pediatric exposure to opioids could be associated with subsequent abuse may be the reason that providers limit use of opiates for pain control in the scenario of long bone fractures.[7,27] Alternative forms of analgesia, such as sub-dissociative doses of ketamine, or alternatives to pain medication altogether with distraction techniques, may be better suited to a given patient's needs in acutely painful conditions and may be better used going forward given comfort with these modalities. Integrating a pain control pathway with an incremental stepwise approach to pain management that would involve the patient and their caregiver could be a future area of study.

## LIMITATIONS

The retrospective nature of the study created a reliance on accurate recordkeeping in our EHR. There was no indication in the medical record whether the provider could speak the patient's language; thus, we did not control for any ability of staff or treating physicians to speak the patient's native language. Future prospective studies may serve to clarify whether or not these concerns played a role in the language barriers noted by this current study. A prospective study could also explore other barriers to pain management specific to the system used in our ED, such as whether arrival during peak time is a more important factor than language issues.

Separate from the concerns that result from the retrospective nature of the study, we must acknowledge the older age of our data, which were collected from January 2011–May 2013. As noted, this time period was chosen due to a change in the ED triage process that occurred in June 2013, which would have adjusted the time intervals to the pain management variables collected for the purpose of this study. The desire to maintain uniformity in the information collected among ED staff was the primary driver of setting this cutoff date. However, we must note that major improvements in technology, access to interpreter services via video chat devices, and overall improvement in internet speed since then could yield different results had a similar study been performed in this same ED in present time. However, as a historical benchmark, this study presents important information about healthcare disparities in a non-English speaking population.

As this was a single-center study, we can only comment on the delivery of analgesia at this site alone. A prospective, multicenter study could further delineate whether language serves as a barrier to pain management and address whether this single site had any flaws in its system of administering analgesia, such as variance in triage nursing delivery of pain medication, which was the source of the differences found. Finally, further management of fractures with splinting would always occur after the initial triage process was complete, generally once the patient had already received some initial form of pain medication and radiographic studies were obtained.

As this study was focused on the initial assessment of pain and delivery of analgesia, we did not assess further means of caring for these long bone fractures and pain score reassessment. We felt that timeliness to delivery of analgesia served as a reasonable surrogate to these patient-oriented factors, despite being a more process-driven measure. Future study efforts could focus more on standardized measurements of pain score at multiple time intervals in order to assess whether the initial effect of language spoken persists throughout a patient's ED or hospitalization course.

## CONCLUSION

Delay to providing analgesics presents a problem for non-English speaking families in the pediatric emergency department. Our study demonstrates significant delays in time to pain score (three minutes), providing initial analgesia (nine minutes), and providing opiate analgesia (83 minutes), all of which were primarily attributed to language barriers. Measures to provide translation services when needed can augment diagnostic accuracy and timeliness of patient care, as well as decrease disproportionate care to these patients. Furthermore, use of opiates overall for long bone fractures was uncommon in children, as just 30% of patients in this study received them, including 37% with moderate triage pain scores.

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# Homeless Shelter Characteristics and Prevalence of SARS-CoV-2

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To the Editor:

We read with interest the article by Rebecca Karb et al[1] titled "Homeless shelter characteristics and prevalence of SARS-CoV-2," published in the *Western Journal of Emergency Medicine*. We appreciated the authors focusing on people experiencing homelessness, a population that has been particularly impacted by the recent coronavirus disease 19 (COVID-19) pandemic and that is more at risk of contracting COVID-19 for specific environmental and individual characteristics.[2]

In this article, the authors compared the characteristics of five different homeless shelters in Rhode Island, USA, and evaluated the prevalence of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection among their residents (n = 299) using reverse transcription polymerase chain reaction (RT-PCR) nasopharyngeal swabbing. The overall prevalence across all shelters was 11.7%; however, a large difference was found between shelters, as 3/5 had no cases while two had 21.6% and 35.3% of positive cases, respectively. The authors concluded that shelters with more transient residents, higher occupation rate, admission of new residents, and absence of daily education had a higher prevalence of SARS-CoV-2 infection.[1] In addition, the authors highlighted the importance of the population density of the neighborhood; in fact, shelters in more densely populated areas had a higher prevalence of COVID-19.[1]

Our group performed an active surveillance over a period of six months (April-September 2020) in a cohort of nearly 200 homeless persons living in shelters in the downtown area of Rome, Italy, through the medical facilities of the Eleemosynaria Apostolica, Holy See; they included the Madre di Misericordia Primary Care Center, an advanced mobile medical unit and an ambulance. In these persons, hosted in homeless shelters managed by the Eleemosynaria Apostolica, prevention strategies were adopted including the use of face masks and hygienizing gels by residents and staff, adequate social distancing, daily symptom screening and temperature checks, routine SARS-CoV-2 testing, and constant education on prevention measures to avoid contagion. Furthermore, all new admissions were tested with RT-PCR and antigen nasopharyngeal swab, rapid serology test, and quantitative antibody evaluation on whole blood before entering the shelter. The prevalence of SARS-CoV-2 infection in our cohort was approximately 2%; this rate is similar to that reported in other studies that investigated SARS-CoV-2 among homeless people living in congregate settings where similar prevention measures were implemented. Rogers et al[3] reported an overall prevalence of 2% of 1434 persons in 5/14 homeless shelters in King County, Washington; Yoon et al[4] found a prevalence of 2.1% of 1684 residents in 24 shelters in Atlanta, Georgia; and Bodkin et al[5] reported a prevalence of 1% of 104 homeless persons in a shelter in Hamilton, ON, Canada.

The prevalence found in our cohort and in other studies strongly suggests that, as stated by Karb et al,[1] symptom screening and temperature monitoring are insufficient means to reduce virus transmission in homeless shelters and emphasizes the importance of daily symptom and temperature checks, adequate physical distancing, use of individual protections, accurate testing of new residents, and daily education to methods and best practices to prevent infection spread. Furthermore, the use of frequent testing among residents and staff is also important, as infection from asymptomatic cases, not identifiable through daily symptom checks, is the predominant mode of SARS-CoV-2 spread in congregate living settings.[6]

In our opinion, these factors which are commonly adopted in shelters with a low SARS-CoV-2 prevalence, can widely contribute to maintain infection control among residents and staff and avoid outbreaks,[7] such as the ones reported by Karb et al. and in a study by Imbert et al,[8] where 67% of residents and 17% of staff tested positive for SARS-CoV-2 in a San Francisco, California, shelter. In this case, the prevention strategies of the shelter relied exclusively on symptomatic cases, person-based

contact tracing, and symptom screening that was demonstrated as insufficient to prevent the outbreak.

It is, therefore, of utmost importance to emphasize the role of these prevention and control measures to prevent outbreaks in homeless shelters which are more vulnerable to virus transmission for their intrinsic characteristics, as well as in other group residential settings such as recovery houses, nursing homes, and other congregate living facilities hosting vulnerable populations.[9] At the same time, shelters play a central role in assistance to homeless persons, and even temporary closures, as often reported during the COVID-19 pandemic,[10] may have severe effects on public health management if alternative residential solutions are not promptly available.

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# Who Stayed Home Under Safer-at-Home? Impacts of COVID-19 on Volume and Patient-Mix at an Emergency Department

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**Introduction:** To describe the impact of COVID-19 on a large, urban emergency department (ED) in Los Angeles, California, we sought to estimate the effect of the novel coronavirus 2019 (COVID-19) and "safer-at-home" declaration on ED visits, patient demographics, and diagnosis-mix compared to prior years.

**Methods:** We used descriptive statistics to compare ED volume and rates of admission for patients presenting to the ED between January and early May of 2018, 2019, and 2020.

**Results:** Immediately after California's "safer-at-home" declaration, ED utilization dropped by 11,000 visits (37%) compared to the same nine weeks in prior years. The drop affected patients regardless of acuity, demographics, or diagnosis. Reductions were observed in the number of patients reporting symptoms often associated with COVID-19 and all other complaints. After the declaration, higher acuity, older, male, Black, uninsured or non-Medicaid, publicly insured, accounted for a disproportionate share of utilization.

**Conclusion:** We show an abrupt, discontinuous impact of COVID-19 on ED utilization with a slow return as safer-at-home orders have lifted. It is imperative to determine how this reduction will impact patient outcomes, disease control, and the health of the community in the medium and long terms.
[West J Emerg Med. 2021;22(2)234–243.]

## INTRODUCTION

### Background

In Los Angeles County (LAC) more than 1 million individuals have tested positive for coronavirus disease 2019 (COVID-19) and more than 14,000 individuals have died as of January 20, 2021.[1] Emergency departments (ED) are at the forefront of the healthcare response to the pandemic, and urban, safety-net public hospitals have been disproportionately impacted by the increase in morbidity and mortality attributed to COVID-19.[2] With more than 150,000 ED visits annually, the LAC+USC Medical Center is normally one of the busiest EDs in the United States. However, in line with numerous accounts in the popular and academic press, the overall number of patients presenting to the LAC+USC ED plummeted in the wake of "safer-at-home" declarations. Specialties ranging from cardiology[3-5] to emergency medicine[6] and otolaryngology[7] noted marked decreases in patient visits for both acute and chronic conditions. This decreased volume allowed providers to focus their efforts on treating COVID-19 patients in a new world of routine personal protective equipment and "hot zones" within the department without the added stress of facing crowded EDs; however, the patients who avoided the ED may have been

placing themselves in danger by skipping needed and emergent medical care.

**Importance**

While much of the academic research comes from international settings or focuses on the acute treatment of suspected COVID patients,[8] accounts in the popular press and commentary pieces in medical literature highlight the danger of patients delaying needed care.[9-11] Emerging academic research from the US bolsters these concerns, showing a 40-60% reduction in ED utilization in the wake of the COVID-19 pandemic and an increase in inpatient admissions as the pandemic intensified.[12] As these articles point out, the question remains as to what the spillover effects have been and will continue to be of these safer-at-home orders and the COVID-19 pandemic on healthcare utilization and outcomes for patients. In addition to the observation that patients have been reluctant to seek care, there is increasing evidence that the impact of COVID-19 in the US has disproportionately affected populations including Blacks, Latinos, patients with pre-existing health conditions, and lower-income individuals.[13-15] As LAC+USC serves many of these populations, it is key to understand whether the decline in ED utilization has had unequal or disproportionate effects on vulnerable patient populations.

*Population Health Research Capsule*

What do we already know about this issue?
*COVID-19 led to a reduction in ED visits and had disproportionate health effects among minorities; its impact on ED visits for that population is understudied.*

What was the research question?
*How did COVID-19 and safer-at-home orders impact ED utilization and patient-mix at a large, safety-net ED?*

What was the major finding of the study?
*Safer-at-home orders were associated with a large, sustained drop in ED use across nearly all patient groups.*

How does this improve population health?
*Identifying patients with disproportionate decreases in ED utilization allows us to prioritize outreach to encourage continued use of necessary healthcare services.*

**Goals of This Investigation**

The goal of this investigation was to describe the impact of the COVID-19 pandemic on operations of a large, urban, public ED in Los Angeles, California. We characterize the effect of the COVID-19 pandemic and California's safer-at-home order on ED visits, patient disposition, and diagnosis-mix of ED visits compared to prior years. We show the impact of COVID-19 on changes to patient demographics (age, gender, race/ethnicity), primary payor, and geographic distribution of patients visiting the ED. We describe the differential return of patients to the ED in the weeks following the safer-at-home declarations.

## METHODS

**Study Design and Setting**

This investigation is a retrospective analysis of all ED encounters for the first 18 weeks of the year (January to early May) in 2018, 2019, and 2020 at the LAC+USC Medical Center ED. All non-HIV-related ED encounters are included. The analysis focuses on the years 2018, 2019, and 2020 to represent ED volume across two influenza seasons and the COVID-19 pandemic. We selected the first 18 weeks of the calendar year because it includes the peak and downturn of influenza seasons and the implementation of LA County's safer-at-home order, as well as the predicted or modeled beginning, peak, and downturn of COVID-19 in LA County at the time of the analysis.[16] The LA County safer-at-home order issued March 19, 2020, shuttered all non-essential businesses, banned all gatherings of more than 10 individuals, and required essential businesses to practice social distancing, provide access to effective hand sanitizer or hand-washing, and to follow any additional communicable disease control recommendations such as requiring the use of face masks.

LAC+USC Medical Center is the largest, county-run hospital in LAC. Annual ED visits average over 150,000 making it one of the busiest EDs in the nation. LAC+USC is situated in a relatively low-income and disproportionately Latino neighborhood, directly adjacent to downtown Los Angeles's Skid Row; it also provides care for persons detained at the largest jail in the US, the Twin Towers Correctional Facility.[17,18]

All data and measures come from the electronic health records (EHR) of patients during these visits; the same EHR system was in place for the entirety of our observation windows. We selected outcomes and measures whose reporting is unchanged over the three-year period. The University of Southern California Institutional Review Board approved all study procedures.

**Outcomes and Measures**

To estimate the impact of the COVID-19 pandemic and attendant safer-at-home declarations, the key outcome of interest was weekly ED volume measured as the number of ED encounters, including transfers to other facilities. Weeks were measured from Sunday to Saturday. We report the proportion of all ED visits that are accounted for by various

patient, diagnosis, and other measures to describe how ED volume has changed across and within years. In addition to the main outcome of ED volume, we also report the rate at which patients were admitted to inpatient units of the same hospital.

Key patient-level characteristics were collected from patients during ED registration. These characteristics include the following: patient age; gender; race or ethnicity; nativity; home address; and primary language spoken by the patient. In addition to patient-reported characteristics we included measures recorded in the EHR: primary payor for the ED encounter; mode of arrival to the ED (eg, arrival by ambulance); Emergency Severity Index (ESI) triage category; ED disposition; and primary diagnosis at discharge. These patient and encounter-level characteristics are presented as the count or proportion of all weekly ED visits accounted for by these categories.

To present a comprehensive, meaningful estimate of the diagnosis-mix of patients presenting to the ED, we categorized all ED encounters by the primary or first-listed diagnosis code in the patient's EHR. Those individual *International Classification of Diseases, 10th Rev* diagnosis codes are bundled into the 18 multilevel Clinical Classification Software (CCS) diagnostic categories developed by the Healthcare Cost and Utilization Project (HCUP).[19] These categories group diagnosis codes by body system (eg, diseases of the circulatory system). We report the 10 most common of these categories observed in our population. In addition, we report a Clinical Classifications Software, Revised (CCSR) diagnosis-based definition of encounters that may be related to COVID-19-specific complaints. COVID-associated respiratory diagnoses includes diagnoses of pneumonia (RSP002); influenza (RSP003); acute bronchitis (RSP005); other specified and unspecified upper respiratory infections and disease (RSP006-7); chronic obstructive pulmonary disease and bronchiectasis (RSP008); asthma (RSP009); pleurisy, pleural effusion, pulmonary collapse (RSP011); respiratory failure, respiratory insufficiency, and respiratory arrest (RSP012); lung disease due to external agents (RSP013); and other specified and unspecified lower respiratory disease (RSP016). All diagnosis categories come from HCUP's CCSR scheme. The specific breakdown of these diagnoses is available in Appendix Table 1.2.

### Statistical Analysis

This investigation presents descriptive statistics comparing changes in ED volume across years and by week within years. In most cases, we present unadjusted counts or shares of ED volume attributed to encounter-specific characteristics. Where appropriate, tests of difference were performed using Student's t-test or f-test. To explore potential changes in the geospatial catchment area of LAC+USC during the study period, we examined and mapped the home addresses of patients presenting to the ED by ZIP code. For this study, we considered only visits by patients whose home addresses were in mainland LAC, and excluded visits from patients living on islands or outside LAC, as well as those representing group facilities. Shapefiles of ZIP codes in LAC were obtained from LAC eGIS. To facilitate comparison between periods, the count of visits per ZIP code was rescaled and centered within each nine-week period. Further details on the geographic analyses are included in Appendix 2.

## RESULTS

### Overall Impact on ED Utilization

The LAC+USC Medical Center ED had approximately 56,000 patient encounters in the first 18 weeks of each year for the initial two years of the study period; in 2020, that number dropped by almost 20% to 45,448. These declines in ED utilization were observed broadly by patient characteristics, encounter acuity, and patient diagnoses. Notably, as shown in Table 1, nearly all these decreases came in the second half of our observation period (weeks 10-18) in 2020 with total ED encounters dropping 36% from 27,778 in weeks 1-9 to 17,670 in weeks 10-18. Across all outcome measures and patient or encounter characteristics recorded in our study, total ED volume as measured in counts decreased from the first half of the observation period to the second half of the observation period in 2020 (Table 1 and Appendix Table 1.1; $P<0.05$ in all but five comparisons). The magnitude of these reductions ranged from a 16% decrease to a 58% decrease with an average decrease of about 33% (authors' calculations based on Table 1).

The geographic distribution of those reductions was uniform. Of all ED visits where patients reported a home ZIP code within LAC, comparing visits in the first half of the 2020 observation window to the second, there was no change in the relative density of ED visits by ZIP code (Appendix Figure 2.1). As a result, the service area of LAC+USC remained uniform as patients were similarly likely to visit the hospital across ZIP codes. More detail on the geographic distribution of visits is available in Appendix 2.

These decreases also coincided with the safer-at-home declarations issued on March 19, 2020 (week 12 of our observation period in 2020). As shown in Figure 1, Panel A, the reduction in ED encounters occurred quickly and sharply in weeks 12-16, just after the announcement of the safer-at-home declaration. At its lowest point, ED encounters were 50% lower in week 16 compared to week 11, just before the order was issued. A similar pattern emerged for inpatient admissions shown in Figure 1, Panel C, with a sharp decrease after the declaration, although a less dramatic drop-off in the number of admissions; the lowest level of admissions occurred in week 15, representing a 38% reduction relative to week 11, before the order was issued.

### Impact on ED Utilization for Respiratory Diagnoses

The only patient group that saw an increase in the number of ED encounters in the first 18 weeks of 2020 as compared to the same weeks in 2018 or 2019 were patients whose primary

**Table 1.** Description of emergency department patients and utilization, 2018, 2019, and 2020.

| | 2018 Weeks 1-9 | | 2019 Weeks 1-9 | | 2020 Weeks 1-9 | | P-value | 2018 Weeks 10-18 | | 2019 Weeks 10-18 | | 2020 Weeks 10-18 | | P-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outcome Measures | N | % | N | % | N | % | | N | % | N | % | N | % | |
| Total ED Volume | 28,436 | (100.0) | 27,678 | (100.0) | 27,778 | (100.0) | | 27,594 | (100.0) | 28,598 | (100.0) | 17,670 | (100.0) | |
| Inpatient Admissions | 4,025 | (14.2) | 3,953 | (14.3) | 3,668 | (13.2) | <0.001 | 3,806 | (13.8) | 3,968 | (13.9) | 3,045 | (17.2) | <0.001 |
| ICU Admissions | 876 | (3.1) | 966 | (3.5) | 902 | (3.3) | 0.023 | 834 | (3.0) | 948 | (3.3) | 750 | (4.2) | <0.001 |
| Patient Characteristics | | | | | | | | | | | | | | |
| 0-18 y.o. | 4,187 | (14.7) | 3,726 | (13.5) | 4,087 | (14.7) | <0.001 | 3,585 | (13.0) | 3,956 | (13.8) | 1,696 | (9.6) | <0.001 |
| 19-39 y.o. | 9,012 | (31.7) | 8,853 | (32.0) | 8,708 | (31.4) | 0.272 | 8,960 | (32.5) | 9,221 | (32.2) | 5,997 | (33.9) | <0.001 |
| 40-64 y.o. | 12,087 | (42.5) | 12,101 | (43.7) | 12,039 | (43.3) | 0.012 | 12,124 | (43.9) | 12,489 | (43.7) | 8,021 | (45.4) | 0.001 |
| 65-80 y.o. | 2,573 | (9.1) | 2,506 | (9.1) | 2,440 | (8.8) | 0.443 | 2,411 | (8.7) | 2,504 | (8.8) | 1,644 | (9.3) | 0.076 |
| >80 y.o | 574 | (2.0) | 492 | (1.8) | 498 | (1.8) | 0.060 | 509 | (1.8) | 427 | (1.5) | 305 | (1.7) | 0.005 |
| Male | 16,081 | (56.6) | 15,731 | (56.8) | 15,404 | (55.5) | 0.002 | 15,772 | (57.2) | 15,930 | (55.7) | 10,691 | (60.5) | <0.001 |
| Patient Acuity[+] | | | | | | | | | | | | | | |
| ESI 1 | 216 | (0.8) | 287 | (1.0) | 303 | (1.1) | <0.001 | 198 | (0.7) | 268 | (0.9) | 235 | (1.3) | <0.001 |
| ESI 2 | 5,059 | (17.8) | 5,360 | (19.4) | 5,409 | (19.5) | <0.001 | 4,745 | (17.2) | 5,564 | (19.5) | 3,810 | (21.6) | <0.001 |
| ESI 3 | 15,643 | (55.0) | 15,197 | (54.9) | 15,256 | (54.9) | 0.964 | 15,475 | (56.1) | 15,494 | (54.2) | 9,232 | (52.3) | <0.001 |
| ESI 4 | 5,106 | (18.0) | 4,560 | (16.5) | 4,674 | (16.8) | <0.001 | 4,702 | (17.0) | 4,984 | (17.4) | 2,611 | (14.8) | <0.001 |
| ESI 5 | 711 | (2.5) | 613 | (2.2) | 654 | (2.4) | 0.083 | 741 | (2.7) | 590 | (2.1) | 352 | (2.0) | <0.001 |
| Ambulance[$] | 5,524 | (19.4) | 5,035 | (18.2) | 4,518 | (16.3) | <0.001 | 5,610 | (20.3) | 5,129 | (17.9) | 3,483 | (19.7) | <0.001 |
| Patient Language | | | | | | | | | | | | | | |
| English | 15,219 | (53.5) | 14,791 | (53.4) | 14,553 | (52.4) | <0.001 | 14,959 | (54.2) | 15,109 | (52.8) | 10,081 | (57.1) | <0.001 |
| Spanish | 11,833 | (41.6) | 11,966 | (43.2) | 12,251 | (44.1) | <0.001 | 11,402 | (41.3) | 12,493 | (43.7) | 7,022 | (39.7) | <0.001 |
| Other | 1,213 | (4.3) | 778 | (2.8) | 799 | (2.9) | <0.001 | 1,097 | (4.0) | 764 | (2.7) | 486 | (2.8) | <0.001 |
| Patient Nativity | | | | | | | | | | | | | | |
| US-born | 15,019 | (53.1) | 13,961 | (50.7) | 13,816 | (50.1) | <0.001 | 14,372 | (52.3) | 14,439 | (50.9) | 8,972 | (51.0) | 0.001 |
| Undocumented* | 171 | (0.6) | 143 | (0.5) | 175 | (0.6) | 0.190 | 136 | (0.5) | 232 | (0.8) | 81 | (0.5) | <0.001 |

*ED*, emergency department; *ICU,* intensive care unit; *y.o.,* years old; *ESI,* Emergency Severity Index.

**Table 1.** Continued.

| | 2018 Weeks 1-9 | | 2019 Weeks 1-9 | | 2020 Weeks 1-9 | | P-value | 2018 Weeks 10-18 | | 2019 Weeks 10-18 | | 2020 Weeks 10-18 | | P-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Patient Primary Payor | N | % | N | % | N | % | | N | % | N | % | N | % | |
| Private Insurance | 1,150 | (4.0) | 1,042 | (3.8) | 1,722 | (6.2) | <0.001 | 1,103 | (4.0) | 1,891 | (6.6) | 1,040 | (5.9) | <0.001 |
| Medicaid | 20,508 | (72.1) | 19,473 | (70.4) | 18,592 | (66.9) | <0.001 | 19,509 | (70.7) | 19,412 | (67.9) | 11,069 | (62.6) | <0.001 |
| Medicare | 2,328 | (8.2) | 2,232 | (8.1) | 2,234 | (8.0) | 0.795 | 2,249 | (8.2) | 2,248 | (7.9) | 1,526 | (8.6) | 0.012 |
| Other Public | 2,572 | (9.0) | 2,796 | (10.1) | 2,624 | (9.5) | <0.001 | 2,836 | (10.3) | 2,848 | (10.0) | 2,147 | (12.2) | <0.001 |
| Uninsured | 1,583 | (5.6) | 1,791 | (6.5) | 2,308 | (8.3) | <0.001 | 1,597 | (5.8) | 1,871 | (6.5) | 1,797 | (10.2) | <0.001 |
| Patient Race or Ethnicity | | | | | | | | | | | | | | |
| White | 1,078 | (3.8) | 1,028 | (3.7) | 1,150 | (4.1) | 0.022 | 1,100 | (4.0) | 1,007 | (3.5) | 745 | (4.2) | <0.001 |
| Black | 3,620 | (12.7) | 3,195 | (11.5) | 3,149 | (11.3) | <0.001 | 3,487 | (12.6) | 3,389 | (11.9) | 2,398 | (13.6) | <0.001 |
| Asian | 1,169 | (4.1) | 1,100 | (4.0) | 1,121 | (4.0) | 0.712 | 1,105 | (4.0) | 1,073 | (3.8) | 607 | (3.4) | 0.008 |
| Hispanic | 19,061 | (67.0) | 18,887 | (68.2) | 19,025 | (68.5) | <0.001 | 18,367 | (66.6) | 19,624 | (68.6) | 11,214 | (63.5) | <0.001 |
| Unknown | 3,264 | (11.5) | 3,251 | (11.8) | 3,098 | (11.2) | 0.090 | 3,318 | (12.0) | 3,223 | (11.3) | 2,577 | (14.6) | <0.001 |

*ED*, emergency department; *ICU*, intensive care unit; *y.o.*, years old; *ESI*, Emergency Severity Index.

diagnosis was categorized as a COVID-associated respiratory diagnosis or a disease of the respiratory system. Depending on the definition and comparison year used, those increases ranged from 444 (12% increase) to 542 (10% increase) visits over the 18-week period (Appendix Tables 1.1 and 1.2). Despite that overall increase in total visits by patients with respiratory diagnoses in 2020, the number of COVID-associated respiratory cases in the ED declined across the weeks with a sharp downturn in the week immediately following the safer-at-home declaration (a 38% reduction relative to week 11).

As shown in Figure 1, Panel B, these cases were elevated relative to prior years in weeks 1-8 (20-34% higher, depending on the comparison year), but after their sharp downturn in week 12, they leveled off at a lower level than in the two prior years by week 15 (26% to 46% lower for weeks 15-18 depending on the comparison year). While much of this reduction came in the form of fewer ED encounters or inpatient admissions for patients with relatively mild complaints, such as asthma, influenza, and other upper respiratory complaints, the within-diagnosis admission rate of patients with COVID-associated respiratory diagnoses nearly doubled from the first to the second half of our 2020 observation period from 11.7% to 20.6% (Appendix Table 1.2). As shown in Figure 1, Panel D, admissions for COVID-associated respiratory diagnoses climbed—particularly from weeks 15 to 18—where they went from about 20 per week to about 35 per week (Figure 1, Panel D). These admissions were concentrated in patients diagnosed with the more serious diagnoses of pneumonia and respiratory failure, insufficiency, or arrest (Appendix Table 1.2).

**What Patients Remain at the ED?**

While there was an across-the-board decrease in ED utilization, certain groups saw *relative* increases in their share of ED volume as they continued to seek care in the ED more frequently than other patient groups. Comparing weeks 1-9 to weeks 10-18 in 2020 shows that the rate of inpatient admissions grew by about four percentage points and the rate of intensive care unit admissions increased by just under one percentage point (both differences $P<0.001$). The share of ED encounters classified as high acuity (ESI 1 and 2) grew by more than two percentage points while the share classified as relatively low acuity (ESI 4) dropped by a similar amount. There was a similar difference between the early and late periods for patients arriving by ambulance. Interestingly, this shift in the distribution of ED encounters from lower to higher acuity occurred just after the introduction of the safer-at-home regulations in week 12 (Figure 2, Panels A and B). There was no similar trend in prior years.

In addition to higher acuity patients accounting for a disproportionate share of ED utilization relative to prior years and to the first half of our observation periods, the patients who continued to visit the ED tended to be older, more likely to be male, Black, uninsured or using non-Medicaid, publicly-provided insurance programs, or English speakers. Just as

the shifts in the distribution of encounters by acuity were observed just after the safer-at-home declarations, so too were the increases in the average age of the patients, which rose by between 2-3 years from week 11 to weeks 13-16 (Figure 2, Panel C). The shift in the distribution of ED encounters for uninsured patients came slightly before the safer-at-home declarations and appears to level off at a higher relative share in weeks 12-13 (Figure 2, Panel D).

Looking by week in 2020, one of the more notable shifts in the ED distribution was the strong, persistent reduction in the share of encounters for children. As shown in Figure 3, Panel A, there were slight, relative increases in the share of patients aged 19-64 after week 11, but children went from about 14% of all ED visits in week 11 to just 5% in week 15. Another notable shift was in the distribution of diagnoses of patients (Figure 3, Panel C). Trauma diagnoses (injury or poisoning), digestive diagnoses, and endocrine diagnoses saw relatively little fluctuation in their share of ED volume across weeks in 2020. In contrast, the share of ED volume accounted for by patients with mental health and substance use diagnoses increased dramatically just after the safer-at-home declarations in week 12. These patients saw a relative increase in their share of ED volume of about four percentage points (from about 7% to 11%).

**What Patients are Returning to the ED?**

By the last four weeks of our observation period in 2020, some patient groups had begun returning to the ED for acute care. Among all non-respiratory encounters, the sharp reductions in ED volume leveled off in week 15 and began to change direction in weeks 17 and 18 (Figure 1, Panel A); increases in inpatient admissions started as soon as week 15 (Figure 1, Panel C). As noted above, one of the main drivers of this increase appears to be an increase in the number of patients coming to the ED for mental health and substance use diagnoses. In addition, beginning in week 15, the observed drop-off in the share of ED encounters for Hispanic patients or patients paying with Medicaid was reduced but not eliminated (Figure 3, Panels B and D). As these are two populations that account for a large proportion of LAC+USC volume historically, their return contributes to the broader reversal in trend. Despite these initial returns of selected patient populations, there were still more than 1000 fewer ED encounters in 2020 as compared to 2018 or 2019 in the final week of our observation window, a nearly 40% reduction in volume compared to prior years.

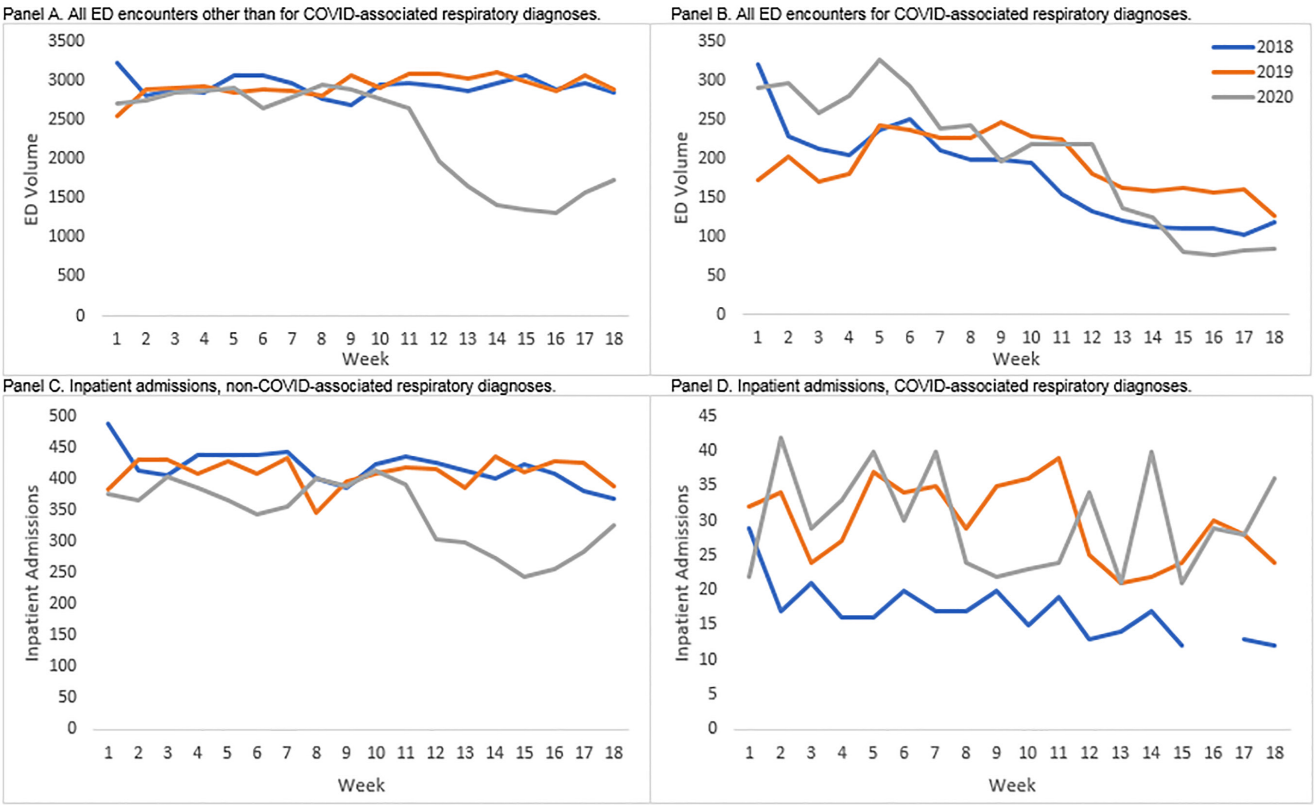


**Figure 1.** Total emergency department volume and inpatient admissions by week, year, and diagnosis.
Notes: Values representing fewer than 10 encounters are omitted.
COVID-associated respiratory diagnoses include pneumonia, influenza, acute bronchitis, other specified and unspecified upper respiratory infections and disease, chronic obstructive pulmonary disease and bronchiectasis, asthma, pleurisy, pleural effusion, pulmonary collapse, respiratory failure, respiratory insufficiency, respiratory arrest, lung disease due to external agents, and other specified and unspecified lower respiratory disease.
*COVID*, corona virus 2019; *ED*, emergency department.

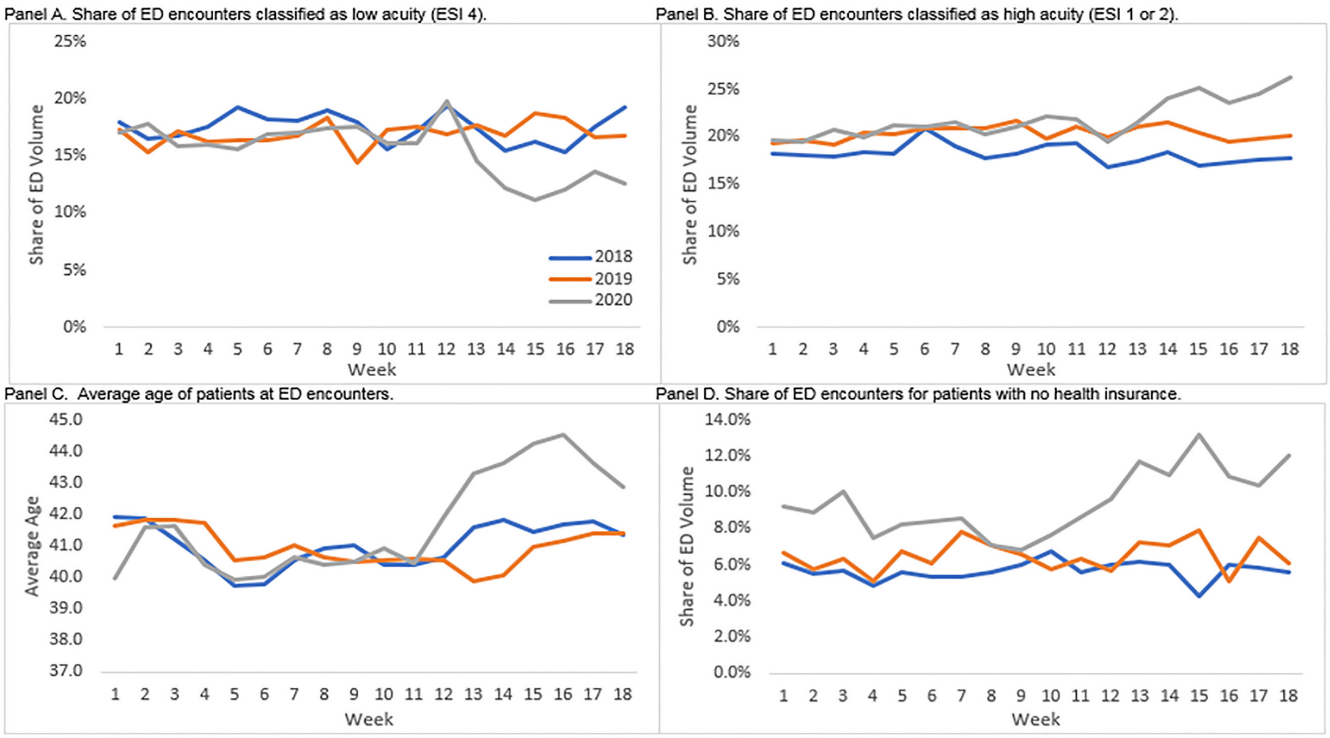


**Figure 2.** Distribution of emergency department (ED) volume by week, year, and selected characteristics.

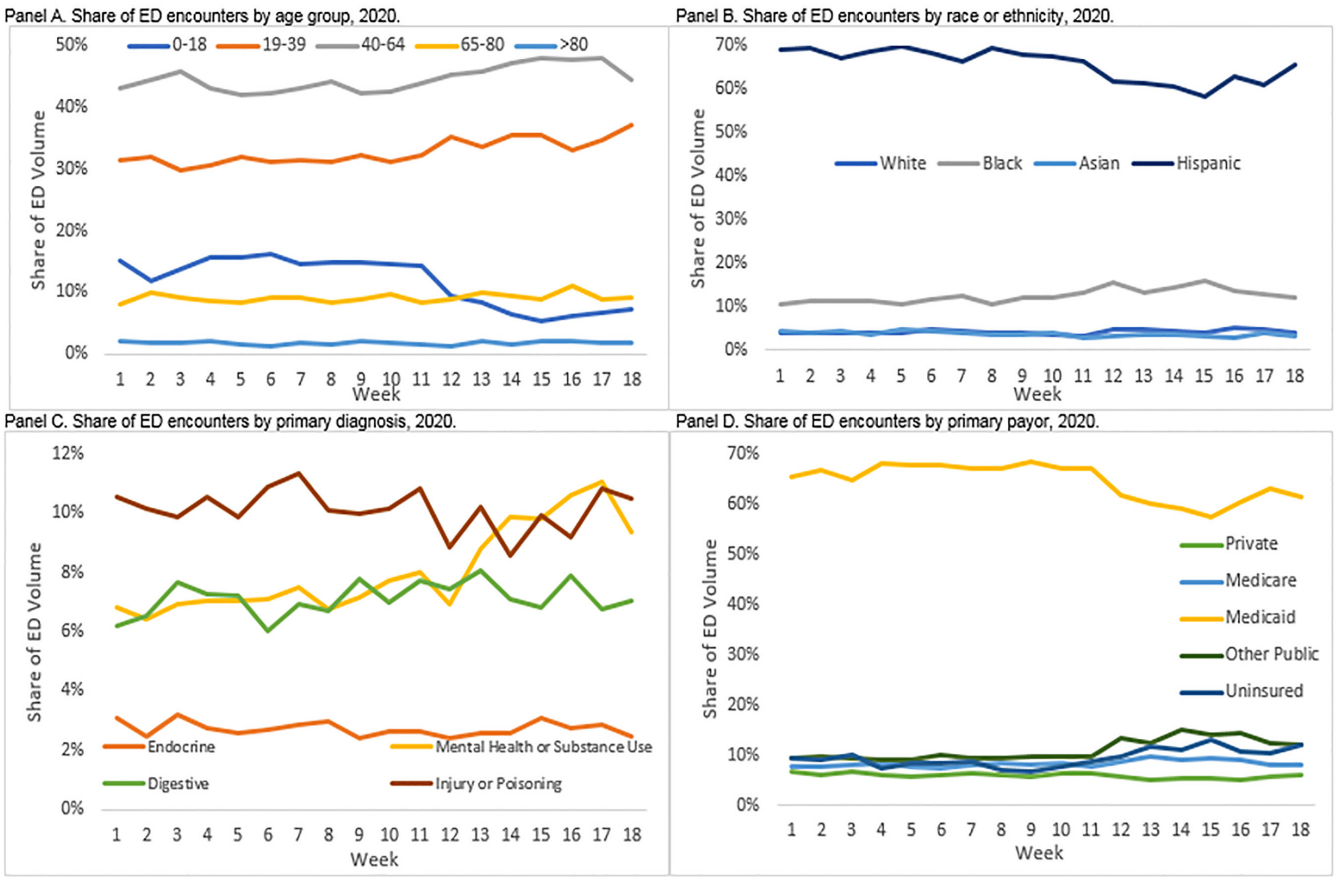


**Figure 3.** Distribution of emergency department (ED) volume by week and selected characteristics, 2020.

## DISCUSSION

In this analysis of administrative patient data from a large, urban, safety-net ED, we found drastic reductions as well as differential changes in ED utilization based on diagnoses and demographic subgroups. The first half of our observation period shows largely identical trends in ED utilization across time, patient populations, and diagnosis mix. Despite those similar trends, there was a sharp, marked reduction in ED utilization after the implementation of safer-at-home measures in LAC, consistent with existing studies on ED utilization.[12] The initial reduction was fairly uniform across patient characteristics and diagnoses, and that reduction relative to prior years, although somewhat attenuated, continued for the duration of our 2020 observation period. Notably, even patients with a collection of diagnoses that are likely to be associated with symptoms of COVID-19 saw a strong reduction in ED utilization in the second half of our observation period in 2020. While much of this reduction came in the form of fewer ED encounters or inpatient admissions for patients with relatively mild respiratory complaints, the admission rate of patients with COVID-associated respiratory diagnoses nearly doubled from the first to the second half of our 2020 observation period. This finding is broadly consistent with existing literature showing an increase in inpatient admission rates as the pandemic intensifies in a given area.[12]

However, what existing research has not documented is that while all classes of patients were less likely to seek care in the ED in the wake of the safer-at-home orders and spread of COVID-19, certain groups saw extreme reductions in utilization while others saw relatively mild decreases. Our findings show some initial evidence that as COVID-19 spread, the patients who continued to visit the ED were relatively sicker, as shown by higher rates of inpatient admissions, higher acuity scores, and higher rates of transport by ambulance. While we cannot rule out the possibility that a relatively empty hospital led to increased admissions – although our clinical experience would combat that explanation – this initial evidence provides an important avenue for future research.

In addition to shifts in patient acuity, we also catalogued shifts in the distribution of ED volume by patient diagnoses and demographics. Most troubling was the sharp increase in the share of patients diagnosed with mental health or substance use disorders. It has been posited that COVID-19 policy responses aimed at curbing disease spread and the resulting economic downturn were likely to have adverse impacts on mental health and substance abuse disorders.[20,21] Yao and colleagues describe how the COVID-19 pandemic triggered a "parallel epidemic" of fear, anxiety, and depression.[22] Our findings provide early evidence that this effect may be seen almost immediately.

Our findings are consistent with those from abroad that report increased levels of stress and anxiety concurrent with the COVID-19 pandemic.[23] At its peak in China, more than half of surveyed respondents rated the psychological impact of COVID-19 as moderate to severe, and about one-third reported moderate to severe anxiety.[24] It is unclear whether this increase in proportion of visits for mental health and substance abuse disorders was driven primarily by increased anxiety and stress, the economic impact of the pandemic, reduced access to medication, reduced services, or isolation from personal support systems, but all explanations provide fruitful avenues for further research.

Our study also adds clarity to the phenomenon of delaying care observed in the time of COVID. Nationally, nearly half of Americans reported that they or a family member skipped or delayed seeking care.[25] Over 20% of those respondents believed the medical condition worsened due to the delay.[25] However, evidence-based estimates of the delay in care for emergency conditions or the timeframe for patients to return are few. There is also a lack of clarity regarding which patients were delaying necessary care: Were those patients at higher risk for severe COVID-19 complications avoiding the ED due to a perceived elevated risk of exposure to germs, or were patients who perceived themselves as healthy enough to withstand their ailments without hospital care more likely to avoid the ED?

In our population, we found disproportionate decreases among several patient subgroups: pediatric patients; Hispanic patients; and patients with Medicaid insurance. These three subgroups represent relatively healthy groups in our patient population. These patients may perceive that they can safely self-treat symptoms at home or wait to have chronic conditions managed. However, early reports from COVID-19-stricken countries indicate that as pediatric ED visits have sharply declined, there are dangerous consequences from lack of access to hospital care.[10,26]

In the context of a sanctuary hospital, we must also recognize the chilling effect that a government directive can have on care-seeking behavior; patients may delay necessary emergency care due to fear of the legal ramifications of being found in violation of federal immigration law.[27] Prior experience has shown these decreases to be small and short term.[28-30] This prolonged decrease, which was only partially rebounding at the end of our study period, does not follow prior patterns with fear of legal ramifications.

## LIMITATIONS

This study has several limitations that affect its generalizability. Our data reflect the impact of the COVID-19 pandemic and "safer-at-home" declaration on a single hospital within a major metropolitan area. It is possible that reductions in ED visits at LAC+USC Medical Center were offset by utilization at other area hospitals. However, national studies, review of data from other public facilities, and personal discussions suggest all area hospitals saw a decrease in visits.[10] Further, there was a collection of institution-specific policy changes made with respect to COVID-19 testing, triage, and admission decisions in the interest of public health and safety (often related to testing availability) during our observation window in 2020 that did not occur in earlier years and may have

occurred differently at other hospitals.

In addition, we employed primary diagnosis, rather than chief complaint, because it is more reliably coded in our underlying data. We do note that primary diagnosis was missing for a disproportionate share of ED encounters in 2020 as compared to 2019 and 2018. One explanation is that diagnosis codes are added to EHRs after the fact and not all charts may have been processed prior to our analysis. The other explanation is that most missing diagnoses were for encounters where patients left without being seen by a physician or left before treatment was complete (99% in 2018, 75% in 2019 and the first nine weeks of 2020, and 54% for the second nine weeks of 2020). While this could have skewed our findings, we could not assign diagnoses or likely diagnoses without more information. In addition, we only captured primary diagnosis rather than all diagnoses because of the inconsistent coding of non-primary diagnoses in the underlying data; this decision may have led us to miss cases of interest where the diagnosis was captured in a non-primary diagnosis variable.

Finally, we caution that the findings in our study represent descriptive rather than causal relationships between the spread of COVID-19, implementation of safer-at-home declarations, and ED utilization. Future studies should work to establish whether the descriptive relationship we observed is causal and whether fear of contracting COVID-19, breaking safer-at-home declarations, or other factors are the primary mechanism explaining the observed patterns in the data.

## CONCLUSION

### Public Health Implications

Our findings point to an abrupt, discontinuous impact of COVID-19 on ED utilization with a slow return as safer-at-home orders weakened in Los Angeles County. Despite this turnaround, there were still 40% fewer ED visits in the final week of our observation period compared to prior years. What remains to be determined is what the medium- and long-term impact of this strong reduction in utilization means for patient outcomes, disease control, and the health of the community.

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# Clinical Features of Emergency Department Patients from Early COVID-19 Pandemic that Predict SARS-CoV-2 Infection: Machine-learning Approach

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**Introduction:** Within a few months coronavirus disease 2019 (COVID-19) evolved into a pandemic causing millions of cases worldwide, but it remains challenging to diagnose the disease in a timely fashion in the emergency department (ED). In this study we aimed to construct machine-learning (ML) models to predict severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection based on the clinical features of patients visiting an ED during the early COVID-19 pandemic.

**Methods:** We retrospectively collected the data of all patients who received reverse transcriptase polymerase chain reaction (RT-PCR) testing for SARS-CoV-2 at the ED of Baylor Scott & White All Saints Medical Center, Fort Worth, from February 23–May 12, 2020. The variables collected included patient demographics, ED triage data, clinical symptoms, and past medical history. The primary outcome was the confirmed diagnosis of COVID-19 (or SARS-CoV-2 infection) by a positive RT-PCR test result for SARS-CoV-2, and was used as the label for ML tasks. We used univariate analyses for feature selection, and variables with $P<0.1$ were selected for model construction. Samples were split into training and testing cohorts on a 60:40 ratio chronologically. We tried various ML algorithms to construct the best predictive model, and we evaluated performances with the area under the receiver operating characteristic curve (AUC) in the testing cohort.

**Results:** A total of 580 ED patients were tested for SARS-CoV-2 during the study periods, and 98 (16.9%) were identified as having the SARS-CoV-2 infection based on the RT-PCR results. Univariate analyses selected 21 features for model construction. We assessed three ML methods for performance: of the three methods, random forest outperformed the others with the best AUC result (0.86), followed by gradient boosting (0.83) and extra trees classifier (0.82).

**Conclusion:** This study shows that it is feasible to use ML models as an initial screening tool for identifying patients with SARS-CoV-2 infection. Further validation will be necessary to determine how effectively this prediction model can be used prospectively in clinical practice. [West J Emerg Med. 2021;22(2)244-251.]

## INTRODUCTION

Within a few months, coronavirus disease 2019 (COVID-19) evolved into a major pandemic causing millions of cases worldwide.[1-2] Early detection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the viral agent that causes COVID-19 disease, is essential for patient isolation, treatment, and containment of the virus to prevent its further community spread. In the absence of reliable screening tools, emergency physicians have to rely on patients' clinical symptoms, travel, and contact histories to determine whether they are suitable candidates to have the molecular diagnostic tests for SARS-CoV-2. At present, reverse transcriptase polymerase chain reaction (RT-PCR) remains the gold standard to detect the presence of SARS-CoV-2.[3-4] However, it takes between 4-8 hours to obtain the test result, and may take up to two days or even a week because of the time spent for sample transport to the lab.[5-7] Additionally, the process of sample collection, transport, and communication of results can be labor intensive and subject to human error.

People with COVID-19 may have a wide range of clinical symptoms ranging from mild to severe illness. Since the symptoms of COVID-19 are similar to other viral respiratory illnesses, an emergency approach to COVID-19 should focus on identifying and isolating patients at risk for infection.[8] Several published reports have described using patients' symptoms to develop a prediction model for identifying SARS-CoV-2 infections.[9-11] Nonetheless, almost all of the constructed models rely on the combination of symptoms and laboratory/radiological exams to develop the model, which may increase the risk of virus exposure to healthcare providers.

With the advancement of information technology, researchers and clinicians have also sought to develop artificial intelligence (AI)- or machine learning (ML)-based diagnostic tools for detecting COVID-19, but they are either focused on the patients visiting the local clinic or individuals in the community.[12-13] For COVID-19 prediction in emergency department (ED) patients using an ML approach, most of the researchers constructed their models by using a combination of symptoms, laboratory data, and image findings.[14-15] In this study, we attempted to investigate the potential of constructing ML models to predict SARS-CoV-2 infection based on clinical features alone from patients visiting a single ED during the early COVID-19 pandemic. The feasibility for clinical application is also discussed.

*Population Health Research Capsule*

What do we already know about this issue?
*Diagnosing coronavirus disease 2019 (COVID-19) in a timely fashion was challenging in the emergency department during the early pandemic.*

What was the research question?
*Is machine learning (ML) a feasible method to predict COVID-19 based only on clinical features from patients visiting the ED?*

What was the major finding of the study?
*We successfully constructed ML models to predict SARS-CoV-2 infection based on the clinical features alone for ED patients.*

How does this improve population health?
*ML has the potential to serve as a screening tool to identify ED patients at risk of SARS-CoV-2 infection.*

## METHODS

### Study Design and Setting

We conducted a retrospective cohort study with data retrieved from the electronic health record (EHR) over the study period (from February 23, 2020, the first case of RT-PCR testing for SARS-CoV-2 in our ED, to May 12, 2020) at the ED of Baylor Scott & White All Saints Medical Center, a 574-bed university-affiliated tertiary care teaching hospital with approximately 50,000 ED visits annually. This study followed the Standards for Reporting of Diagnostic Accuracy statement: explanation and elaboration.[16]

### Selection of Participants and Methods of Measurement

In this study we identified all patients with suspected COVID-19 who were tested for SARS-CoV-2 using RT-PCR technique. Samples for RT-PCR tests were taken from the upper (nasopharyngeal or oropharyngeal swabs) respiratory tract, and assayed by using the cobas SARS-CoV-2 Test (Roche Molecular Systems, Inc., Pleasanton, CA). We included only patients attending the ED. Patients without ED triage data were excluded from the analysis. The decision to perform the RT-PCR test for SARS-CoV-2 was left to the discretion of the emergency physicians or physician assistants who cared for the patient. There was no intervention in this study. This study was institutional review board-approved by the Baylor Scott & White Research Institute.

Patient demographics, including age, gender, race, insurance status, weight, height, body mass index (BMI), smoking, and past medical histories (PMH), were obtained from the EHR. We also extracted data on oxygen supplied (yes or no) at ED triage and other ED triage data, including the five-level triage acuity, emergency medical services (EMS) transport (yes or no), Glasgow Coma Scale (GCS) score, body temperature, pulse rate, respiratory rate, oxygen saturation ($SpO_2$), duration of symptoms before presentation, travel (to areas with ongoing community transmission of SARS-CoV-2), and contact (in

close contact with a confirmed or probable case of COVID-19) histories. Clinical symptoms were manually retrieved from the narrative patient records (including chief complaints and history of present illness) and review of systems recorded by a template with structural format during patient encounters. A total of 36 different clinical symptoms were included for analyses in this study. The primary outcome was the confirmed diagnosis of COVID-19 (or SARS-CoV-2 infection), defined as a positive RT-PCR test result for SARS-CoV-2. The positivity rate for COVID-19 was calculated as the number of positive results divided by the number of tests ordered in patients presenting to the ED.

**Primary Data Analysis**

After data collection and preparation, we included the features (variables) as listed above. Missing values in variables were retrieved by a research assistant from the patient's EHR, or replaced with imputed values if no substantial missing rate (<10%) in that specific variable. The binary outcome of SARS-CoV-2 infection was designated as the classification label. We split the dataset into the training and testing cohorts by time of presentation at a ratio of 60:40 to simulate a prospective validation of the derived model. Data were entered and processed with Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA) and then analyzed with IBM SPSS Statistics for Windows version 24.0 (IBM Corporation, Armonk, NY). We reported results as mean with standard deviation for continuous variables, percentages for categorical variables, and median with interquartile range for time variables.

We used univariate analyses (outcome differences between groups evaluated with Student's t-test, chi-squared test, Fisher's exact test, or Mann–Whitney U test depending on the distribution) as the feature selection strategy, and we selected variables with $P<0.1$ in the training cohort as the input features for constructing the ML models. Supervised ML algorithms using random forest, gradient boosting, and extra trees classifier were employed to construct the prediction models. Models were trained in the training cohort and performances were evaluated in terms of area under the receiver operating characteristic curve (AUC) on the testing cohort. We also reported the classification performances on the testing cohort using accuracy, F1-score, precision (or positive predictive value [PPV]), recall (sensitivity), specificity, negative predictive value (NPV), and area under the precision-recall curve, also known as average precision (AP), for each model. All ML analyses were performed using Python 3.8 programming language (Python Software Foundation, Wilmington, DE) with package scikit-learn 0.23.1 installed.[17]

## RESULTS

We retrieved a total of 598 cases from the EHR system during the targeted study period. After excluding those non-ED patients or patients without ED triage data, we identified 580 cases receiving the RT-PCR testing for SARS-CoV-2. Of them, 98 were confirmed to have the SARS-CoV-2 infection based on the RT-PCR results. The positivity rate of COVID-19 in this cohort was 16.9%. Missing data ranged from a low of 0% for most of the variables to a high of 7.6% for BMI. There were 36 cases (6.2%) with travel history and 110 (19.0%) with contact history. Of the 36 included symptoms, shortness of breath was the most common symptom (334, 57.6%), followed by fever (266, 45.9%) and cough (362, 26.4%). The training cohort consisted of 348 cases presented to our ED from February 23–April 14, 2020, while the testing cohort consisted of 232 cases from April 14–May 12, 2020. The characteristics of the study population are shown in Supplementary Table 1.

The characteristics and univariate analyses of variables (features) between patients with or without COVID-19 are summarized in Supplementary Table 2, for the training and testing cohorts, respectively. We selected a total of 21 features by setting the *P*-value of less than 0.10 from the training cohort, including four demographics (race, weight, BMI, smoking history); six triage data (EMS transport, temperature, respiratory rate, oxygen saturation, travel history, contact history); seven symptoms (altered mental status, fever, myalgia, sore throat, hypogeusia/ageusia, cough, diarrhea); and four PMH (comorbidities if any, chronic obstructive pulmonary disease, cerebrovascular accident, depression).

Classification results on the testing cohort for the three different ML models are presented in Table 1 and Figure 1. The top classifier in terms of AUC was random forest (0.86), followed by gradient boosting (0.83), and extra trees classifier (0.82). While adjusting the tradeoff between precision and recall for different thresholds to calculate the AP, random forest (0.53) performed better than gradient boosting (0.48) and extra trees classifier (0.39). However, differences between each model in terms of AUC and AP were not significant. When considering the other performance measures (except recall, or sensitivity), random forest also outperformed the other two ML models in terms of accuracy, F1-score, precision (PPV), specificity, and NPV. Figure 2 shows the feature importance for three different ML models and their feature scores. Of them, all of the three ML models selected temperature, weight, BMI, contact history, respiratory rate, and $SpO_2$ as their most important features for the construction of the prediction models.

## DISCUSSION

In this study, we applied ML techniques to predict SARS-CoV-2 infection from patients who visited the ED during the early months of the COVID-19 pandemic. By using 21 clinical features available at ED encounters, we successfully built ML models capable of classifying the risk of SARS-CoV-2 infection. Instead of using base models like decision tree learning, all of the models we used in this study were ensemble methods, which are ML methods that construct a set of predictive models and combine their

outputs into a single prediction to achieve better predictive performance.[18] Our use of the advanced ML algorithms allowed for achieving good predictive performances and also identifying more clinical variables related to the diagnosis of COVID-19. Using AUC as the performance indicator, random forest outperformed gradient boosting and extra trees classifier when applied to the testing cohort. The leading features recognized by these ML models – temperature, weight, BMI, contact history, respiratory rate, and $SpO_2$ – are discussed below.

**Comparison with Previous Studies**

The spectrum of symptoms caused by COVID-19 ranges from mild to critical; most patients' symptoms are not severe and they may even be asymptomatic,[19-22] which makes it difficult for clinicians to differentiate COVID-19 from other common respiratory diseases. Novel technology may facilitate timely identification of possible patients to deploy appropriate interventions. The potential employment of ML in clinical practice for detecting and predicting the coronavirus (CoV) family has been previously discussed.[23] In a review published in May 2020 Albahri et al surveyed state-of-the-art techniques for CoV prediction algorithms based on data mining and ML assessment; they found a total of eight articles published between 2016–2019. Of those articles, seven focused on the prediction or identification of Middle East respiratory syndrome (MERS)-CoV and one focused on extracting difference and similarity between SARS-CoV and MERS-CoV.[24] The most common algorithms and methods used in the literature review were decision tree (5), naïve Bayes (4), support vector machine (4), and k-nearest neighbor (2). Only one study used the random forest algorithm, one of the ensemble methods used in our study.[25]

In a multicenter study conducted in China, Mei et al developed AI algorithms to combine findings on chest computed tomography (CT) with clinical symptoms, contact history, and laboratory results to diagnose patients with COVID-19.[5] In their cohort, the average age was 40.7 years with 46.3% (419/905) of the patients testing positive for COVID-19. Patient's age, exposure to SARS-CoV-2, fever, cough, cough with sputum, and white blood cell counts were significant clinical features associated with COVID-19. In the joint model combining both clinical data and CT imaging, the AUC achieved 0.92 with 84.3% sensitivity and 82.8% specificity. The convolutional neural network (CNN) model employing only CT imaging data achieved 0.86 AUC with 83.6% sensitivity and 75.9% specificity while the multilayer perceptron (MLP) model incorporating clinical data alone achieved 0.80 AUC with 80.6 % sensitivity and 68.3% specificity.

In comparison with either CNN or MLP models in the Mei et al study, our random forest model achieved 0.86 AUC with clinical features alone. This improved AUC may be caused by the increased number of clinical features incorporated in our model as compared to the model developed by Mei et al.[5] Despite the fact that their joint model outperformed our random forest model, the employment of CT findings could raise additional concerns. First, the process of CT scanning may be complicated by the infection control protocol, thereby lengthening the time consumed by the radiological procedure.[26-27] Second, whether the convalescent patients could be immune to recurrent infections by SARS-CoV-2 is still debated, but recurrent infections have been reported[28]; therefore, repeat CT scanning with high radiation dose may be both costly and harmful. In contrast, our models incorporated only those clinical variables available at the time of initial ED encounter; therefore, potential COVID-19 patients could be proactively identified and introduced to isolation areas before lab work, imaging or physician evaluation, thus minimizing the risk of person-to-person transmission of SARS-CoV-2 while these patients stayed in the waiting zone.

**Interpretation of Current Study**

In a study conducted by Peyrony et al that included a cohort of 391 patients with 57.5% infected with COVID-19, the most commonly reported symptoms were fever, cough, dyspnea, and myalgia.[10] However, among the collected symptoms and signs, only four of them (myalgia, anosmia, temperature ≥38°C and $SpO_2$ <95%) achieved more than 80% specificity. Similarly, features selected to construct the ML models in our studies – temperature, BMI, weight, contact history, oxygen saturation, and respiratory rate – were consistently ranked as the top six

**Table 1.** Comparison between model performances on the testing cohort.

| Models | AUC | AP | Accuracy | F1-score | Kappa | Recall (Sensitivity) | Specificity | PPV (Precision) | NPV |
|---|---|---|---|---|---|---|---|---|---|
| Random Forest | 0.86 | 0.53 | 0.89 | 0.39 | 0.27 | 0.29 | 0.98 | 0.58 | 0.92 |
| Gradient Boosting | 0.83 | 0.48 | 0.88 | 0.36 | 0.34 | 0.29 | 0.96 | 0.50 | 0.91 |
| Extra Trees Classifier | 0.82 | 0.39 | 0.86 | 0.36 | 0.27 | 0.32 | 0.94 | 0.41 | 0.91 |

*AUC*, area under the receiver operating characteristic curve; *AP*, area under the precision recall curve (average precision); *PPV*, positive predictive value; *NPV*, negative predictive value.

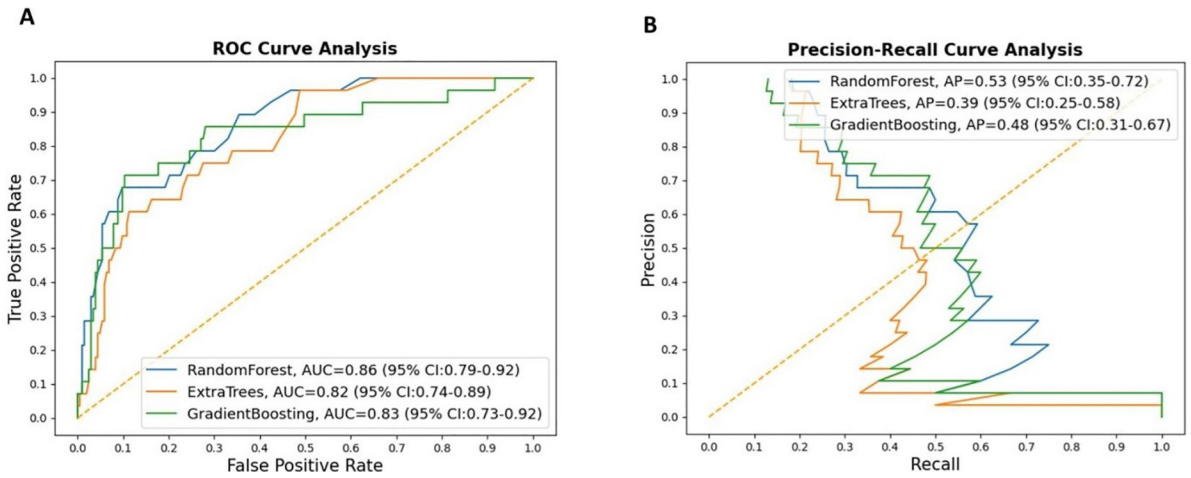


**Figure 1.** Results of the machine-learning models on the test cohort. (A), Receiver operating characteristic (ROC) curves and the comparison of area under the curve (AUC); (B), Precision-recall curve and the comparison of average precision (AP) for three different machine-learning models.

important variables in predicting COVID-19. It has been reported that people with elevated BMI or body weight may sustain a more serious SARS-CoV-2 infection.[29-31] Therefore, COVID-19 patients with elevated BMI may have higher chances to receive RT-PCR exam due to severe symptoms or signs, compared with those with lower BMI, resulting in selection bias. Interestingly, in the Peyrony et al study, anosmia was reported in 13.8 % of COVID-19 patients and was identified to be the most specific symptom of SARS-CoV-2 infection (specificity: 98%). In contrast, our cohort reported anosmia in only 3% of COVID-19 patients. Since anosmia and dysgeusia were initially noted among COVID-19 patients in April,[32] these symptoms may be under-reported in a retrospective study, resulting in reporting bias.

Our study included 580 patients receiving RT-PCR testing for SARS-CoV-2 during late February and early May 2020, among whom, 98 (16.9%) patients tested positive. The training and testing cohorts were divided chronologically to simulate a prospective study; ie, the performance of the ML models were developed on the basis of the past (training) cohort and evaluated in the future (testing) cohort. The study demonstrated excellent AUC results based on the three ML models we used, with the random forest model achieving the best performance in this analysis (0.86). During this period, the policy for performing RT-PCR testing did not change substantially in our hospital and, therefore, the features between training and testing cohorts were quite similar (Supplementary Table 1). Although the proportions of COVID-19 patients differed significantly between training (20.1%) and testing (12.1%) cohorts, our random forest model still achieved excellent classification performance in the testing cohort.

In addition to AUC, we evaluated the performance of our models by using a series of the available performance measures, including specificity, recall (sensitivity), and precision (or PPV). Precision is a measure of how often the predictions for the positive class are actually true, and the goal of a good ML model is to obtain the right balance of precision and recall (Figure 1B). While we obtained very high specificity values for all of the constructed ML models, our results nevertheless showed that the recall values in all of the constructed models were low, implying the models are good for ruling in the disease of interest (COVID-19) rather than ruling it out. Our results showed that the specificity and NPV of the random forest model achieved 0.97and 0.92, respectively, which may be employed to classify the risk of SARS-CoV-2 infection for ED visits if appropriately adjusting the cut-point. Because of the wide spectrum of presented symptoms and signs of COVID-19, it may be difficult for clinicians to determine who should receive RT-PCR testing for SARS-CoV-2. In communities that have limited resources for SARS-CoV-2 testing kits or enough space for isolation, a prediction model with high specificity or NPV may assist clinicians in allocating precious healthcare resources and initiating early intervention for high-risk patients.

**Feasibility for Clinical Application**

The COVID-19 pandemic has propagated exponentially because of widespread person-to-person transmission and global transportation.[2, 33] Infection of SARS-CoV-2 is confirmed with RT–PCR exam, but it could take up to a week to get the test results.[7] Because of the increasing need for testing and isolation, we proposed that an ML algorithm could facilitate triaging the relatively limited healthcare resources in order to halt the progress of the current pandemic. Moreover, since we used only clinical features, which can be obtained immediately at ED triage, suspected patients with COVID-19 could thus be rerouted to isolation areas even before they enter the ED, limiting the potential person-to-person transmission and nosocomial infection.

Getting safe emergency care during the COVID-19 pandemic is of paramount importance both for the patients

seeking help when they feel ill and for the healthcare providers in the ED. With appropriate risk stratification, healthcare personnel may thus have fewer risks of exposure to patients with suspected SARS-CoV-2 infection. As the COVID-19 pandemic persists, an ML-assisted prediction algorithm could help slow transmission and more judiciously allocate our finite healthcare resources. To be used as a diagnostic tool for aiding the identification of patients at risk of COVID-19 infection

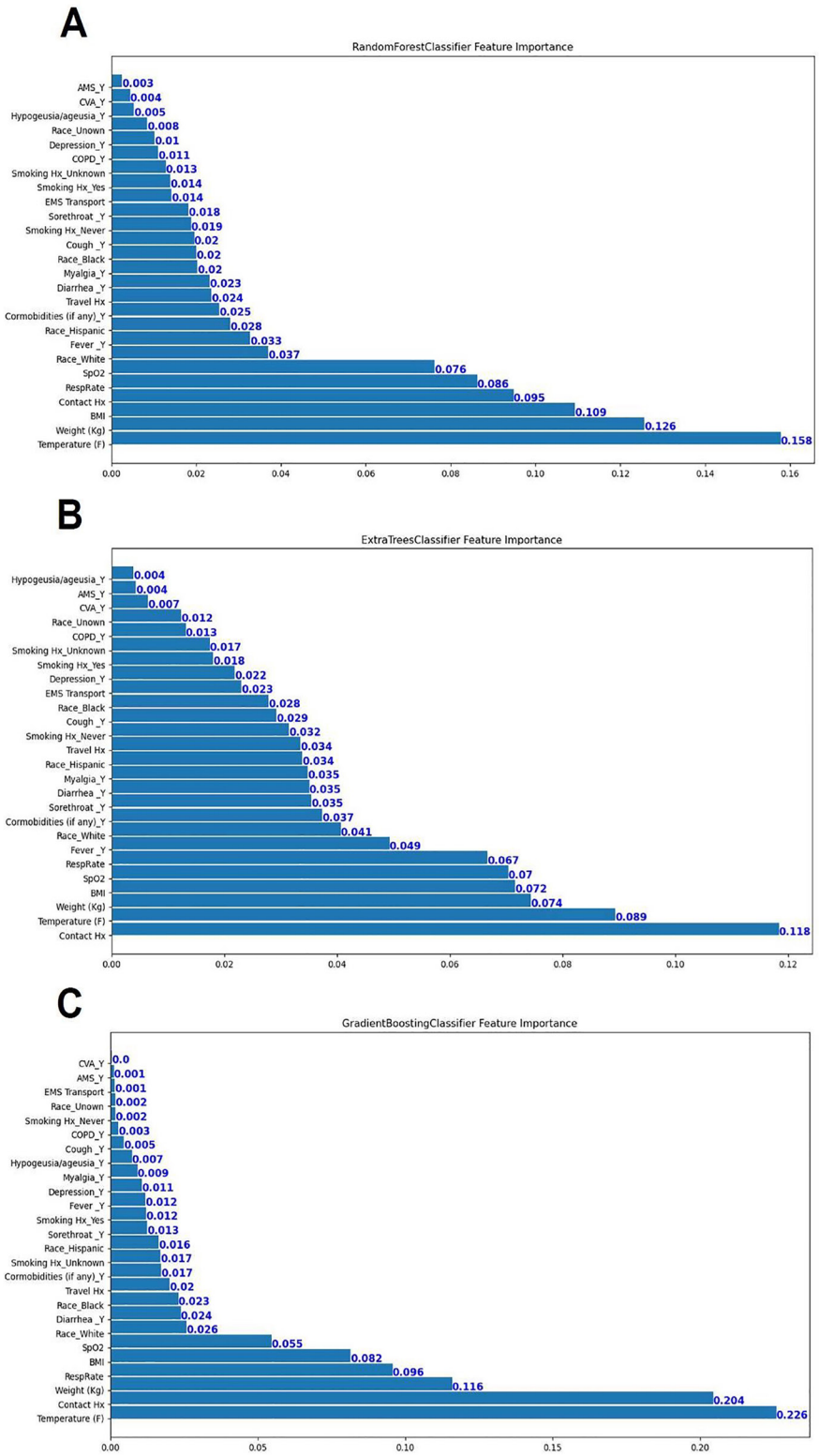


**Figure 2.** Feature importance for three different machine-learning models: (A), random forest; (B), gradient boosting; and (C), extra trees classifier.

in the near future, technological feasibility assessment has to be conducted before the full implementation of the decision support tool. This assessment should be based on outlining the design of the resource requirements, and understanding the barriers and obstacles related to both science and logistics.[34]

## LIMITATIONS

There are several limitations in this study. First, clinical symptoms were collected retrospectively, which could have been subject to reporting bias. For example, anosmia seemed to be under-reported in our report when compared with other studies.[5,10] Second, this study was conducted in an ED of a single center during the early period of the pandemic with limited sample size. Enrollment was based on patients who were judged to have the need for RT-PCR testing, and not all patients were tested for SARS-CoV-2. Despite the discriminatory performance of the ML models to identify patients with SARS-CoV-2 infection, this approach may introduce selection bias and more data are required to examine the generalizability of the models to other patient populations. Third, in consideration of the dynamic course of the COVID-19 pandemic and the constantly changing policies concerning screening and isolation, the presenting features of COVID-19 patients may also change substantially.

In addition, the fact that we split the dataset into training and testing cohorts by time of presentation may have introduced sampling bias since test availability in the US varied over the study period. Therefore, our proposed model should be proactively updated and adapted to the current patient population. Forth, clinical symptoms were manually retrieved in our study rather than being automatically extracted from the EHR. It is possible that such an approach would be biased in variable selection.

Finally, due to the low positivity rate of COVID-19 in our population, our ML model construction suffered from the problem of imbalanced classification.[35] It can be a challenging task to report the classification performances with regard to the imbalanced distribution of the dataset. We balanced the data by weighing the samples by the imbalanced ratio, and evaluated the prediction performances of our ML models by using most of the available methods of performance measures, including AUC and AP, to avoid bias or over-interpretation by any of the results. Nevertheless, our study showed fair results in performance measures using recall and kappa, leaving room for future improvement.

## CONCLUSION

We successfully constructed the ML models to predict COVID-19 with excellent discrimination ability based on the clinical features of initial ED encounters. Implementation of this tool may serve as an initial screening tool for identifying patients at risk of SARS-CoV-2 infection. Further validation will be necessary to determine how effectively this prediction model can be used prospectively in clinical practice.

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# Drive-through Medicine for COVID-19 and Future Pandemics

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## BACKGROUND

The outbreak of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has reached pandemic levels and continues to spread across much of the world.[1] Hospitals and public health authorities are struggling to appropriately manage potentially infectious individuals to limit transmission to others, care for ill patients with proven or suspected COVID-19, and restart society after the pandemic. Crucial features of a successful response to a pandemic virus are early detection and isolation of potentially infectious individuals.[2]

With the increase in the global population, estimated to reach 9.7 billion by 2050, public health systems have less time to detect and contain a pandemic before it spreads. Fast and efficient screening and testing are key tools in controlling pandemics.[3] This capacity should be rapidly scalable. During the current pandemic, most of the testing in the United States has occurred in emergency departments (ED), hospitals, and clinics. More recently, stand-alone diagnostic centers have been used as well, primarily by local public health departments. At the Stanford ED, there was a surge of patients wanting to be tested, which created a need for an efficient screening and testing model for COVID-19.

Testing and using drive-through models after appropriate triage have been shown to be more efficient compared to testing offered in traditional medical settings.[4] Drive-through medicine also offers additional benefits, including better infection control and resource allocation.[5] Furthermore, these models can also be rapidly scaled up to provide vaccinations and dispense medications.[6] Therefore, it is important to consider drive-through medicine as a tool in controlling pandemics. Here we examine best practices of drive-through medicine based on global and US experiences.

## RISK OF TRANSMISSION

COVID-19 as well as a number of other coronaviruses have been shown to be transmitted by three main epidemiological patterns: family clusters; healthcare-acquired infections; and community cases.[7,8] Hospitals, enclosed housing complexes, religious complexes, and mass transportation are documented sites of super-spreader events for SARS, Middle East respiratory syndrome, and COVID-19.[5,9,10] The implementation of drive-through medicine decreases the risk of super-spreader events by reducing transmission between patients as well as workers in an already outstretched system.

COVID-19 is transmitted through respiratory droplets as well as through airborne mechanisms. A simulation of a drive-through model for an influenza pandemic demonstrated a social distancing strategy that reduced the risk of infection between patients and workers.[11] Standard operating procedures for most EDs is to direct patients to potentially crowded waiting areas, which increases the risk of cross-infection, especially for respiratory illnesses. The drive-through influenza clinic simulation allowed patients to stay in their vehicles as healthcare workers evaluated them. The study found that the drive-through model was a feasible alternative that provided a social distancing strategy by using the patient's vehicle as an *isolation compartment*.[7] Furthermore, the stationing of the drive-through model outdoors reduced contamination of inpatient spaces.

The number of negative pressure rooms and high efficiency particulate air (HEPA)-filtered rooms that are appropriate to treat patients who are potentially infected by airborne pathogens is limited. Drive-through medicine can be a rapidly scalable solution to build capacity for evaluating and testing such patients safely. Furthermore, medical staff may feel more protected if potentially infectious individuals do not enter healthcare settings, thus reducing absenteeism previously observed in pandemics.[12]

## ALLOCATION OF RESOURCES

The COVID-19 pandemic is placing additional strain on a number of already overstretched healthcare facilities. In EDs,

the surge in patients has threatened to exacerbate crowding. The World Health Organization estimates that 15-35% of the population will develop an influenza-like illness during a typical pandemic. In the US, this could result in an estimated 18-42 million ED visits, exacerbating existing ED crowding.[13] The Institute of Medicine has called ED crowding a national threat because it would diminish regional disaster response capacity.[14] Furthermore, during pandemics and epidemics, the demand for critical care services may quickly exceed available intensive care unit staff, beds, negative pressure rooms, and equipment, leaving a large infected population without lifesaving critical care.[15] Efficient methods of testing and screening patients with influenza-like illness would expand the limited surge capacity of our healthcare system.

Drive-through settings allow for mass evaluation and testing in a quick, efficient manner while limiting exposure to healthcare workers and conserving personal protective equipment (PPE). In a typical healthcare setting, all involved hospital staff would have to change PPE after examining one potentially infectious patient. In some drive-through models, only the medical staff in the specimen-collection station would need to change disposable apron gowns and gloves without changing the entire PPE (inner and outer gloves, N95 respirator, eye-shield/face shield/goggles, and hooded gowns).[18]

Rooms do not need to be cleaned in between patients, preventing further potential exposure of house cleaning staff and reducing turnaround time between patients. This then opens up beds in the ED for other patients to be seen. In the drive-through influenza clinic simulation, the physicians transitioned to the next vehicle without waiting for the previous one to be discharged from the drive-through model.[11] The patient's vehicle acted as a moving examination room that relieved the need for fixed rooms and spaces, as in traditional healthcare settings.[11]

Time is also an essential resource during pandemics. Drive-throughs have been shown to reduce throughput times compared with care provided in traditional medical settings for both testing and vaccination. A study that measured the feasibility of influenza vaccinations for children in a drive-through clinic setting found that the median total clinic time regardless of services was nine minutes.[16] In another study that focused on throughput times for adults and children during drive-through influenza vaccinations, the median throughput time was five minutes. The simulation concluded that drive-through vaccination clinics could rapidly vaccinate large populations of children and adults.[17] In South Korea it takes an hour to test each patient in traditional healthcare settings, but in drive-throughs the time is reduced to 10 minutes per patient.[14] The implementation of drive-throughs in South Korea has reduced the strain on resources during the COVID-19 pandemic and has been critical in contributing to South Korean success in curbing the spread of COVID-19.[13]

In a traditional healthcare setting, in addition to more expansive cleaning of surfaces, an airborne infection isolation room would require 12 air changes per hour, which could add 30 minutes or more turn-around time between patients.[18] A drive-through system, however, does not require such cleaning procedures as the testees' cars can be used as specimen-collection rooms. This means that fewer medical and cleaning staff are necessary.

Additionally, using drive-throughs can potentially be a more cost-effective method of providing screening and testing compared to an ED or clinic. PPE costs for the Stanford ED were calculated at $26 per patient for a physician and nurse team who would normally interact with the patient. Drive-throughs can be staffed without any additional direct patient-care labor costs by repurposing nurses who would otherwise be providing triage or care in an ED setting. The primary additional labor cost in the below model is a facilities traffic coordinator.

## STANFORD EXPERIENCE AND BEST DRIVE-THROUGH MODEL PRACTICES

Drive-through systems have been implemented in various settings during the COVID-19 pandemic. By adding the capacity to run drive-through evaluation, testing, and vaccination to EDs, outpatient clinics, and community testing sites/centers, there has been a global effort to diagnose and control COVID-19 more efficiently.

### Stanford Experience

At Stanford Health Care, a multifocal approach was used for COVID-19 testing of patients who did not require hospitalization. In the ED, patients who arrived with respiratory complaints were screened upon arrival to the department. Based on risk factors including age, comorbidities, and vital signs at presentation, patients were either triaged into the main ED or sent to an outdoor testing area. If they presented to the triage area in their vehicle, nurses obtained a quick history and vital signs check with the patient still in the vehicle, and if appropriate, patients were routed to a garage while still remaining in their vehicle. If they presented on foot, they were directed to a section of the garage with chairs after the triage process.

A medical screening exam was then performed by a physician via telemedicine, which determined whether the patient met the criteria for a COVID-19 test. Nasopharyngeal swabs were obtained, and patients were discharged pending test results, which were subsequently communicated to patients by call-back nurses and Stanford's healthcare web application. The ED provides unscheduled care, and therefore efficiency and throughput are important metrics for any care process. The drive-through testing model was present in the ED for four weeks, from March 13, 2020–April 8, 2020. During this time, a total of 790 patients were screened, with 48 of those patients, or 6.1%, ultimately requiring an actual in-person ED visit for treatment. Length of stay for patients who presented to the ED needing a COVID-19 test and could be discharged decreased from 1.27 hours prior to drive-

through implementation to 0.38 hours post drive-through implementation. The positivity rate of COVID-19 for patients screened in the ED drive-through site was 8.61%.

The ambulatory clinics at Stanford Health Care also used a scheduled drive-through model, with screening for patients being performed via telemedicine visits while the patient was still at home. If the patient screened into being tested, they were then given a dedicated time to arrive by vehicle to one of several outpatient, outdoor testing sites set up throughout the catchment area. These testing options helped to promote PPE conservation and healthcare worker safety.

**Automation, Efficiency and Safety Through the Use of Digital Health and Telemedicine**

Numerous other medical centers, as well as California public health departments, have initiated drive-through testing and evaluation programs.[19,20] In the US, the use of telemedicine in these drive-through systems is especially notable. Telemedicine reduces unnecessary contact between physicians and patients and develops standard protocols of screening via online or telephone visits.[19] Alphabet's Verily health sciences testing initiative, contracted by the California Health Department, deployed stand-alone testing sites and tested more than 3700 cases.[20] By using community-testing models with online screening and online scheduling, Verily generates order automatically without physicians needing to see the patient. This promotes the safety of healthcare workers, while automating significant portions of the entire process.[20]

**Adapting Drive-Through Models to Specific Settings and Resources**

In designing drive-through evaluation and testing models, adaptability and fit are key. For example, phone screenings may be particularly relevant in communities where patients have limited internet access or where this type of workflow is better suited for resources available to local public health departments. Palm Beach County, Florida, offers drive-through testing, but patients are screened over the phone in order to get tested. The Healthcare District of Palm Beach County is handling phone screenings, scheduling appointments, and conducting tests with the Florida Army National Guard and Palm Beach County's Department of Emergency Management and the Governor's Office.[19]

Internationally, South Korea's implementation of drive-through systems has proven to be effective in reducing transmission and allocating resources efficiently. The first drive-through system in South Korea for COVID-19 was implemented in February 2020.[14] Since then, 68 screening centers among the 577 centers in the county have established drive-throughs for evaluation and testing. The drive-through operations are standardized across these centers and include four stations: registration and questionnaire; examination; specimen collection; and instructions and information leaflet.[14]

**Utilization of Drive-Throughs for Evaluation, Testing, Vaccinations and Dispending of Medications**

Although during the current pandemic the drive-throughs have been used primarily for screening of patients with influenza-like illness and for testing, as the pandemic and our response to it evolves, the same models could also be used for vaccinations and dispensing of medications. The Hawaii Department of Health developed a similar drive-through model for dispensing Strategic National Stockpile medication.[21] During the two-hour session in April 2005, 622 patients were evaluated with a rate of 5.2 persons per minute with minimal human contact. The results found that local health departments, particularly in rural areas, could facilitate healthcare services and limit mortality during a public health emergency when dispensing medication. This model also demonstrates that drive-throughs are effective in both rural and urban areas for both testing and outpatient treatment. Drive-through medicine has the value of rapid scalability of capacity and services provided as the stresses on individual health systems and communities vary.

## POTENTIAL CHALLENGES AND SOLUTIONS

Through the previous implementation of drive-throughs, there have been several limitations and challenges identified. At Stanford, we experienced firsthand that drive-through testing centers may be impractical in certain outdoor conditions, particularly in areas with colder or damp climates. We mitigated this challenge by having the drive-through testing in a parking garage and through the use of heat lamps during periods of colder weather. When drive-throughs were conducted in garages, a Stanford study found carbon monoxide levels to be safe.[7] Another option would be to use negative pressure tents for triage or additional ED space[22] or tents with HEPA filters.[23] Coordination between extensive entities within our health system was needed for initial activation, including security, facilities, information technology, and parking services. State and county department of public health permits also had to be obtained for new treatment areas.

Another challenge at Stanford was an initial lack of standardization around registration, charting, and providing discharge instructions. We used technology including secure text communication to improve communication among the clinical and non-clinical staff. Standardization in the electronic health record also facilitated keeping up with medical charting, appropriate symptomatic test ordering, and discharging a high throughput volume of patients with appropriate discharge instructions. Staff allocation of nurses and providers was an ongoing challenge in a health system with limited staff resources, requiring a daily review of optimization of each care area inside and outside the ED.

Outside of Stanford, there was observed to be a lower barrier for access to testing in drive-through centers, which may be both an advantage as far as improving access, but

also a limitation. In South Korea, people were visiting drive-through testing centers for unnecessary repeat tests, which can be problematic from the standpoint of resource allocation due to the costs of testing as well as limited testing supplies. Sentara Healthcare and M Health Fairview suspended drive-through centers to preserve a limited supply of testing supplies (PPE, COVID-19 test kits).[24] This potential limitation could be mitigated by educating the public on proper testing criteria and prior screening, either online or in-person.

Moreover, access to higher level medical care is not available in stand-alone testing centers, which may result in suboptimal medical care of patients in such centers. For example, in South Korea implementation of testing centers meant that immediate response to medically unstable patients could be limited if drive-through testing centers are located far from emergency centers and hospitals. Therefore, appropriate prior triage is critical, and sicker patients should be referred to testing at medical centers with appropriate level of care. Thus, these issues can be mitigated by appropriate triage and patient communication.

By addressing these limitations, best practices of drive-through medicine can be implemented across states that are currently highly impacted by the COVID-19 pandemic.

## CONCLUSION

Rapid testing has been a key tool in helping to control COVID-19 and other pandemics.[3] Drive-through medicine has been used for provision of testing during the COVID-19 pandemic and has been shown to offer a number of advantages including rapid scalability, safety, faster throughput times, and efficient allocation of resources. Furthermore, as a pandemic evolves, drive-through medicine can be potentially used for vaccinations and dispensing of medications, if medically appropriate. EDs, clinics, medical centers, and public health departments should consider utilization of drive-through models as a tool in controlling the COVID-19 pandemic.

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# Emergency Physician Survey on Firearm Injury Prevention: Where Can We Improve?

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**Introduction:** Firearm injury and death is increasingly prevalent in the United States. Emergency physicians (EP) may have a unique role in firearm injury prevention.The aim of this study was to describe EPs' beliefs, attitudes, practices, and barriers to identifying risk of and counseling on firearm injury prevention with patients. A secondary aim was assessment of perceived personal vulnerability to firearm injury while working in the emergency department (ED).

**Methods:** We conducted a cross-sectional survey of a national convenience sample of EPs, using questions adapted from the American College of Surgeons' Committee on Trauma 2017 survey of surgeons. Descriptive statistics and chi-square tests were calculated as appropriate.

**Results:** A total of 1901 surveys were completed by EPs from across the United States. Among respondents, 42.9% had a firearm at home, and 56.0% had received firearm safety training. Although 51.4% of physicians in our sample were comfortable discussing firearm access with their high-risk patients, more than 70% agreed or strongly agreed that they wanted training on procedures to follow when they identify that a patient is at high risk of firearm injury. Respondents reported a variety of current practices regarding screening, counseling, and resource use for patients at high risk of firearm injury; the highest awareness and self-reported screening and counseling on firearm safety was with patients with suicidal ideation. Although 92.3% of EPs reported concerns about personal safety associated with firearms in the ED, 48.1% reported that there was either no protocol for dealing with a firearm in the ED, or if there was a protocol, they were not aware of it. Differences in demographics, knowledge, attitudes, and behavior were observed between respondents with a firearm in the home, and those without a firearm in the home.

**Conclusions:** Among respondents to this national survey of a convenience sample of EPs, approximately 40% had a firearm at home. The majority reported wanting increased education and training to identify and counsel ED patients at high risk for firearm injury. Improved guidance on personal safety regarding firearms in the ED is also needed. [West J Emerg Med. 2021;22(2):257-265.]

## INTRODUCTION

Firearm injury in the United States is a continuing epidemic.[1,2] In 2017 alone, there were 39,773 firearm- related deaths: 23,854 suicides; 14,542 homicides; 486 resulting from unintentional discharge of a firearm; and 338 of undetermined origin.[3] The rate of firearm death has increased 20% in the last five years.[4] Although firearm injury statistics are unreliable, the best available data estimates that in the last five years there were more than twice as many nonfatal firearm injuries seen in emergency departments (ED).[5] In 2018 and 2019, medical organizations joined together to assert the need for a public health approach to firearm injury, highlighting the need for research and describing ways in which the medical community could design and implement clinically-based firearm injury prevention initiatives.[6,7]

Physicians effectively risk stratify and counsel patients regarding preventive health including tobacco and alcohol cessation, correct use of infant car seats, the importance of wearing seatbelts and helmets, drowning prevention, and vaccinations.[8-10] Evidence suggests that similar risk stratification and counseling discussions may be effective for preventing firearm injury and its consequences.[11] Physicians can identify at-risk patients, provide factual information about firearm injury risk and, if needed, refer patients to resources that may reduce risk.[12-14] Contrary to the myth that patients resent being counseled on firearm safety by their doctors, the literature shows that patients are receptive to discussing firearm injury prevention with physicians, as long as counseling is delivered in a respectful manner.[15,16] While physicians who own firearms may be more likely to discuss firearm injury prevention with patients than those that don't,[17] in general, few physicians raise the subject with patients. This is true despite physicians in general believing they have the right to discuss firearm safety, and medical leadership groups and patients concurring and encouraging such discussions.[18]

There are approximately 150 million ED visits each year in the US.[3] Emergency physicians (EP) are not only the first (and sometimes only) physicians to treat patients with firearm injuries, we also have a well-documented role in identification and implementation of injury prevention strategies in general.[19] However, a recent study found that the charts of only 3% of patients presenting with suicidal ideation documented whether or not the patient had access to a firearm,[20] and according to a small, non-scientific survey in 2016, few EPs discussed risk of firearm injury with victims of domestic violence, assault, or other high-risk categories.[21] A survey of EPs in 22 states reported that although two-thirds of respondents had encountered a firearm in the ED, fewer than half felt at all confident in their ability to safely handle the situation.[22] These missed opportunities may be related to the paucity of education on this topic in medical schools, or due to other unmeasured factors.[1,2]

Prior work conducted by the American College of Surgeons described attitudes, beliefs, and practices of US surgeons regarding firearms and firearm injury prevention, and was used to develop consensus recommendations on surgeons' roles in firearm injury prevention.[23] Given EPs' critical role in injury prevention, a similar assessment of EPs is warranted. The aims of this study were to assess EPs' knowledge, attitudes, and self-reported practice regarding firearm injury prevention, and to evaluate their perceived personal vulnerability to firearm injury in the workplace.

*Population Health Research Capsule*

What do we already know about this issue?
*Firearm injury and death is increasingly prevalent in the United States. Emergency physicians (EP) may have a unique role in firearm injury prevention.*

What was the research question?
*What are EPs' beliefs, attitudes, practices, and barriers to identifying and counseling on firearm injury prevention.*

What was the major finding of the study?
*EP's reported wanting increased education and training to identify and counsel ED patients at high risk for firearm injury.*

How does this improve population health?
*Education, training, protocols and open dialogue between EPs and patients may improve screening and counseling of at-risk patients - and, potentially, reduce incidence of firearm injury and death.*

## MATERIALS AND METHODS

A cross-sectional survey, adapted from the previously published American College of Surgeons' Committee on Trauma (ACS-COT),[23,24] was endorsed and distributed by the American Academy of Emergency Medicine (AAEM), the Resident Student Association (RSA/AAEM) and the US Council of Residency Directors in Emergency Medicine (CORD-EM). The questionnaire was sent via email and online newsletters to a convenience sample of ~6000 US resident and attending EPs using an online survey tool (SurveyMonkey, San Mateo, CA); the exact number of recipients is unknown, due to unknown overlap between survey lists. The survey opened on June 26, 2019 and remained open until August 31, 2019.

A consensus panel of experts in emergency medicine (EM) developed the survey items based on a 2017 survey from the ACS-COT.[23,24] The final survey is available in Appendix 1. All authors reviewed, tested, and edited multiple iterations of the survey prior to approving the final version. No identifiers were incorporated to ensure the privacy of the respondents, and no

individuals were identified in the analysis or written results. No incentives were awarded for completion of the survey.

Descriptive statistics were expressed as the number of observations, percentages, means ± standard error of the mean (SEM), and 95% confidence intervals (CI). For ease of analysis and presentation, some questions with four or five category outcomes were collapsed into a dichotomous variable (e.g., "always or almost always" vs "neutral, rarely, never"; or "strongly agree or agree" vs "neutral, disagree, or strongly disagree"). We conducted chi-square tests of association to examine the association between reporting owning a gun or having a firearm in the home, and an array of study participants' characteristics, beliefs, knowledge, and attitudes. SPSS version 26 (IBM Corp., Armonk, New York) was used for statistical analysis.

The study was given exempt status by the Institutional Review Board at Mount Sinai Medical Center, Miami Beach, Florida. This research was conducted without grant funding or support from any public, commercial, or non-profit source.

## RESULTS

A total of 1901 respondents completed surveys, of whom 62.3% self-identified as men, 79.8% as White, and 64.3% as attending physicians (Table 1). All regions of the country were represented, with the highest proportion of responses (32.0%) from the Northeast. Three quarters (75.3%) of respondents identified their location of current practice or residency training site as a large city or a suburb near a large city. Most (86.1%) of the respondents were civilians without any military experience. Almost half (42.9%) reported having at least one firearm at home, of whom 84.8% personally owned the firearms (Table 1). More than half of participants (56.0%) had some prior training on firearm safety for personal use, more than half (57.1%) strongly agreed or agreed that personal ownership of firearms by private individuals in the US should be a constitutional right, and almost half (45.1%) strongly agreed or agreed that personal ownership of firearms protects personal liberty. Demographic differences were observed in who reported having a gun at home, with male (49.3%) and White (45.1%) respondents being more likely

**Table 1.** Demographics and characteristics of survey participants (N=1,901).

| Characteristics | Total % (N) | Characteristics | Total % (N) |
|---|---|---|---|
| Gender (n = 1901) | | Resident PGY 4 | 2.2 (41) |
| Male | 62.3 (1,185) | Resident PGY 5 | 0.3 (5) |
| Female | 36.0 (684) | Region of Practice (n = 1825) | |
| Rather not answer | 1.5 (29) | Northeast | 32.0 (584) |
| Other | 0.2 (3) | Southeast | 24.0 (438) |
| Race and Ethnicity (n = 1893) | | Midwest | 16.0 (292) |
| White | 79.8 (1,511) | Southwest | 14.0 (256) |
| Asian or Asian American | 9.2 (174) | West | 14.0 (255) |
| Hispanic/Latino | 6.2 (118) | Location of Current Practice or Training (n = 1897) | |
| Other | 3.8 (72) | Large city | 54.9 (1,042) |
| Black or African American | 3.7 (69) | Suburb near a large city | 20.4 (386) |
| Middle East/North Africa | 1.8 (34) | Small city or town | 19.6 (371) |
| Native American or Alaska Native | 0.7 (13) | Rural area | 3.4 (65) |
| Level of Training in Emergency Medicine (n = 1898) | | Other | 0.9 (17) |
| | | Not currently in a clinical practice | 0.8 (16) |
| Attending 1-5 year out of residency | 23.1 (439) | Has military experience (previous or active) | 13.9 (263) |
| Attending more than 16 years out of residency | 15.9 (301) | No military experience (previous or active) | 86.1 (1,635) |
| Attending 6-10 years out of residency | 15.5 (294) | Has training on firearms safety for personal purposes | 56.0 (1,063) |
| Resident PGY 1 | 13.3 (252) | No training on firearms safety for personal purposes | 44.0 (835) |
| Attending 11-15 years out of residency | 9.9 (187) | Has firearms stored in home (even if not owner) | 42.9 (806) |
| Resident PGY 3 | 9.9 (187) | Personal owner of firearm stored in home | 84.9 (656) |
| Resident PGY 2 | 7.9 (150) | No firearms stored in home (even if not owner) | 57.1 (1,074) |
| Other | 2.2 (42) | | |

Notes: Total number of participants in study is N = 1 901. Participants could skip questions, which is why different questions have different n.
*PGY*, postgraduate year.

than women (30.3%), Hispanic (34.2%), and Black (22.8%) respondents, while rural (58.7%) and small town (51.9%) respondents reported being more likely to have a gun at home than respondents in large cities (38%) or suburbs (44.5%). Of respondents who considered gun ownership a constitutional right and a personal liberty, 81.0% and 85.9% reported having a gun at home. (Table 1).

Regarding barriers to *asking* at-risk patients about firearms, most (51.4%) reported "no barriers to, or felt comfortable with, asking patients about firearm access" (Figure 1). Yet almost half (47.7%) reported lack of knowledge (e.g., "I don't know what to do with the information"); more than half (55.8%) reported attitudinal barriers (e.g., "I don't think it makes a difference"); and one-fifth (21.3%) reported negative attitudes and normative beliefs (e.g., "Asking is someone else's responsibility, not mine") about screening (Figure 1).

Respondents had a wide variety of beliefs about *counseling* on firearm injury prevention. Only a quarter (25.7%) of respondents "strongly agreed" or "agreed" that patients would change how they store their firearms if physicians educated patients on firearm injury prevention. Almost half (46.1%) said that they personally had the training necessary to educate/counsel patients on firearm injury prevention. Nonetheless, nearly three-quarters (71.0%) wanted additional training in procedures to follow for patients at risk, and only a quarter (24.8%) "strongly agreed" or "agreed" that EPs in general are knowledgeable about firearm injury prevention (Figure 2).

Self-reported frequency of asking patients about firearm access was dependent on the clinical scenario (Figure 3). Almost all (82.3%) EPs self-reported almost always or often asking a patient with suicidal ideation or suicide attempt (SI/SA) about firearm access, compared to 52.4% of cases where patients presented as victims of domestic violence, and lower rates for patients with psychosis or intoxication (11.7%). Knowing that a patient had access to a firearm would reportedly increase concern of future risk of violence or self-harm for 91.7 % for suicidal patients, vs only 46.6% of assault-injured patients (Figure 4). Knowing that a patient had access to a firearm would change an EP's assessment of a patient only rarely, except for suicidal or psychotic patients (Figure 5). When asked about counseling, however, less than half (46.9%) of respondents reported "almost always" or "often" counseling suicidal patients and their families on lethal means.

Differences in responses were observed between respondents with a firearm in the home, and those without a firearm in the home. Although the majority (79%) of respondents with a firearm in the home believed that they had the training necessary to educate/counsel patients on firearm injury prevention, only 38.1% believed that other EPs were knowledgeable on firearm injury prevention. Of the EPs who strongly agreed that they wanted additional training in procedures to both identify and counsel patients at risk, only 26.4% and 22.9%, respectively, were gun owners (vs 73.6% and 77.1% non-gun owners; $P<0.0001$). Of EPs who strongly agreed that counseling would change how patients stored their firearms, only 34.4% were gun owners (vs 65.6% non-gun owners; $P<0.0001$). Compared to those without a firearm in the home, respondents with a firearm in the home were less likely to report that knowing a patient had firearm access changed their assessment about their risk of future violence/self-harm for a victim of domestic violence (30.6 vs 69.4%), a suicidal patient (38.2% vs 61.7%), an assault-injured patient (27.2% vs 72.8%), a psychotic/agitated patient (37.1%

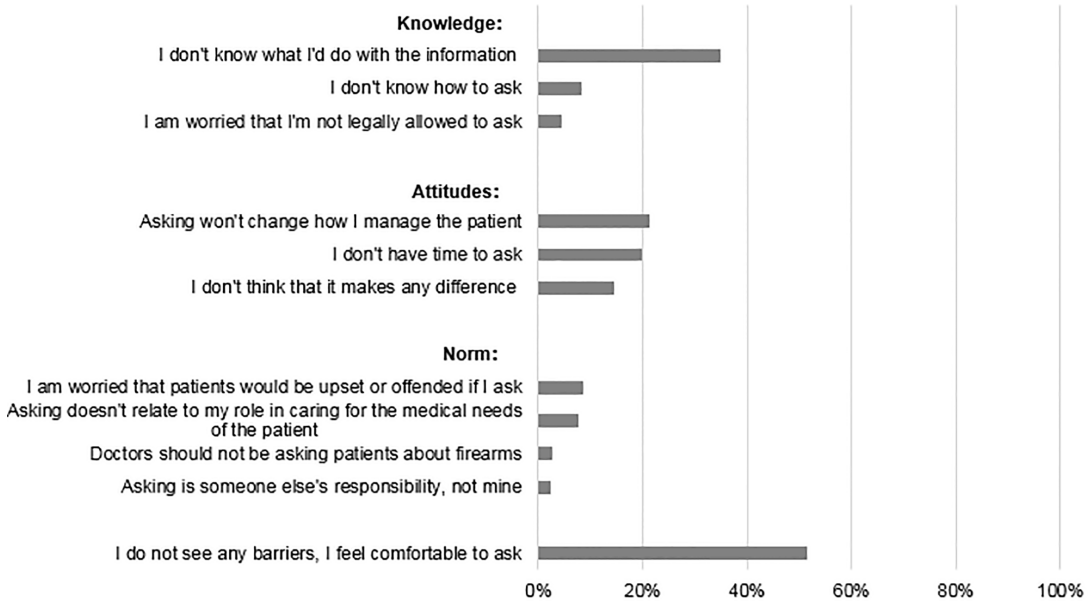


**Figure 1.** Participants were asked which of these are significant knowledge, attitudinal, and norm-related barriers to personally asking patients about firearm access. (Total n = 1,701.)

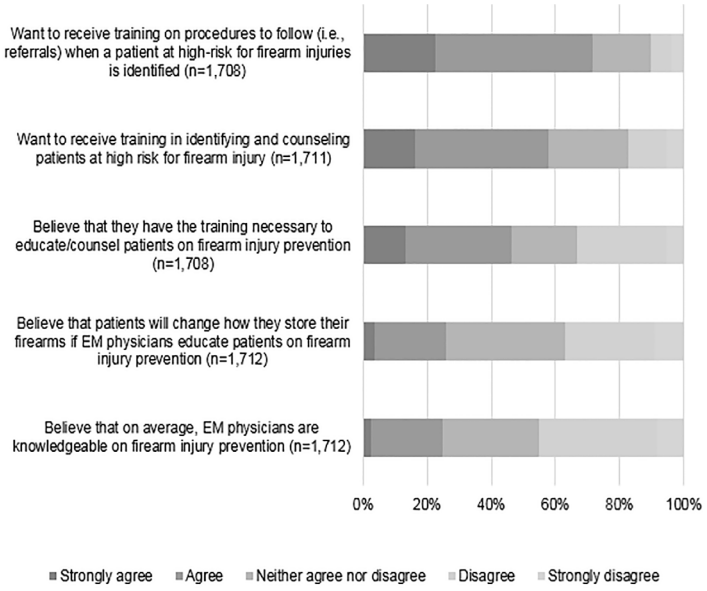


**Figure 2.** Participants agreement with the statements about training in firearm injury prevention (on a scale from strongly agree to strongly disagree).
*EM,* emergency medicine.

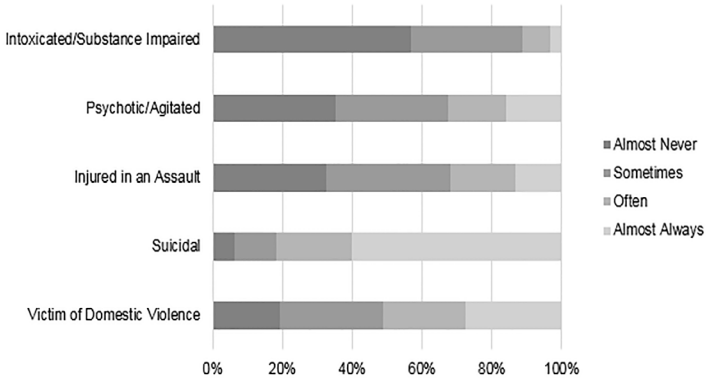


**Figure 3.** Frequency of asking a patient about firearm access in different scenarios. (Total n = 1,710)

vs. 62.9%), or an intoxicated/substance impaired patient (27.9% vs 72.1%) ($P$<0.001). Yet respondents with firearms in the home more frequently reported asking about lethal means compared to non-gun owners (almost never asked: gun-owners 68%; non-gun owners: 32%; $P$<0.0001).

When asked, "How big a concern for you is your personal safety associated with firearms while you are working in the ED?," only 7.7% responded "no concern at all"; 25.3% expressed "very great concern"; 36.8% expressed "moderate concern"; and 30.1% expressed "some concern." Almost 40% (n = 654) of EPs responded that they did not know whether their ED had a procedure for securing patient firearms, and 9.8% said that no protocols existed. Respondents with a firearm in the home were less likely to report concern about their personal safety while working at the ED (very great concern: 35.9% gun owners vs 64.1% no gun owners, $P$<0.0001).

## DISCUSSION

To our knowledge, this study is the most comprehensive assessment to date of EPs' attitudes, beliefs, and self-reported behaviors in relation to firearm injury prevention in the clinical setting. Despite respondents representing a convenience sample, the percent of respondents with a firearm in their home is similar to that reported in national surveys, and the geographic, gender, and racial/ethnic distribution of the respondents is similar to that in national data on emergeny medicine.[22] Among this diverse sample of EPs, despite half reporting no barriers to asking high-risk patients about firearm access, numerous training needs were identified. The most notable findings were the disparities between reported knowledge, attitudes, and normative beliefs about the values of screening vs actual reported counseling of high-risk patients. There were stark disparities between what respondents said they did, and what others did. Differences in knowledge, attitudes, and beliefs about screening and counseling were also observed between firearm owners and non-owners.

Reassuringly, our survey identifies that neither knowledge nor normative beliefs are major barriers to firearm injury screening and counseling for high-risk patients. Most respondents reported knowing how to ask, and most reported that a positive finding would affect their judgment (but not necessarily their behavior) regarding evaluation of an at-risk patient. Only 8.6% reported being afraid to ask a patient about access to a firearm. This finding differs from other surveys of other physicians' knowledge and attitudes, which reported low rates of knowledge about the incidence of firearm injury and discomfort with asking about firearms.[25] This difference may reflect multiple medical societies' educational efforts over the last half-decade emphasizing that patients are open to respectful, non-judgmental discussions of firearm injury risk.[26,27]

According to this survey, the two primary barriers to EPs' effectively screening and counseling ED patients about firearm injury were not knowing how to respond to the information, and not thinking it will change management. Lack of resources, and skepticism about efficacy has been identified by others[22,25-28] as common barriers to effective firearm injury prevention in the ED. Our findings, therefore, reinforce the importance of physician and patient self-training resources and handouts, In 2019, Pallin et al published a guide to when and how to intervene to reduce firearm injury.[11] In response, multiple resources have been recently developed, including the following: 1) "What You Can Do" and "BulletPoints," initiatives from University of California at Davis[29]; 2) "Gun Safety and Your Health" (available in both English and Spanish) from the American College of Surgeons[30]; 3) Guides to home firearm safety and pediatric counseling from the Firearm Safety Among Children and Teens (FACTS) Consortium[31]; 4) safe storage resources from the Colorado Firearm Safety

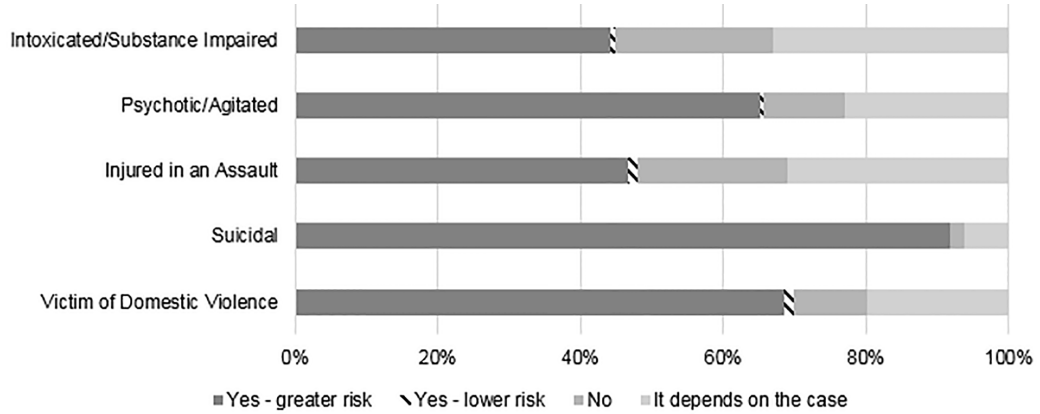


**Figure 4.** Knowledge of a patient's firearm access changes assessment of risk of harm. (Total n=1,711)

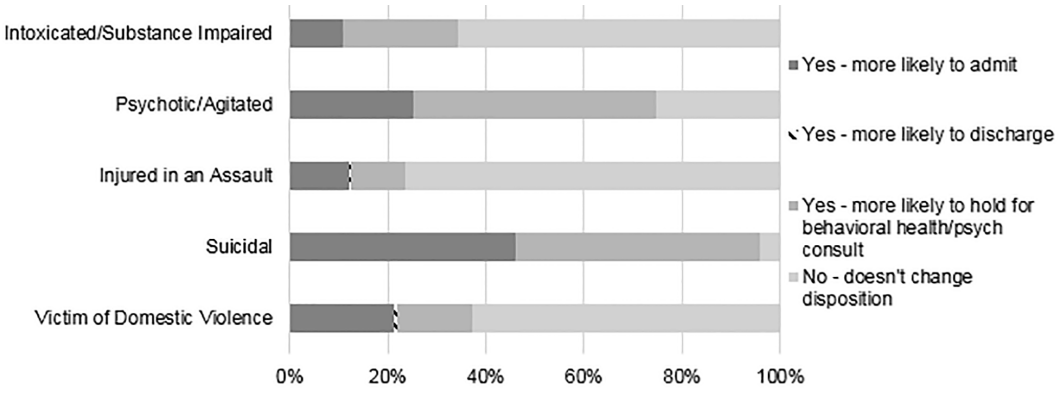


**Figure 5.** The proportion of participants that changed their assessment about a patient's risk of future violence/self-harm if the patient was intoxicated/substance impaired (n = 1,704), psychotic/agitated (n = 1,704), injured in an assault (n = 1,703), suicidal (1,710), and/or a victim of domestic violence (1,707). Total participants who answered this question n = 1,711.

Coalition[32]; and 5) a compendium of resources from the American Foundation for Firearm Injury Reduction in Medicine (AFFIRM), a non-partisan network of health professionals dedicated to changing the conversation about firearm injury prevention.[33] Emergency departments interested in decreasing barriers to screening and intervention could review and share these well-developed resources.

In line with national surveys, having a firearm in the home was more common among White men, those practicing in rural areas and small cities/towns, and those who believe that gun ownership is a constitutional right, a personal liberty, and a self-protection.[34] Those EPs with a firearm in the home were more likely to ask patients about lethal means, reported less concerns about their safety while working at the ED, were less interested in wanting additional training to identify patients at risk, and were less likely to agree that counseling would change how patients stored their firearms. Additionally, EPs with a firearm in the home were less likely than those without a firearm in the home to report insufficient knowledge about how to ask. These findings concord with our and others' work showing that firearm owners can help lead evidence-based interventions to reduce firearm injury risk.[22,28,35-37] Future educational programs should make an effort to highlight the voices, expertise, and experience of firearm-owning EPs.[37,38] Nonetheless, deficits in knowledge were identified among this group, including lack of belief in the value of screening or counseling for patients who were at risk of non-suicide-related firearm injury.

The findings also suggest, unfortunately, that simple knowledge alone is unlikely to change behavior. For example, despite most participants reporting that screening is important and would change their behavior, and most respondents saying that they personally were comfortable with firearm counseling, almost all said that *other* EPs were not comfortable screening or counseling at-risk patients, and most requested at least some additional training for themselves. Similarly, despite most participants reporting that they "always or almost always" screen suicidal patients for firearm access (much higher than previous literature has reported),[20,26,39] and most participants reporting that this knowledge would change their disposition decision for suicidal patients, less than half report delivering

lethal means counseling. These incongruities may reflect social desirability bias (e.g., it may be easier for respondents to admit that others were unsure of what to do or how to do it, compared to admitting it about themselves). Others' work has studied physicians' actual behavior, using both electronic health records and self-report, and has similarly found that physicians screen far less often than self-report.[11,26,39,40] Even if a large percentage of subjects in this study are asking patients with suicidal ideation about firearm access, competent counseling should be part of the discussion.[20]

The contradictions in responses may reflect a key lesson of behavior change theory[41,42] and dissemination and implementation research: Attention must be paid to not just internal factors, but also healthcare and societal structures that influence change.[42] For example, Runyan et al have suggested that having departmental written protocols for lethal means counseling has been associated with a higher rate of counseling for all suicidal patients, and that developing such standard protocols across the country might increase lethal mean counseling.[40] Betz et al have developed physician-independent, web-based, lethal means counseling resources, with high acceptability and feasibility.[43] Development and dissemination of similar resources that reduce physician burden and address physician-independent barriers may be necessary.

Finally, our data confirm that EPs were significantly concerned about their safety associated with firearms while working in the ED, with a quarter expressing "very great" and more than a third expressing "moderate concern" about their personal safety. This concern is exacerbated by both a lack of policy regarding firearm handling, and a lack of knowledge of any existing policies; the majority of respondents reported that they are concerned for their own safety, yet a third had no idea whether a policy existed. This finding could potentially be explained by several factors including physicians' attitude toward the subject, professional priorities, or a lack of education or communication on the topic from ED leadership. In a survey conducted by Ketterer et al, 20% of attending and 25% of resident physicians reported encountering firearms in the ED or its immediate surroundings. Attending physicians, however, had more knowledge of hospital policy regarding handling and management of the firearm once it was discovered in a patient's possession, as compared to residents.[22-28] In another study Ketterer et al reports that "up to 25% of trauma patients brought to the emergency department (ED) have been found to carry weapons."[28] Overall, more research is needed to address safety in the ED and the handling of firearms when they are brought into the department; further collaborative work is needed.[24,45]

The American College of Surgeons' Committee on Trauma[23] published results from a similar survey of surgeons in 2016, with the primary objectives of identifying advocacy initiatives and efforts related to firearm safety. Our respondents were similar to ACS' in demographics, percent firearm ownership, percent with gun safety training, and percent with a military background; the one major difference is that our EM survey included resident physicians, while the ACS survey did not. ACS found that the vast majority of respondents believed that healthcare professionals should be allowed to counsel patients on firearm safety and injury prevention, with 88% setting injury prevention as a high priority and 94% responding that federal funding should be allocated for firearm safety and injury prevention research.[23] Our study, conducted two years later after extensive educational work by both ACS and EM professional societies,[7,45] assumed that healthcare professionals have the duty to discuss firearm safety and injury prevention with at-risk patients, and sought instead to determine how often these conversations were taking place (< 50% of encounters with suicidal patients), how comfortable physicians were in having these conversations (51.4%), and what percentage of physicians felt the need for further training to effectively engage patients in these conversations (>70%).

The overarching theme of our organizations, institutions and collaborations is to explore shared goals among healthcare professionals, public health researchers, educators, advocates, firearm owners, gun shops,[46] and law enforcement officials who are collectively committed to working toward suicide prevention and firearm safety.[32] Our study supports the need for increased training and protocols regarding firearm counseling, handling, and medical record documentation. Physicians are aware of the lack of training and are open to learning the necessary skills to save lives through education and prevention of firearm injuries. Further research is needed on the efficacy of current training and available resources.

## LIMITATIONS

Selection bias is always present when a survey is sent to one or more large organizations by email; it is likely that respondents have stronger feelings or opinions about the survey topic. Another limitation associated with survey studies is the potential for over- or under-reporting of results due to inaccuracies attributable to social desirability or recall biases. However, social desirability bias has been shown to be less likely to occur with online surveys, such as ours, where no personal identifiers are involved and responses are more accurate than those obtained from face-to-face or telephone surveys.[47,48] This study is subject to a geographic bias, since most respondents were from the East coast of the US, although geographic bias is far more likely to impact results when surveys are done in various countries whose socioeconomic, religious, and political climates may vary considerably.

## CONCLUSION

Emergency physicians, whether firearm owners or not, believe in the importance of screening and counseling to reduce risk of firearm injury among at-risk patients. Nonetheless, further training, resources, and innovative interventions are needed to aid EPs in accurate identification and management of these high-risk patients. Additional resources are also needed to increase knowledge about personal safety from firearm injury in the ED.

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# California ACEP Firearm Injury Prevention Policy

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Firearm-related deaths and injuries are a serious public health problem in California and the United States. The rate of firearm-related deaths is many times higher in the US than other democratic, industrialized nations, yet many of the deaths and injuries are preventable. The California American College of Emergency Physicians Firearm Injury Prevention Policy was approved and adopted in 2013 as an evidence-based, apolitical statement to promote harm reduction. It recognizes and frames firearm injuries as a public health epidemic requiring allocation of robust resources, including increased governmental funding of high-quality research and the development of a national database system. The policy further calls for relevant legislation to be informed by best evidence and expert consensus, and advocates for legislation regarding the following: mandatory universal background checks; mandatory reporting of firearm loss/theft; restrictions against law-enforcement or military-style assault weapons and high capacity magazines; child-protective safety and storage systems; and prohibitions for high-risk individuals. It also strongly defends the right of physicians to screen and counsel patients about firearm-related risk factors and safety. Based upon best-available evidenced, the policy was recently updated to include extreme risk protection orders, which are also known as gun violence restraining orders. [West J Emerg Med. 2021;22(2)266–269.]

Firearm-related injuries and deaths are a serious public health problem in the United States (US), yet the idea of regulating firearm ownership and access is complicated, politically charged, and potentially conflicts with US Constitution 2nd Amendment rights. The rate of firearm-related deaths is many times higher in the US than in other democratic, industrialized nations.[1] In 2015, there were 113 firearm deaths per million individuals in the US as compared with 0.8 in the United Kingdom.[1,2]

Despite this disparity, and largely due to politics, firearm violence prevention research receives significantly less US federal funding compared with other leading causes of death; yet available research suggests that many firearm-related injuries and deaths are preventable.[3,4,5,6] A 1993 study published in the *New England Journal of Medicine* and funded by the US Centers for Disease Control and Prevention (CDC) identified an association between elevated homicide risk within homes with guns. In response, the National Rifle Association (NRA) successfully lobbied US Congress in 1996 to include the "Dickey Amendment" in the federal omnibus spending bill.[7] That amendment stripped $2.6 million from the CDC's budget (the amount it had spent on firearm research the previous year) and added the following language: "none of the funds made available for injury prevention may be used to advocate or promote gun control." Thereafter, federal firearm safety and violence research funding at the CDC, and later the National Institutes of Health (NIH), was effectively eliminated.[8] A 2013 report from the Institute of Medicine concluded, "the scarcity of research on firearm-related violence limits policymakers' ability to propose evidence-based policies that reduce injuries and deaths and maximize safety."[9] Using a methodology that calculated

expected levels of research investment based on mortality rates, one study estimated that between 2004 and 2015 firearm violence prevention research received just 1.6% of the federal research support projected, and had just 4.5% of the volume of publications anticipated.[10] Congress in 2018 clarified that the CDC can conduct research into firearm injury prevention, but again cannot use government funds to specifically advocate for gun control. Subsequently, the 2020 federal omnibus spending bill specifically allocated $25 million to the CDC and NIH toward firearm violence prevention research.[11]

Founded in 1971, the California Chapter of the American College of Emergency Physicians (California ACEP) is a 501(c)(6) non-profit, non-partisan, association representing California's board-certified emergency physicians (EP). California ACEP's mission is to support EPs in providing the highest quality of care to all patients and to their communities. In 2000, the California ACEP board of directors (BOD) voted to make firearms injury prevention one of the organization's legislative priorities and approved a position statement concerning firearm injury prevention. In 2013, multiple bills regarding mandatory firearm restrictions were proposed to the California State Senate and Assembly. The California ACEP BOD tasked a subcommittee with reviewing the chapter's position statement and available research, updating the chapter's official policy, and guiding its legislative and advocacy efforts. The California ACEP Firearm Injury Prevention Policy (Firearm Policy) was approved and adopted in 2013 as an evidence-based, apolitical statement to promote harm reduction. The Firearm Policy recognizes and frames firearm injuries as a public health epidemic requiring allocation of robust resources, including increased government funding of high-quality research and the development of a national database system of firearm injuries. The policy further calls for legislation to be informed by best evidence and expert consensus, and advocates for legislation focused on the following:

1. Mandatory universal background checks
2. Mandatory reporting of firearm loss/theft
3. Restrictions against law-enforcement or military-style assault weapons and high capacity magazines
4. Child-protective safety and storage systems
5. Prohibitions against gun possession or purchase for high-risk individuals
6. The right of physicians to screen and counsel patients about firearm-related risk factors and safety.

In a subsequent review of the scientific literature on the effects of firearm injury prevention policies, the RAND Corporation cited evidence supporting child-access prevention laws, mandatory waiting periods, universal background checks, prohibitions related to domestic violence and mental illness, along with minimum age and licensing/permitting requirements.[6] Notably, all these recommendations are included in the Firearm Policy.

In 2016, in response to recent highly publicized mass shootings including San Bernardino and Sandy Hook, the state of California overwhelmingly passed Proposition 63 (63% in favor vs 37% opposed).[12] Proposition 63 focused mainly on the regulation of ammunition. It mandated a universal background check and California Department of Justice authorization to purchase ammunition (in addition to firearms, which was already regulated), and it specifically prohibited *possession* of large capacity magazines (LCM), which hold more than 10 rounds of ammunition. Prior to Proposition 63, it had been illegal in California to manufacture, purchase, receive, import, keep, sell, give, or lend LCMs. Proposition 63 also levied fines against firearm owners who fail to report the theft or loss of their firearm.[13] Several regulations in Proposition 63, including a ban on LCM possession and mandatory reporting of firearm loss or theft, were advocated by the Firearm Policy. The NRA subsequently sponsored a legal challenge to Proposition 63 (DUNCAN v BECERRA),[14] and in March 2019, the District Court for the Southern District of California ruled that Proposition 63 was unconstitutional, despite testimony by EPs on behalf of California ACEP. On August 14, 2020, a divided three-judge panel of the Ninth District Federal Court of Appeals upheld the federal district court's ruling. That decision is currently being further appealed,[15] and the case is being closely tracked by California ACEP's BOD and staff.

Another crucial firearm-related violence prevention policy topic recently reviewed by the California ACEP BOD concerns extreme risk protection orders (ERPO), which are also known as gun violence restraining orders. In many states including California, medical professionals, law enforcement officers, coworkers, teachers, and family members may petition a court for ERPOs, which preemptively and temporarily authorize law enforcement officers to remove firearms from individuals deemed high risk for self-harm or violence against others. ERPO laws often allow formal court appeal and forbid harassment, to prevent misuse of ERPOs that could restrict access to firearms for defense, hunting, or recreation.[16] Several studies examining ERPOs in states outside of California suggest that they are modestly effective in reducing firearm-related suicides.[17] Per a RAND analysis, there were limitations in these studies, including the extrapolation of suicide attempts, rather than observed data, and a lack of comparison groups.[6] However, the data was convincing enough to move the chapter's BOD in 2020 to include ERPOs in an update to the Firearm Policy.

California ACEP strongly believes that it should advocate for evidence-based solutions to public health and policy issues, including firearm violence prevention and safety. Clearly, preventing injuries and deaths is more effective than, and preferable to, heroic saves in the emergency department or trauma bay. The Firearm Policy promotes evidence-based legislative recommendations and highlights the urgent need

for more robust government funding, data, and evidence to effectively address the firearm violence epidemic in California and the US.

**California ACEP Firearm Injury Prevention Policy:**

It is the position of the California Chapter of the American College of Emergency Physicians that:

1. Emergency Medicine is well positioned, as a profession and specialty, to appreciate the multifaceted ramifications of firearm injuries in our society. Firearm violence is a public health epidemic that can only be effectively cured by deploying necessary and appropriate resources.
2. California ACEP deplores attempts to politicize or silence physicians and science on firearm violence. We recommend robust funding (federal and otherwise) of research on firearm injury and evidence-based prevention as well as its impact on public health and safety. It is our hope and belief that such research will guide better future legislation and lead to well-informed public policy.
3. Legislative measures and policies to curb or reduce firearm violence should be informed by evidence-based consensus. We advocate for continued research and implementation of programs focused on the safe storage of legitimate firearms, development of childproof or personalized guns, prevention of both interpersonal and self-directed violence by firearms, including the prevention of gang-related and domestic violence.
4. We support mandatory, comprehensive, and universal background checks for the purchase of firearms. Background checks should be required for essentially all firearm transfers, including at gun shows and auctions and from private sellers. Prohibited straw purchases of firearms should be recognized as serious crimes and be treated as such, and all secondhand gun sales and firearm transfers should be regulated. We support continued efforts to improve the quality of the data on which background checks are performed, such that all prohibited persons can be detected.
5. We support requiring that all firearm owners of record be required to report the theft or loss of their firearm within a timely period of becoming aware of such a loss.
6. We recommend legislation banning civilian purchase or access to assault weapons, large-capacity ammunition magazines, and any munitions specifically designed for the use by military and law enforcement agencies.
7. We encourage all healthcare providers, including emergency physicians, to screen and counsel patients with diagnosed mental illnesses or believed to be at risk of harming themselves or others for their potential access to firearms, and to refer such patients to appropriate mental health services in a timely manner. Policies and procedures for this process need to be validated and standardized.
8. We recommend the creation of a national database and surveillance system to track firearm-related injury and mortality, including mandatory reporting of firearm injuries and fatalities by all hospitals and healthcare centers.
9. We support restraining orders that allow for the removal of a firearm to provide a rapid, focused response when risk for imminent firearm violence, including suicide and homicide, is high. We support restraining orders that rely on actions by judicial officers and include due process protections and provide for immediate firearm recovery and include a prohibition on possession and purchase of firearms and ammunition. We support allowing petitions for such orders to be submitted by family members, law enforcement officers, physicians, and other mental health professionals including school counselors.
10. We recommend prohibiting firearm purchases by individuals in high-risk categories that include but are not limited to habitual criminals, drug traffickers, persons with mental illness who are suicidal or high risk, those with violent misdemeanors, persons with multiple convictions for alcohol-related offenses, those with a history of domestic violence, juveniles convicted of violent crimes, and violators of parole and restraining orders.
11. We believe in the protection of healthcare providers' rights to educate patients regarding firearm safety. We encourage all healthcare providers, including emergency physicians, to counsel patients about firearm safety when appropriate including discussing with parents safe storage of firearms in homes with children.

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# Patterns and Predictors of Firearm-related Spinal Cord Injuries in Adult Trauma Patients

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**Introduction:** Firearm-related spinal cord injuries are commonly missed in the initial assessment as they are often obscured by concomitant injuries and emergent trauma management. These injuries, however, have a significant health and financial impact. The objective of this study was to examine firearm-related spinal cord injuries and identify predictors of presence of such injuries in adult trauma patients.

**Methods:** This retrospective cohort study examined adult trauma patients (≥16 years) with injuries from firearms included in the 2015 United States National Trauma Data Bank. We performed descriptive and bivariate analyses and compared two groups: patients with no spinal cord injury (SCI) or vertebral column injury (VCI); and patients with SCI and/or VCI. Predictors of SCI and/or VCI in patients with firearm-related injuries were identified using a multivariate logistic regression analysis.

**Results:** There were 34,898 patients who sustained a firearm-induced injury. SCI and/or VCI were present in 2768 (7.9%) patients. Patients with SCI and/or VCI had more frequently severe injuries, higher Injury Severity Score (ISS), lower mean systolic blood pressure, and lower Glasgow Coma Scale (GCS). The mortality rate was not significantly different between the two groups (14.7%, N = 407 in SCI and/or VCI vs 15.0%, N = 4,811 in no SCI or VCI group). Significant general positive predictors of presence of SCI and/or VCI were as follows: university hospital; assault; public or unspecified location of injury; drug use; air medical transport; and Medicaid coverage. Significant clinical positive predictors included fractures, torso injuries, blood vessel or internal organ injuries, open wounds, mild (13-15) and moderate GCS scores (9 – 12), and ISS ≥ 16.

**Conclusion:** Firearm-induced SCI and/or VCI injuries have a high burden on affected victims. The identified predictors for the presence of SCI and/or VCI injuries can help with early detection, avoiding management delays, and improving outcomes. Further studies defining the impact of each predictor are needed. [West J Emerg Med. 2021;22(2)270–277.]

## INTRODUCTION

### Background

Firearm-related injuries continue to have a significant health and financial impact worldwide. In the United States (US), mass shootings are responsible for increasing proportions of total firearm-related homicidal deaths.[1] In 2017, the rate of nonfatal, firearm-related gunshot injuries was 41.1 per 100,000 injured.[2] The fatality rate of firearm-related gunshot injuries was 12.2 per 100,000 injuries.[3] Between the years 2006 and 2010, a total of 385,769 emergency department (ED) visits secondary to firearm-related injuries yielded 141,914 inpatient admissions with an estimated cost of more than 88 billion US dollars.[4]

Firearm injuries can result in a myriad of health outcomes, with both short- and long-term sequelae, including spinal cord injuries (SCI). Firearms are the main cause of traumatic

spinal cord injuries in Brazil (28.4%). This rate varies from one country to another, dropping down to 8.4% in Thailand and as low as 1.9% in Turkey.[5-7] In the US, 12.2% (784 out of a total of 17,730 new annual SCIs) are secondary to gunshot injuries.[8,9] Spinal cord injuries also result in a significant health and financial burden at the level of the individual patient and their families, as well as at the level of the healthcare system. Less than 1% of affected individuals achieve complete neurological recovery upon hospital discharge, with the most frequent sequela being incomplete tetraplegia. Mortality rates are also highest during the first year post-injury.[10]

In contrast to most injuries that take priority in the management of trauma cases, SCIs can often be missed initially and not detected until later in the management process via imaging. They are often obscured by the presence and or need to manage more life-threatening concomitant injuries, particularly severe head trauma or hemorrhage, in addition to the performance of emergent procedures such as intubation, sedation, and surgical procedure.[6,11-12]

*Population Health Research Capsule*

What do we already know about this issue?
*Firearm-related spinal cord injuries (SCI) are commonly missed in the initial assessment as they are often obscured by more life-threatening injuries.*

What was the research question?
*This study examines firearm-related SCI in adult trauma patients and identifies predictors of such injuries.*

What was the major finding of the study?
*SCI and/or vertebral column injury (VCI) were present in 7.9% of adult patients with trauma. Several clinical and non-clinical predictors were identified.*

How does this improve population health?
*The identified predictors can help with early detection of SCI/VCI injuries, avoid management delays, and improve outcomes of trauma patients.*

**Importance**

This is the first study to identify general and clinical predictors of firearm-induced SCI and/or vertebral column injury (VCI), which would serve as cues for earlier detection and management of SCI/VCIs.

**Objectives**

This study examines firearm-related spinal cord injuries in adult trauma patients in the US and identifies predictors of presence of such injuries in this patient population.

## METHODS

**Study Design and Setting**

For this retrospective cohort study we used the public release dataset from the 2015 National Trauma Data Bank (NTDB). This dataset is an annually issued, US population-based, multicenter cohort and is considered the largest aggregation of US-based trauma registry data.[13] The institutional review board at the American University of Beirut approved the use of the de-identified dataset to conduct this study.

**Selection of Participants**

The total number of patients in the dataset was 917,865. The study sample included adult patients (≥16 years) who sustained firearm-induced injury coded under a list of *International Classification of Diseases, Ninth Revision* E codes "Mechanism" (Appendix) (N = 34,898). We excluded pediatric patients (age < 16 years, similar to other trauma studies[14]) and cases with missing age documentation (Figure).

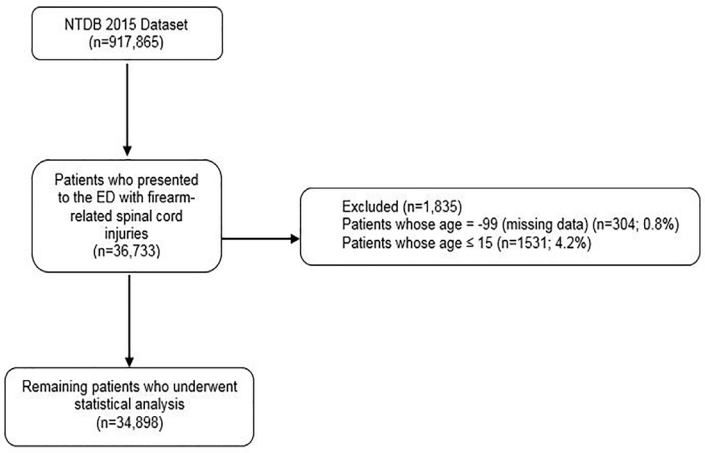


**Figure 1.** Flowchart showing inclusion and exclusion of patients with firearm-induced injuries.
*NTDB,* National Trauma Data Bank ; *ED,* emergency department.

**Analysis**

We conducted descriptive analyses to summarize the categorical variables by calculating their frequencies and percentages and to present the mean ± standard deviation (SD) of the continuous variables. Comparison of the percentages of all categorical variables according to the two groups of the cord injuries (none vs SCI and/or VCI) was done by using Pearson's chi-square test. Due to the non-normal distribution, we used the Mann-Whitney test instead of Student's t-test to compare the means of the continuous variables. More than 5% of the

variables (ethnicity, whether patient used alcohol, whether patient used drug, the patient's primary method of payment) were categorized as being not known/not recorded, and as a result we performed multiple imputation procedures to account for these missing data and thus to provide accurate estimates.

We conducted a multivariate logistic regression using a backward selection procedure to determine the predictors of SCI/VCI in patients with firearm-related injury. A receiving operating characteristic (ROC) curve was plotted to assess the validity of the logistic regression results. It indicated that the generated model discriminated excellently patients with no SCI or VCI from those with SCI and/or VCI (area under the ROC curve = 0.9, 95% confidence interval (CI), 0.88 – 0.89, $P<0.001$). Statistical significance was considered at an alpha value set at 0.05 and below. We performed analyses using the SPSS 24 (IBM Corporation, Armonk, NY) statistical package.

## RESULTS

### Characteristics of Study Subjects

*Population and Hospital Characteristics (Table 1)*

A total of 34,898 patients who sustained a firearm-induced injury were included in the analysis. Among those, 2768 patients (7.9%) had SCI or VCI. The mean age of patients with firearm-induced SCI and/or VCI was 30.1 (± 11.5 years), and 90.4% (N = 2501) were males.

### Main Results

*Firearm Injury Characteristics and Locations (Table 2 and Table 3)*

Firearm injuries associated with SCI and/or VCI were more likely to occur in public buildings, streets, and recreation areas (44.1% vs 38.5%; *P*-value <0.001). Assault (vs self-inflicted and unintentional injuries) was significantly higher in the SCI and/or VCI (86.4% vs 71.5%; *P*-value <0.001). Patients with SCI and/or VCI had more torso injuries (79.8% vs 44%; *P*-value <0.001); more head and neck injuries (28.1% vs 23.9%; *P*-value <0.001); and fewer injuries to the extremities (40.6% vs 60.1%; *P*-value <0.001); and fewer open wounds (52.5% vs 63.2%; *P*-value <0.001). Patients with SCI and/or VCI also commonly sustained more fractures (97.1% vs 53.0%; *P*-value <0.001), internal organ injuries (75.9% vs 35.6%; *P*-value <0.001), and blood vessel injuries (24.9% vs 12.2%; *P*-value <0.001). Patients with SCI and/or VCI more commonly had lower GCS score categories (severe [≤ 8] 22.7% vs 18.2%; *P*-value <0.001) and moderate [9–12] 4.5% vs 2.1%; *P*-value <0.001); lower systolic blood pressure (SBP≤ 90 millimeters mercury) (20.0% vs 12.7%; *P*-value <0.001); and higher Injury Severity Score (ISS) (≥ 16) (63.7% vs 26.0%; *P*-value <0.001).

*Firearm Injury Outcomes (Table 3)*

The mean length of hospital stay was significantly higher for patients with SCI and/or VCI (13.8 ± 17.3 days) compared to those with none (5.6 ± 9.4 days) (*P*-value <0.001). On the other hand, mortality rate in the ED or in hospital was not significantly different between the two groups (14.7%, N = 407 in SCI and/or VCI vs 15.0%, N = 4811 in no SCI or VCI group) (*P*-value = 0.703).

*Predictors of SCI/VCI in Patients with Firearm-induced Injuries (Table 4)*

*General Predictors:* After adjusting for important confounders, significant positive general predictors of presence of SCI and/or VCI included the following: assault injuries (odds ratio [OR] = 1.44; 95% CI, 1.17 – 1.79; Ref: Unintentional injuries); university hospital (OR = 1.16; 95% CI, 1.05 – 1.30; Ref: community hospital); public buildings, streets, or recreation sites as well as unspecified locations of injury (OR = 1.21; 95% CI, 1.07 – 1.36; Ref: home and residential institution); drug use (OR = 1.35; 95% CI, 1.22 – 1.49; Ref: No drug use); Medicaid coverage (OR = 1.19; 95% CI, 1.06 – 1.34; Ref: self-pay); and air medical transport (OR = 1.22; 95% CI, 1.06 – 1.41; Ref: ground ambulance). Increasing age was a slightly negative predictor for presence of SCI and/or VCI (OR = 0.995, 95% CI, 0.991 – 0.999).

*Clinical Predictors:* Additionally, the following positive clinical predictors were found to be significant for firearm-induced SCI and/or VCI: blood vessel injury (OR = 1.81; 95% CI, 1.60 – 2.05; Ref: no blood vessels injury); fractures (OR = 43.72; 95% CI, 33.94 – 56.32; Ref: no fractures); internal organ injury (OR = 1.38; 95% CI, 1.20 – 1.59; Ref: no internal organ injury); torso injury (OR = 3.25; 95% CI, 2.83 – 3.72; Ref: no torso injury); open wounds (OR = 1.19; 95% CI, 1.07 – 1.32; Ref: no open wounds); a mild or moderate GCS score (OR = 1.36; 95% CI, 1.19 – 1.55 and OR = 1.39; 95% CI, 1.06 – 1.81, respectively; Ref: severe GCS score [≤ 8]); and an ISS ≥ 16 (OR = 2.25; 95% CI, 2.00 – 2.53; Ref: ISS [<16]). Injury to extremities was a negative clinical predictor (OR = 0.32; 95% CI, 0.29 – 0.36; Ref: no extremity injury).

## DISCUSSION

This retrospective cohort study of 2768 patients who sustained a firearm-induced injury to the spinal cord or vertebral column is the largest to date to report on such injuries. With the exception of a study conducted by Jain et al on traumatic spinal cord injuries in general in the US,[8] most studies were limited to small sample sizes and to single centers. Firearm-induced SCIs are relatively uncommon. The rate of SCI and/or VCI in firearm injuries in the current study was found to be 7.9%. This rate of SCI and/or VCI is lower than the previously reported rates of 10%[12] and 23%[15] among the civilian population, and the 11.10%[16] rate of combat firearm injuries in the military population. The difference in rates across different studies is probably related to civilian vs military setting characteristics and firearms types.

While the mortality rate was not different among patients with SCI or VCI compared to those without, patients with firearm-induced SCI and/or VCI had more severe injuries than

**Table 1.** Demographics of the general study population and the two groups: patients with no spinal cord injury (SCI) or vertebral column injury (VCI), and patients with SCI and/or VCI.

| | General population (N = 34,898) | No SCI or VCI (N = 32,130)** | SCI and/or VCI (N = 2,768) | P-value‡ |
|---|---|---|---|---|
| Age (years) | 31.9 ± 13.5 | 32.1 ± 13.7 | 30.1 ± 11.5 | <0.001* |
| Gender | | | | |
| Female | 3,867 (11.1%) | 3,601 (11.2%) | 266 (9.6%) | 0.010 |
| Male | 31,022 (88.9%) | 28,521 (88.8%) | 2,501(90.4%) | |
| Not known/Not recorded | 9 (0.0%) | | | |
| Race | | | | |
| White | 11,379 (32.6%) | 10,704 (34.4%) | 675 (25.2%) | <0.001 |
| Black | 18,686 (53.5%) | 17,016 (54.6%) | 1,670 (62.3%) | <0.001 |
| Other race† | 3,771(10.8%) | 3,437 (11.0%) | 334 (12.5%) | 0.023 |
| Not known/Not recorded | 1,062 (3.0%) | | | |
| Hospital Teaching Status | | | | |
| Community | 11,127 (31.9%) | 10,373 (32.3%) | 754 (27.2 %) | <0.001 |
| Non-teaching | 3,327 (9.5%) | 3,148 (9.8%) | 179 (6.5 %) | <0.001 |
| University | 20,444 (58.6%) | 18,609 (57.9%) | 1,835 (66.3 %) | <0.001 |
| State Designation | | | | |
| Not applicable | 3,039 (8.7%) | 2,827 (8.8%) | 212 (7.7%) | 0.041 |
| I | 21,215 (60.8%) | 19,334 (60.2%) | 1,881 (68.0%) | <0.001 |
| II | 8,430 (24.2%) | 7,857 (24.5%) | 573 (20.7%) | <0.001 |
| III | 2,058 (5.9%) | 1,965 (6.1%) | 93 (3.4%) | <0.001 |
| IV | 65 (0.2%) | 61 (0.2%) | 4 (0.1%) | 0.595 |
| Other | 91 (0.3%) | 86 (0.3%) | 5 (0.2%) | 0.389 |
| Hospital Geographic Region | | | | |
| Northeast | 4,537 (13.0%) | 4,138 (13.0%) | 399 (14.5%) | 0.021 |
| Midwest | 6,837 (19.6%) | 6,333 (19.8%) | 504 (18.3%) | 0.056 |
| South | 17,234 (49.4%) | 15,877 (49.7%) | 1,357 (49.3%) | 0.700 |
| West | 6,095 (17.5%) | 5,603 (17.5%) | 492 (17.9%) | 0.651 |
| Missing | 195 (0.6%) | | | |
| Patient's Primary Method of Payment | | | | |
| Self-Pay | 11,927 (34.2%) | 11,057 (34.4%) | 870 (31.4%) | 0.002 |
| Medicaid | 10,361 (29.7%) | 9,352 (29.1%) | 1,009 (36.5%) | <0.001 |
| Medicare | 1,822 (5.2%) | 1,733 (5.4%) | 89 (3.2%) | <0.001 |
| Private/Commercial insurance | 7,880 (22.6%) | 7,304 (22.7%) | 576 (20.8%) | 0.020 |
| Other Government | 1,450 (4.2%) | 1,353 (4.2%) | 97 (3.5%) | 0.074 |
| Other and not billed (for any reason) | 1,458 (4.2%) | 1,331 (4.1%) | 127 (4.6%) | 0.261 |
| Mode of Transportation | | | | |
| Ground Ambulance | 25,389 (72.8%) | 23,288 (73.1%) | 2,101 (76.2%) | <0.001 |
| Air Medical Transport | 3,864 (11.1%) | 3,485 (10.9%) | 379 (13.7%) | <0.001 |
| Police | 487 (1.4%) | 436 (1.4%) | 51 (1.8%) | 0.040 |
| Public/Private vehicle walk-in | 4,474 (12.8%) | 4,282 (13.4%) | 192 (7.0%) | <0.001 |
| Other | 399 (1.1%) | 365 (1.1%) | 34 (1.2%) | 0.680 |
| Not known/not recorded | 285 (0.8%) | | | |

*The Mann-Whitney test was used to calculate the P-value.
**Missing values were disregarded when calculating percentages.
†"Other" race includes Asian, American Indian, Native Hawaiian, or other Pacific Islander and other race.
‡P-values are comparing the "no SCI or VCI" group to the "SCI and/or VCI" group.

**Table 2.** Firearm injury characteristics and locations of the general study population and the two groups: patients with no spinal cord injury (SCI) or vertebral column injury (VCI) and patients with SCI and/or VCI.

| | General population (N = 34,898) | No SCI or VCI (N =32,130) | SCI and/or VCI (N = 2,768)* | P-value |
|---|---|---|---|---|
| Injury intentionality as defined by the CDC Injury Intentionality Matrix | | | | |
| Assault | 25,348 (72.6%) | 22,957 (71.5%) | 2,391 (86.4%) | <0.001 |
| Self-inflicted | 3,766 (10.8%) | 3,671 (11.4%) | 95 (3.4%) | <0.001 |
| Unintentional | 4,050 (11.6%) | 3,905 (12.2%) | 145 (5.2%) | <0.001 |
| Other and undetermined | 1,734 (5.0%) | 1,597 (5.0%) | 137 (4.9%) | 0.961 |
| Location where injury occurred | | | | |
| Home and residential institution | 11,656 (33.4%) | 10,936 (35.3%) | 720 (27.1%) | <0.001 |
| Industry, farm and mine | 185 (0.5%) | 171 (0.6%) | 14 (0.5%) | 0.870 |
| Public building, street and recreation | 13,116 (37.6%) | 11,944 (38.5%) | 1,172 (44.1%) | <0.001 |
| Unspecified and other | 8,691 (24.9%) | 7,942 (25.6%) | 749 (28.2%) | 0.003 |
| Not known/not recorded | 1,250 (3.6%) | | | |
| Comorbidity | | | | |
| No | 16,728 (47.9%) | 15,424 (48.0%) | 1,304 (47.1 %) | 0.036 |
| Yes | 18,170 (52.1%) | 16,706 (52.0%) | 1,464 (52.9 %) | |
| Alcohol use | | | | |
| No | 27,087 (77.6%) | 24,978 (77.7%) | 2,109 (76.2%) | 0.061 |
| Yes | 7,811 (22.4%) | 7,152 (22.3%) | 659 (23.8%) | |
| Drug use | | | | |
| No | 25,710 (73.7%) | 23,918 (74.4%) | 1,792 (64.7%) | <0.001 |
| Yes | 9,188 (26.3%) | 8,212 (25.6%) | 976 (35.3%) | |
| Nature of injury as defined by the Barell Injury Diagnosis Matrix | | | | |
| Blood vessels | 4,597 (13.2%) | 3,909 (12.2%) | 688 (24.9%) | <0.001 |
| Fractures | 19,726 (56.5%) | 17,037 (53.0%) | 2,689 (97.1%) | <0.001 |
| Internal organ | 13,533 (38.8%) | 11,432 (35.6%) | 2,101 (75.9%) | <0.001 |
| Open wounds | 21,749 (62.3%) | 20,297 (63.2%) | 1,452 (52.5%) | <0.001 |
| Others | 3,902 (11.2%) | 3,486 (10.8%) | 416 (15.0%) | <0.001 |
| Region 1: ICD-9 body region as defined by the Barell Injury Diagnosis Matrix | | | | |
| Extremities | 20,438 (58.6%) | 19,315 (60.1%) | 1,123 (40.6%) | <0.001 |
| Head and neck | 8,458 (24.2%) | 7,681 (23.9%) | 777 (28.1%) | <0.001 |
| Spine and back | 2,768 (7.9%) | 0 (0%) | 2,768 (100%) | <0.001 |
| Torso | 16,347 (46.8%) | 14,138 (44.0%) | 2,209 (79.8%) | <0.001 |
| Unclassifiable by site | 2,280 (6.5%) | 2,016 (6.3%) | 264 (9.5%) | <0.001 |
| GCS Total (ED) | | | | |
| Severe (≤ 8) | 6,322 (18.1%) | 5,708 (18.2%) | 614 (22.7%) | <0.001 |
| Moderate (9 – 12) | 776 (2.2%) | 655 (2.1%) | 121 (4.5%) | <0.001 |
| Mild (13 – 15) | 26,994 (77.4%) | 25,025 (79.7%) | 1,969 (72.8%) | <0.001 |
| Not known/not recorded | 806 (2.3%) | | | |
| SBP (ED) | | | | |
| ≤ 90 | 4,520 (13.0%) | 3,981 (12.7%) | 539 (20.0%) | <0.001 |

*Missing values were disregarded when calculating percentages.
*ICD-9,* International Classification of Diseases, Ninth Edition; *CDC,* US Centers for Disease Control and Prevention; *GCS,* Glasgow Coma Scale Score; *ED,* emergency department; *SBP,* systolic blood pressure.

**Table 2.** Continued.

| | General population (N = 34,898) | No SCI or VCI (N =32,130) | SCI and/or VCI (N = 2,768) | P-value |
|---|---|---|---|---|
| ≥ 91 | 29,427 (84.3%) | 27,275 (87.3%) | 2,152 (80.0%) | |
| Not known/not recorded | 951 (2.7%) | | | |
| ISS | | | | |
| < 16 | 24,245 (69.5%) | 23,266 (74.0%) | 979 (36.3%) | <0.001 |
| ≥ 16 | 9,877 (28.3%) | 8,162 (26.0%) | 1,715 (63.7%) | |
| Not Known/not recorded | 776 (2.2%) | | | |

*Missing values were disregarded when calculating percentages.
*SCI,* spinal cord injury*; VCI,* vertebral column injury; *ISS,* Injury Severity Score.

those without SCI or VCI. They more frequently had higher ISS, lower GCS scores, and lower SBP. These findings further reiterate the high impact of spinal injuries on affected victims in terms of clinical outcomes. However, this analysis may have missed patients with severe injuries or those who died from other major injuries, as they may not have survived long enough for evaluation for SCI and/ or VCI.

Patients with SCI and/or VCI were more commonly found to have concomitant fractures, internal organ injuries, and blood vessel injuries compared to patients with no SCI or VCI. Furthermore, the injury location among patients with SCI and/or VCI involved the torso and head and neck more commonly than those with no SCI and/or VCI injury. These findings are in line with those of a previous study that examined patients who presented with gunshot wounds to the trunk, neck, or head over a 10-year period to a trauma center in Miami, Florida, where concomitant spine injuries were found in 10% of cases. It is worth noting that in the latter study, 13% of the detected cases of spine injuries were unsuspected, particularly when they involved the face (75%), abdomen (27%), chest (10%), shoulder (10%), back (5%), and flank (5%), but not the head.[12]

The mean length of hospital stay of 13.8 days (± 17.3) is slightly higher than the mean of 11 days reported by the National Spinal Cord Injury Statistical Center. Rehabilitation duration is not reported in the NTDB, but the national average rehabilitation length of stay is estimated to be around 31 days.[10] The intensive care unit stay and ventilator days in the current study were also found to be significantly higher for patients with SCI and/or VCI compared to none. This translates into high healthcare costs secondary to firearm-induced SCI and/or VCI. According to the National Spinal Cord Injury Statistical Center, the average yearly expenses of affected individuals vary between US dollars $44,766 – $1,129,302, depending on the degree of neurological impairment, level of education, and pre-injury employment history.[10] This is important in estimating the potential impact of the high cost of care of these injuries on patients and the government, especially given that a large portion of the study population is covered by Medicaid. Mitigation strategies, such as the adoption and enforcement of strict gun control laws, are needed to prevent such injuries and reduce their financial burden on affected victims.

**Table 3.** Outcomes of the general study population and the two groups: patients with no spinal cord injury (SCI) or vertebral column injury (VCI) and patients with SCI and/or VCI.

| | General population (N) | General population (Mean ± SD) | No SCI or VCI (N = 32,130) | SCI and/or VCI (N = 2,768) | P-value |
|---|---|---|---|---|---|
| Died in ED/hospital | | | | | |
| No | 28,887 (82.8%) | | 26,608 (82.8%) | 2,279 (82.3%) | 0.521 |
| Yes | 5,218 (15.0%) | | 4,811 (15.0%) | 407 (14.7%) | 0.703 |
| Not known/not recorded | 793 (2.3%) | | | | |
| Total length of stay in days | 34,850 | 6.3 ± 10.45 | 5.6 ± 9.4 | 13.8 ± 17.3 | <0.001* |
| Total number of days spent in the intensive care unit | 11,883 | 6.0 ± 8.5 | 5.5 ± 7.7 | 9.0 ± 11.9 | <0.001* |
| Total number of days spent on a ventilator | 8,427 | 4.9 ± 7.8 | 4.3 ± 6.4 | 7.8 ± 12.7 | <0.001* |

*The Mann-Whitney test was used to calculate the P-values.
*SCI,* spinal cord injury; *VCI,* vertebral column injury; *ED,* emergency department; *SD,* standard deviation.

**Table 4.** Predictors of spinal cord injury/vertebral column injury in patients with firearm-induced injury.

| | Odds ratio | 95% CI | P-value |
|---|---|---|---|
| General predictors | | | |
| Age* | 1 | 0.99-1.00 | 0.027 |
| Hospital teaching status (community) | | | |
| Non-teaching | 0.84 | 0.69 – 1.03 | 0.085 |
| University | 1.16 | 1.05 – 1.30 | 0.006 |
| Injury Intentionality as defined by the CDC Injury Intentionality Matrix (Unintentional) | | | |
| Self-inflicted | 0.31 | 0.23 – 0.42 | <0.001 |
| Assault | 1.44 | 1.17 – 1.79 | 0.001 |
| Other and undetermined | 1.25 | 0.93 – 1.68 | 0.144 |
| Location where injury occurred (Home & residential institution) | | | |
| Industry, farm and mine | 1.15 | 0.58 – 2.27 | 0.698 |
| Public building, street and recreation | 1.21 | 1.07 – 1.36 | 0.002 |
| Unspecified and other | 1.2 | 1.05 – 1.37 | 0.008 |
| Drug use | | | |
| Yes | 1.35 | 1.22 – 1.49 | <0.001 |
| The patient's primary method of payment (self-pay) | | | |
| Medicaid | 1.19 | 1.06 – 1.34 | 0.004 |
| Medicare | 1.07 | 0.81 – 1.42 | 0.628 |
| Private/commercial insurance | 1.06 | 0.92 – 1.21 | 0.412 |
| Other government | 0.82 | 0.62 – 1.07 | 0.146 |
| Other and not billed (for any reason) | 1.1 | 0.87 – 1.39 | 0.441 |
| Mode of transportation (Ground Ambulance) | | | |
| Air Medical Transport | 1.22 | 1.06 – 1.41 | 0.007 |
| Police | 0.61 | 0.41 – 0.90 | 0.013 |
| Public/private vehicle walk-in | 0.71 | 0.59 – 0.86 | <0.001 |
| Other | 0.94 | 0.62 – 1.44 | 0.782 |
| Clinical predictors | | | |
| Nature of injury as defined by the Barell Injury Diagnosis Matrix (Reference: No) | | | |
| Blood vessel injury | 1.81 | 1.60 – 2.05 | <0.001 |
| Fractures | 43.72 | 33.94 – 56.32 | <0.001 |
| Internal organ injury | 1.38 | 1.20 – 1.59 | <0.001 |
| Open wounds | 1.19 | 1.07 – 1.32 | 0.001 |
| Extremities injury | 0.32 | 0.29 – 0.36 | <0.001 |
| Torso injury | 3.25 | 2.83 – 3.72 | <0.001 |
| GCS total (ED) (Severe (≤ 8)) | | | |
| Moderate (9 – 12) | 1.39 | 1.06 – 1.81 | 0.016 |
| Mild (13 – 15) | 1.36 | 1.19 – 1.55 | <0.001 |
| ISS (≤ 15) | | | |
| ≥ 16 | 2.25 | 2.00 – 2.53 | <0.001 |

*Rounded up: 3-decimal odds ratio for age = 0.995; 95% confidence interval [0.991 – 0.999.]
*CI,* confidence interval; GCS, Glasgow Coma Scale Score; *ED,* emergency department; *SBP,* systolic blood pressure; *ISS,* Injury Severity Score.

This study is the first to identify predictors of firearm-induced SCI and/or VCI. A previous study examined prehospital predictors of traumatic spinal cord injuries in general: male gender; neurological deficit; altered mental status; high falls; diving injuries; and bike/motorbike collisions.[17] Main predictors for firearm-induced SCI and/or VCI included unintentional

injuries, assault forms of injuries, public or unspecified location of injuries, concomitant drug use by the subject, injury of the torso, as well as concomitant fractures, injuries to blood vessels, internal organs, or open wounds. Familiarity with these predictors is important for emergency providers, which would translate into earlier detection and management of SCI and/or VCI injuries and ultimately improved patient outcomes. Nevertheless, the full clinical utilization of such predictors, among others, would require further studies and the development and verification of clinical prediction rules.

## LIMITATIONS

This study did have a number of limitations. While the NTDB cohort is the largest registry representative of US-based trauma, some data elements that better characterize firearm-induced SCI and/or VCI (such as types of firearms, interval neurological examinations, and neurological outcomes at discharge) are not collected or reported. For instance, low GCS may be related to different factors and not limited to traumatic brain injury, which is not specified in the NTDB. While missing data is also considered a limitation of this study, the latter was addressed in the analysis via multiple imputations. Despite these limitations, the findings of this study, which used the NTDB dataset, apply in hospitals and trauma centers across the US and in similar clinical settings.

## CONCLUSION

Firearm-induced spinal cord and/or vertebral column injuries have a high burden on affected victims. This study identifies important general and clinical predictors for the presence of these injuries in trauma patients with firearm injuries. These predictors can help physicians suspect and detect the presence of SCI and/or VCI injuries for earlier management in order to improve outcomes of affected patients. Future studies involving databases with more detailed, neurological clinical data points can help further define the impact of such injuries on affected victims.

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# Collaboration and Decision-Making on Trauma Teams: A Survey Assessment

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**Introduction:** Leadership, communication, and collaboration are important in well-managed trauma resuscitations. We surveyed resuscitation team members (attendings, fellows, residents, and nurses) in a large urban trauma center regarding their impressions of collaboration among team members and their satisfaction with patient care decisions.

**Methods:** The Collaboration and Satisfaction About Care Decisions in Trauma (CSACD.T) survey was administered to members of ad hoc trauma teams immediately after resuscitations. Survey respondents self-reported their demographic characteristics; the CSACD.T scores were then compared by gender, occupation, self-identified leader role, and level of training.

**Results:** The study population consisted of 281 respondents from 52 teams; 111 (39.5%) were female, 207 (73.7%) were self-reported White, 78 (27.8%) were nurses, and 140 (49.8%) were physicians. Of the 140 physician respondents, 38 (27.1%) were female, representing 13.5% of the total surveyed population. Nine of the 52 teams had a female leader. Men, physicians (vs nurses), fellows (vs attendings), and self-identified leaders trended toward higher satisfaction across all questions of the CSACD.T. In addition to the comparison groups mentioned, women and general team members (vs non-leaders) gave lower scores.

**Conclusion:** Female residents, nurses, general team members, and attendings gave lower CSACD.T scores in this study. Identification of nuances and underlying causes of lower scores from female members of trauma teams is an important next step. Gender-specific training may be necessary to change negative team dynamics in ad hoc trauma teams. [West J Emerg Med. 2021;22(2):278-283.]

## INTRODUCTION

Collaboration and communication are recognized factors in successful team dynamics. On trauma teams, leadership, task completion, and delegation are additional characteristics vital to success.[1] Gender differences in team leadership in acute care settings have not been well studied. Speck and associates reported that male leaders at an academic trauma center perceived themselves as teachers and educators more often than female leaders.[2] Additionally, based on data from 42 intensive care units, Shortell and colleagues demonstrated that improved physician–nurse communication was associated with better patient outcomes and higher patient and family satisfaction.[3] In a survey of emergency department (ED) clinicians, Rosenstein and Naylor found unclear roles and responsibilities to be a contributing factor in ineffective communication.[4] None of these studies, however, addressed

communication or collaboration by gender. Emergency departments and trauma resuscitation units must maximize effective collaboration to prevent dangerous and life-threatening situations for their patients.[5,6]

Trauma teams are ad hoc assemblages of attending physicians, fellows, residents, nurses, technicians, and medical students who come together for the initial assessment and immediate treatment of a trauma patient.[7] These teams are generally very effective at treating patients, but team members may have different perceptions of collaboration and communication.[8,9] To our knowledge, this is the first study of collaboration within ad hoc trauma teams from the viewpoint of their members. We also specifically studied gender differences in responses.

The purpose of this study was to investigate trauma team members' perceptions of collaboration, communication, and leadership and their satisfaction with patient care decisions. We hypothesized that team members have differing views on collaboration during resuscitation, leading to inconsistent levels of satisfaction, and that role, level of responsibility, and gender contribute to these differing views.

*Population Health Research Capsule*

What do we already know about this issue?
*Collaboration and communication are critical for successful teams and patient outcomes. Ad hoc trauma teams are effective in patient care but may have different perceptions of team dynamics.*

What was the research question?
*How do trauma team members' perceptions of collaboration, communication, and satisfaction with patient care decisions differ?*

What was the major finding of the study?
*Gender, occupation, and team leadership affect perceptions of collaboration and satisfaction among trauma team members.*

How does this improve population health?
*Recognizing differences in perceptions of ad hoc team dynamics allows targeted improvements in collaboration and communication, which ultimately improves the care of trauma patients.*

## METHODS

### Setting

We conducted this study at a regional Level I trauma center designated for the resuscitation and stabilization of critically ill and injured patients. The center has more than 7000 trauma patient encounters per year. This study was approved by the institutional review board at the university where the trauma center is located.

### Participants

Trauma team members involved in resuscitations were enrolled prospectively, as a random sample, between 2014–2016.

### Survey Methodology

Research assistants spent at least 40 hours per week surveying team members in the trauma center. They conducted the surveys at various times of day and on weekends over two 10-week periods in summer 2015 and summer 2016. New research assistants were trained on the methods of survey administration and collection by the lead investigator. Following completion of a trauma resuscitation, research assistants surveyed at least half of the members of that trauma team; participation was voluntary. On rare occasions, team members declined to participate in the study.

Gender identity, ethnicity, age, occupation, and team role (leader vs non-leader or general team member) were self-reported by participants. Gender options were binary: male and female. Race or ethnicity was self-reported and respondents were given the following ethnicity/race options to choose from: African American, Asian American, Hispanic, Native American, White, or other. Team leaders were typically a senior resident or fellow at the study site.

We excluded teams with fewer than four members or less than 50% of team members participating in the survey (Figure 1) because, at the study site, trauma teams typically consist of nine or more people. Demographic information from surveyed team members was used to calculate the gender, ethnicity, and occupational composition of the team. The team score for each survey question was the mean of the individual responses to the question. Overall team score was the mean of the individual overall scores.

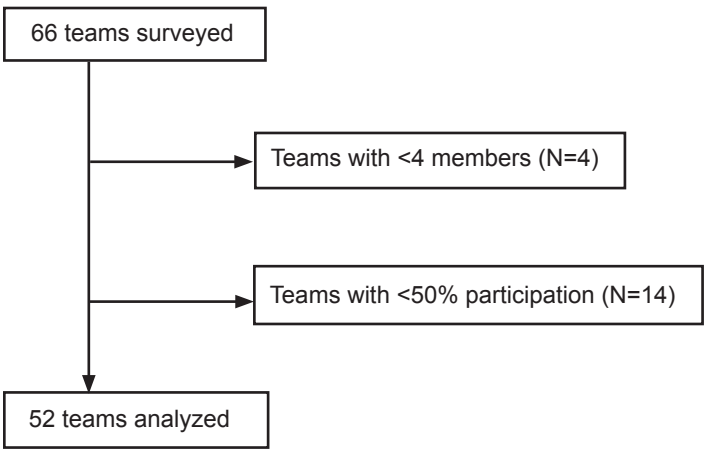


**Figure 1.** Flow diagram of trauma teams' eligibility to be included in study analysis.

### Collaboration and Satisfaction About Care Decisions in Trauma (CSACD.T) Instrument

The original Collaboration and Satisfaction About Care Decisions instrument has been validated for assessment of nurse–physician collaboration and satisfaction with patient care decisions.[10] It consists of nine questions measured on a seven-point Likert scale that ask about cooperation, assertiveness, shared responsibility for planning, shared decision-making, open communication, and coordination as important attributes of collaboration.[11] We chose this instrument for this study because of its excellent internal consistency (Cronbach $\alpha = 0.95$) and because it has been tested on both physicians and nurses.[11]

The questions were reframed slightly to reflect the trauma setting, creating the CSACD.T (Appendix). The specific questions changed were 1, 8, and 9. A qualifier of "in the trauma bay" was added at the end of Questions 1 and 8 to reflect the location of the resuscitation. Question 8 was changed from "How satisfied were you with the way this decision was made for this patient?" to "How satisfied are you with the overall collaboration between physicians and nurses in the trauma bay?" Question 9 was reworded from "How satisfied were you with the decisions made for the patient?" to "How satisfied are you with collaboration on the trauma service overall?" The total participant satisfaction score is the sum of the scores from the nine questions.

**Table 1.** Comparison of self-identified demographic characteristics of individual respondents by gender (n = 281).

| | Female (n = 111, 39.5%) | Male (n = 170, 60.5%) |
|---|---|---|
| Age | | |
| 20-30 | 49 (44.1) | 70 (41.2) |
| 31-40 | 40 (36) | 70 (41.2) |
| 41-45 | 4 (3.6) | 11 (6.5) |
| 46-55 | 12 (10.8) | 8 (4.7) |
| 56-65 | 6 (5.4) | 1 (0.6) |
| >65 | 0 (0) | 10 (5.9) |
| Ethnicity | | |
| African American | 3 (2.7) | 15 (8.8) |
| Asian American | 7 (6.3) | 26 (15.3) |
| White | 93 (83.8) | 114 (67.1) |
| Hispanic | 2 (1.8) | 4 (2.4) |
| Native American | 0 (0) | 1 (0.6) |
| Other | 6 (5.4) | 10 (5.9) |
| Team leader | 17 (15.3) | 52 (30.6) |
| Occupation | | |
| RN | 48 (43.2) | 30 (17.7) |
| Attending | 6 (5.4) | 15 (8.8) |
| Fellow | 4 (3.6) | 11 (6.5) |
| Resident | 28 (25.2) | 76 (44.7) |
| ED technician | 17 (15.3) | 24 (14.1) |
| Medical student | 8 (7.2) | 13 (7.7) |
| Other | 0 (0) | 1 (0.6) |

*RN,* registered nurse; *ED,* emergency department.

### Statistical Analysis

We compared relative frequencies of categorical variables using chi-squared and Fisher's exact test. Mean scores were compared between two categorical groups using the Mann-Whitney *U* test. Mean scores were compared across multiple groups using the Kruskall-Wallis test. We calculated individual total scores by summing an individual's responses from Questions 1-9 of the CSACD.T. The Pearson correlation coefficient was used to determine the linear correlation between a team's score and percentage of female members. To test for differential effects of gender on satisfaction scores among different occupations and leadership roles, we performed a linear regression with total satisfaction score as the dependent variable and independent variables of gender, occupation, and leadership roles, as well as two- and three-way interaction terms. Survey data were recorded in Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA), and statistical analysis was performed using SAS University Edition Studio version 3.5 (SAS Institute Inc., Cary, NC.).

## RESULTS

Our study group consisted of 281 survey participants from 52 teams. Table 1 presents their demographic information: 39.5% were female and most were between the ages of 20-40 (consistent with the typical age group for residents, fellows, and junior attendings). Most respondents (73.7%) self-identified as White. Half (49.8%) of survey respondents were physicians (attendings, fellows, and residents), and 27.8% were nurses. Team leaders were less likely to be female than non-leaders (24.6% vs 44.3%, $p = 0.004$), and physicians were less likely to be female (27.1%) compared to registered nurses (61.5%) and those with other roles (39.7%, $p < 0.001$).

Table 2 lists the characteristics of the ad hoc trauma teams. Nine (17.3%) of the 52 teams had a female leader. Although we made an effort to survey the team leaders, 14 (26.9%) teams did not have a self-identified leader participate in the survey. The leader might have gone directly from the trauma resuscitation unit to the operating suite or declined to participate in our study. Seventeen teams (32.7%) had more than one self-identified leader; on 15 teams (28.8%), a resident as well as another resident, a fellow, an attending, or a nurse identified themselves as the leader. In these situations, a fellow or an attending could have been supervising a resuscitation that a resident was leading. Teams with more than one self-identified leader gave higher overall mean [SD] team scores compared with teams with no leader or one leader (54.6 [1.6] vs 51.8 [1.9], $p = 0.03$).

Male respondents, physicians, and self-identified leaders gave higher scores on almost every question compared with females, non-physicians, and general team members, respectively (Table 3). A higher proportion of team members being female was weakly correlated with lower overall team satisfaction scores ($r^2 = 0.14$). Difference in overall team score

**Table 2.** Demographics of trauma teams included in analysis of the Collaboration and Satisfaction About Care Decisions in Trauma survey (n = 52).

| Characteristic | Number of teams (%) | Median (IQR) |
|---|---|---|
| No leader | 14 (26.9) | |
| 1 leader | 21 (40.4) | |
| More than 1 leader | 17 (32.7) | |
| Female leader | 9 (17.3) | |
| Unknown leader gender | 20 (38.5) | |
| All physician respondents | 5 (9.6) | |
| All male respondents | 7 (13.5) | |
| < 25% female respondents | 11 (21.2) | |
| 25%-50% female respondents | 16 (30.8) | |
| 50%–75% female respondents | 18 (34.6) | |
| > 75% female respondents | 7 (13.5) | |
| Size of team | | 6 (5, 8) |
| Response rate for team | | 62.5 (50.0, 75.0) |
| Percent of team male | | 58.6 (36.7, 75.0) |
| Percent of team white | | 75.0 (63.3, 100.0) |
| Percent of team physician | | 46.4 (33.3, 73.2) |
| Percent of team nurse | | 25.0 (7.1, 46.4) |

*IQR,* interquartile range.

was not statistically significant between male and female leaders (53.9 vs 51.6 [$p = 0.2$]). Thirty male nurses and 48 female nurses completed the survey. The raw scores on most questions of the CSACD.T instrument were higher for male nurses than female nurses. When comparing CSACD.T scores among physicians based on level of training (Figure 2), the scores suggested that, generally, fellows were most satisfied and attendings were least satisfied with team collaboration.

The results of the linear regression containing interaction terms for gender, occupation, and leader showed that there was no significant difference in average total scores between female and male physician leaders (difference 1.47, $p = 0.52$) or between female and male nurse team members (difference 1.23, $p = 0.52$).

## DISCUSSION

This inquiry revealed interesting patterns of perceptions of satisfaction and collaboration in a trauma setting. Physicians gave higher overall scores than did nurses. Steinemann and colleagues surveyed trauma nurses and surgeons and found that those groups had different perceptions of their responsibilities in trauma resuscitations.[12] Our results indicate a trend toward a greater overall level of satisfaction with care decisions and collaboration between physicians compared with nurses and nursing/medical students, as well as between males compared with females. Prior research has also revealed significant disparities between nurses' and physicians' perceptions of teamwork and communication, possibly based in the traditional differences in power and authority between the two occupations.[13,14]

Fellows in our study were more satisfied with overall team collaboration than were attendings. There could be several reasons for this finding. Fellows are often making decisions and performing the most critical procedures, while attendings tend to supervise the resuscitation and intervene only when necessary. Attendings are also responsible for teaching and so may have a more critical eye on how the resuscitation is carried out. We also found that teams with more than one self-identified leader gave higher CSACD.T scores than those with a single leader, which could be related to improved communication and collaboration among team members and between physicians and nurses.[15] Based on these data, we speculate that if multiple team members are assigned to be co-leaders, the perception of collaboration by all of the team members may increase. Alternatively, since leaders had higher scores, the entire team score may be artificially increased. At the study site, trauma team leaders can change with each resuscitation.

The composition of the team can also change as new members rotate on and off a team. Such staffing changes—a feature of ad hoc teams—might play a role in team members' scores, depending on when the surveys were administered. For example, perceptions within a team may be different at the start of a rotation with team members newly working together compared with a team that has worked together for a number of resuscitations. In future studies, adding trained independent observers to monitor the trauma team will add objective measures of collaboration. Adding time variables—time of day, day of rotation, and number of resuscitations on a given shift—may lead to further insights on team dynamics.

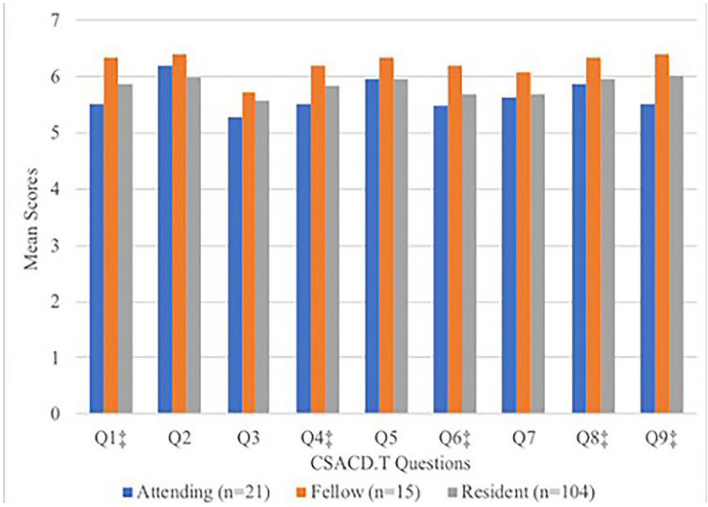


**Figure 2.** Differences in Collaboration and Satisfaction About Care Decisions in Trauma survey: mean scores* by physician level of training.
* Scores based on a 7-point Likert scale. ‡ Denote P value < 0.05.

**Table 3.** Differences in individual responses to Collaboration and Satisfaction About Care Decisions in Trauma survey: mean scores* and 95% confidence intervals by gender, occupation, and team role.

| Questions | Male N = 170 | Female N = 111 | *P*-value | Physician† N = 161 | Nurse N = 78 | *P*-value | Leader N = 61 | Team Member N = 212 | *p*-value |
|---|---|---|---|---|---|---|---|---|---|
| Q1: Nurses and physicians plan together to make decisions about care for the patients in the trauma bay | 5.9 (5.8, 6.1) | 5.7 (5.5, 5.9) | 0.04 | 5.9 (5.8, 6.1) | 5.7 (5.4, 6) | 0.42 | 6.1 (5.9, 6.4) | 5.8 (5.6, 5.9) | 0.002 |
| Q2: Open communication between physicians and nurses about patient care decisions takes place. | 6.1 (6, 6.3) | 5.9 (5.7, 6.1) | 0.01 | 6.1 (6, 6.3) | 5.8 (5.6, 6.1) | 0.09 | 6.3 (6.1, 6.5) | 6 (5.8, 6.1) | 0.01 |
| Q3: Decision-making responsibilities for patients are shared between nurses and physicians. | 5.7 (5.5, 5.9) | 5.5 (5.3, 5.7) | 0.05 | 5.6 (5.4, 5.8) | 5.5 (5.2, 5.8) | 0.99 | 5.9 (5.6, 6.1) | 5.6 (5.4, 5.7) | 0.06 |
| Q4: Physicians and nurses cooperate in making decisions about patient care. | 6 (5.8, 6.1) | 5.7 (5.5, 5.9) | 0.01 | 5.9 (5.7, 6) | 5.6 (5.4, 5.9) | 0.27 | 6.1 (5.9, 6.3) | 5.8 (5.6, 5.9) | 0.02 |
| Q5: In making decisions, both nursing and medical concerns about patients' needs are considered. | 6.1 (6, 6.3) | 5.8 (5.6, 6) | 0.002 | 6 (5.9, 6.2) | 5.7 (5.5, 6) | 0.09 | 6.2 (6.1, 6.4) | 5.9 (5.7, 6) | 0.02 |
| Q6: Decision-making for patients is coordinated between physicians and nurses. | 5.9 (5.7, 6) | 5.5 (5.3, 5.7) | 0.001 | 5.8 (5.6, 5.9) | 5.5 (5.2, 5.8) | 0.25 | 6.1 (5.8, 6.3) | 5.6 (5.5, 5.8) | 0.001 |
| Q7: How much collaboration between nurses and physicians occurs when making patient care decisions? | 5.8 (5.7, 6) | 5.6 (5.4, 5.8) | 0.02 | 5.8 (5.6, 5.9) | 5.5 (5.2, 5.7) | 0.15 | 6 (5.7, 6.2) | 5.6 (5.5, 5.8) | 0.02 |
| Q8: How satisfied are you with the overall collaboration between physicians and nurses in the trauma bay? | 6.1 (5.9, 6.2) | 5.7 (5.6, 5.9) | 0.003 | 6.1 (5.9, 6.2) | 5.6 (5.3, 5.9) | 0.01 | 6.2 (6, 6.3) | 5.9 (5.7, 6) | 0.05 |
| Q9: How satisfied are you with collaboration on the trauma service overall? | 6.1 (6, 6.2) | 5.9 (5.7, 6.1) | 0.03 | 6.1 (5.9, 6.2) | 5.8 (5.5, 6) | 0.11 | 6.2 (6, 6.3) | 6 (5.8, 6.1) | 0.26 |
| Total score | 54 (52.9, 55.1) | 51.5 (50.1, 53) | 0.001 | 53 (51.8, 54.2) | 50.9 (48.9, 53) | 0.14 | 55.2 (53.8, 56.6) | 52.3 (51.2, 53.4) | 0.01 |

*Scores based on a 7-point Likert scale.
†Physicians included attendings, fellows, and residents.

In a study by Speck et al, trauma team participants described attributes of "good leaders" to be confidence, ability to remain calm, having the respect of team members, and clinical abilities.[2] Medical students described good leaders as those with intelligence and experience and those who taught well.[2] In our study, male respondents, physicians, and self-identified team leaders all gave higher CSACD.T scores than female respondents, non-physicians, and general team members. Male leaders and male nurses gave higher raw scores than female leaders and female nurses, respectively, but the differences were not statistically significant. The gender differences might be attributable to women feeling less heard during an intense situation such as a trauma resuscitation and attempting to avoid being perceived negatively if they become aggressive and violate expected norms of gender behavior.[16]

Multiple strategies have been employed to attain the goal of improving patient outcomes. Simulation and cross-disciplinary training fill gaps in care providers' knowledge of traumatic injuries and diagnostic/stabilization procedures.[17-19] Although increased attention has been directed toward communication, handoffs, and checklists in medicine, specific attention to training on how to function efficiently on ad hoc teams is lacking.

## LIMITATIONS

The study site is unique in that a dedicated trauma team evaluates and manages trauma patients; thus, team attitudes may vary at hospitals with different clinical practice. The survey instrument used in the study was reframed for the trauma team setting from the original validated CSACD instrument. The use of a self-administered survey has inherent limitations. Team members may have declined to participate due to being deeply unsatisfied, biasing the results. In future studies, a trained independent observer can be used to add objective measures of team dynamics.

Our study also lacked unique identifiers; so although attempts were made to avoid surveying the same individual twice during a shift, it is possible that multiple surveys were completed by one individual. Potential confounding factors that are independent of responder demographics yet can influence survey outcomes include severity of patient injury, patient outcome, time of day, postgraduate year of training and experience, and symptoms of burnout. This study did not attempt to link the CSACD.T scores of ad hoc trauma team members with patient outcomes. Larger, multicenter studies addressing similar questions may want to include patients' characteristics and outcomes.

## CONCLUSION

Gender may appear to affect perceptions of collaboration and satisfaction with patient care decisions among trauma team members. This observation raises interesting questions about the underlying causes of those differences. Identification of the causes and their impact on trauma team collaboration and decision-making is an important next step.

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# Point-of-care Ultrasound to Evaluate Breast Pathology in the Emergency Department

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**Introduction:** As physician-performed point-of-care ultrasound (POCUS) becomes more prevalent in the evaluation of patients presenting with various complaints in the emergency department (ED), one application that is significantly less used is breast ultrasound. This study evaluates the utility of POCUS for the assessment of patients with breast complaints who present to the ED and the impact of POCUS on medical decision-making and patient management in the ED.

**Methods:** This was a retrospective review of ED patients presenting with breast symptoms who received a POCUS examination. An ED POCUS database was reviewed for breast POCUS examinations. We then reviewed electronic health records for demographic characteristics, history, physical examination findings, ED course, additional imaging studies, and impact of the POCUS study on patient care and disposition.

**Results:** We included a total of 40 subjects (36 females, 4 males) in the final analysis. Most common presenting symptoms were breast pain (57.5%) and a palpable mass (37.5%). "Cobblestoning," ie, dense bumpy appearance, was the most common finding on breast POCUS, seen in 50% of the patients. Simple fluid collections were found in 37.5% of patients.

**Conclusion:** Our study findings illustrate the utility of POCUS in the evaluation of a variety of breast complaints in the ED. [West J Emerg Med. 2021;22(2)284-290.]

## INTRODUCTION

Physician-performed point-of-care ultrasound (POCUS) has become increasingly more prevalent over recent years in the evaluation of patients presenting with various complaints in the emergency department (ED). One application significantly less used is breast ultrasound. It has been suggested that healthcare providers may be less confident in their ability to diagnose breast pathologies and concerned about potential litigation should an ominous pathology, such as malignancy, be missed. Breast complaints vary among many pathologies that can be unfamiliar to emergency physicians (EP).[1] While prior studies have evaluated the use of ultrasound for patients who present to the ED with breast complaints, they are few in number and do not use physician-performed ultrasound examinations, but rather ultrasounds performed by sonographers and interpreted by radiologists.[2] To our knowledge there are no studies to date that have evaluated the use of physician-performed POCUS for breast complaints in the ED.

Readily available in many EDs, POCUS makes the initial screening of breast complaints a viable option. It may be preferable to other imaging modalities due to absence of radiation, improved patient safety, real-time image acquisition, and relatively low cost.[3-7] Point-of-care ultrasound allows for efficient and cost-effective decision-making in the care of ED patients. To our knowledge, no study to date has investigated the direct impact of POCUS on the medical decision-making of the EP in patients presenting with breast complaints. The

purpose of this study was to evaluate the utility of POCUS for assessment of patients presenting to the ED with breast complaints and the impact of breast POCUS on medical decision-making and patient management in the ED.

## METHODS

### Study Design and Study Setting

We performed a a retrospective review of ED patients presenting with a breast complaint who received a POCUS over approximately a five-year period from November 27, 2014–December 29, 2019. This study includes breast POCUS examinations performed at two urban academic EDs totaling approximately 110,000 patient visits per year. Both EDs have an Accreditation Council for Graduate Medical Education (ACGME)-accredited emergency medicine (EM) residency program. One ED has an additional five-year combined EM/pediatrics residency program and an emergency ultrasound fellowship-training program. The residents receive emergency ultrasound training per ACGME guidelines. The attending physicians completed EM residency training and are board certified in EM. The attending physicians had been credentialed in superficial ultrasound.

Hospital-based credentialing in POCUS is available for ED attending physicians at both sites and was derived from the American College of Emergency Physicians ultrasound guidelines. Credentialing at these institutions required that physicians performed a minimum of 25 superficial ultrasounds. A specific ED POCUS protocol for evaluating breast pathology was not followed. Rather, when performing a POCUS examination of the breast, physicians took a similar approach as other superficial examinations. A high-frequency linear transducer was used for all studies. The entirety of the breast was examined, with more extensive imaging taking place at the area of concern. In cases where a suspected fluid collection, mass, or other concerning structure was identified, color Doppler was often used. In some cases, images of the contralateral breast were obtained for comparison.

The POCUS examinations included in this study were performed by both EM residents and attending physicians. All POCUS examinations were archived in the web-based workflow solutions database, Qpath (Q-path, Telexy Healthcare, Maple Ridge, BC, Canada), and quality assurance of all ultrasounds were performed by either emergency ultrasound fellows or emergency ultrasound fellowship-trained EPs. This database stores all POCUS examinations performed at both EDs, including interpretation reports detailing indications, findings, and final diagnoses that accompany each POCUS examination. Institutional board review approval was obtained for this study.

### Study population/inclusion criteria

We included patients in the study if they had received a breast POCUS examination in the ED and it was saved in the Qpath database. Patients received the POCUS when a credentialed EP was on duty.

*Population Health Research Capsule*

What do we already know about this issue?
*Point-of-care ultrasound (POCUS) is used in a variety of applications; its role in the evaluation of breast pathology has been less explored.*

What was the research question?
*Our goal was to evaluate the utility of POCUS for breast complaints in the emergency department.*

What was the major finding of the study?
*Emergency physicians are able to use POCUS to evaluate a variety of breast complaints.*

How does this improve population health?
*POCUS may impact management of breast pathology, aid in performance of procedures and treatment, and affect disposition.*

### Study Protocol

The Qpath database was initially queried for eligible subjects who received breast POCUS examinations followed by an electronic medical record review. A trained chart abstractor performed the chart review using a standardized data extraction form. The data extraction form included information about demographic characteristics, history, physical examination findings, ED course, POCUS findings, additional imaging studies, impact of breast POCUS on patient management in ED, disposition, and repeat visits to ED. Impact of breast POCUS on patient management was defined as the emergency provider's decision to perform invasive procedures, order further imaging, request consultation, order antibiotics, and decision to admit or discharge the patient.

### Statistical Analysis

We used descriptive statistics to summarize the data. Continuous data were presented as means with standard deviations, and dichotomous and nominal data were presented as percentage frequency of occurrence.

## RESULTS

We included a total of 40 subjects (36 females, 4 males) and 40 breast POCUS studies in the final analysis. The mean age was 35.9 ±14.9 years (range 0-61). Pain was the most common presenting symptom (57.5%) followed by a palpable mass (37.5%). Presenting symptoms are summarized in Table 1. Patient characteristics were recorded and are summarized in Table 2. Half of the

patients were found to have a history of skin/soft tissue infections, and 42.5% had a surgical history. The remaining characteristics documented made up a very small minority of the patients. The POCUS findings as reported by the EPs are listed in Table 3.

Of the 40 studies performed, the use of POCUS was documented in the medical decision-making section of the patient's note in 38 (95%) of the cases. Six out of 40 POCUS studies were followed up by additional diagnostic imaging in the ED. Five were followed up by a dedicated breast US from radiology, and one was followed up by a chest radiograph. Of the patients who received a breast POCUS examination, 27 (67.5%) received antibiotics in the ED. Eleven patients received a surgery consult, and only three (27.3%) of these patients required additional imaging while in the ED. Thirteen patients underwent a needle aspiration in the ED as a result of POCUS examination findings that documented a fluid collection suspicious for an abscess. All of the procedures were documented as successful, confirming the presence of an abscess. None of the patients who had an ED procedure required additional imaging. Four of the patients who received a POCUS study in the ED required a procedure in the operating room.

With regard to patient disposition, 10 (25%) of the patients were admitted. Of the 30 patients who were discharged from the ED, 18 (60%) were sent home with a prescription for antibiotics. Seven patients had a repeat ED visit within three weeks of their visit. Fifteen patients had a documented follow-up within two weeks of their ED visit. Fourteen of these visits were to either breast clinic or oncology and one visit was with a primary care provider. The diagnoses made in the ED are summarized in Table 4. In some cases, patients received more than one diagnosis.

**Table 1.** Presenting symptoms of patients presenting to the emergency department with breast complaints.

| Presenting Symptom | N (%) |
|---|---|
| Pain | 23/40 (57.5) |
| Mass | 15/40 (37.5) |
| Swelling | 10/40 (25) |
| Redness | 9/40 (23) |
| Cutaneous lesion | 2/40 (5) |
| Discharge | 2/40 (5) |

**Table 2.** Characteristics of patients presenting with breast complaints.

| Patient Characteristics | N (%) |
|---|---|
| History of skin/soft tissue infection | 20/40 (50) |
| Surgical history | 17/40 (42.5) |
| Diabetes Mellitus | 6/40 (15) |
| Lactating | 5/40 (12.5) |
| Postpartum | 6/40 (15) |
| Breast implants | 4/40 (10) |
| Male | 4/40 (10) |
| Pediatric (<18 years of age) | 3/40 (7.5) |
| History of breast cancer | 2/40 (5) |
| Immunocompromised | 1/40 (2.5) |

**Table 3.** Breast point-of-care ultrasound findings.

| Findings on POCUS | N (%) |
|---|---|
| Cobblestoning | 20/40 (50) |
| Fluid collection (simple) | 15/40 (37.5) |
| Increased tissue thickness | 9/40 (22.5) |
| Fluid collection (complex) | 8/40 (20) |
| Increased echogenicity | 4/40 (10) |
| Hyperemia | 3/40 (7.5) |
| No sonographic abnormalities | 3/40 (7.5) |
| Positive "squish sign" (movement of echogenic particles in response to compression) | 2/40 (5) |
| Homogenous mass | 2/40 (5) |
| Heterogeneous mass | 1/40 (2.5) |

*POCUS*, point-of-care ultrasound.

## DISCUSSION

The importance of access to breast ultrasound in the ED has been described.[8,9] It is not uncommon for patients with breast pathology to present to the ED for an initial evaluation. The differential diagnosis for breast complaints is extensive, from trauma to infection and malignancy.[1,10] Prior literature has shown that breast pain is one of the most common breast complaints.[11,12] This is consistent with our study in patients presenting to the ED where a majority of the patients (57.5%) reported a complaint of breast pain, followed by patients presenting for evaluation of a palpable breast mass. While POCUS provides a potential answer for evaluating these patients, no prior literature exists on the use of this modality to evaluate breast complaints in the ED. For other applications, POCUS has already been found to play a critical role in screening for pathology and has several advantages over other imaging modalities. It is performed rapidly at the patient's bedside by the treating clinician and is relatively inexpensive. Additionally, POCUS can also direct healthcare providers to more appropriate imaging modalities and consultations, as was demonstrated in our study.

One of the most common uses of breast ultrasound is to identify a drainable fluid collection when infection with abscess is being considered. This is of utmost importance for patients who present to the ED, as breast abscesses are generally considered to be a diagnosis that requires prompt intervention and treatment[8,13] In our study, the majority of patients (57.5%) had either a simple or complex fluid collection found on

**Table 4.** Emergency department diagnosis.

| Diagnosis | N (%) |
|---|---|
| Abscess | 14/40 (50) |
| Cellulitis | 11/40 (27.5) |
| Mastitis | 7/40 (17.5) |
| Breast mass | 5/40 (12.5) |
| Breast pain | 5/40 (12.5) |
| Lipoma | 2/40 (5) |
| Breast wound | 1/40 (2.5) |
| Fibroadenoma | 1/40 (2.5) |

POCUS. Of these patients, 65.2% received a final diagnosis of a breast abscess. These patients went on to undergo a procedure in the ED, and many were started on a course of antibiotics.

In several cases, the POCUS findings led EPs to obtain a surgical consult**.** Confirming a drainable fluid collection can prevent patients from undergoing painful and unnecessary procedures. For example, a young, female patient presented to the ED with a complaint of apparent breast swelling and a tender mass palpated near the areola. To further evaluate whether this was a soft tissue infection or a drainable fluid collection, the physician performed a POCUS examination and instead found a solid, well-circumscribed mass (Image 1). As these findings were more consistent with a fibroadenoma, an incision and drainage was not performed and antibiotics were withheld. The patient was sent to the breast clinic where the diagnosis of a fibroadenoma was confirmed. In some cases, POCUS was also used for needle guidance and to assess for successful drainage.

Only two of the patients in whom an abscess was suspected based on POCUS findings received additional imaging through radiology, which may speak to the confidence that these physicians had in diagnosing this particular breast pathology. In both of these cases, the physician's original findings, which suggested a breast abscess, were confirmed with a radiology department breast ultrasound, and no new pathology was discovered. Findings were similar for patients in which cellulitis/mastitis was suspected based off a POCUS examination. The utility for POCUS in diagnosing skin and soft tissue infections is well documented.[14,15] However, its role in the evaluation of skin and soft tissue infections in the breast has been significantly less explored. Forty-five percent of the patients were diagnosed with cellulitis or mastitis based off of a POCUS exam, and as a result all of these patients received a course of antibiotics. Of the two patients who had follow-up imaging, there were no discrepancies between the results of the studies. In regard to evaluating patients with breast complaints for abscess or skin and soft tissue infections, POCUS proved to be useful in guiding patient management.

Of greater importance perhaps is not finding a definitive diagnosis, but rather ruling out diagnoses that require urgent intervention and knowing when to suspect a more ominous process that requires an urgent follow-up or consultation with a specialist. For example, a female patient in this study presented initially to the ED after palpating a tender mass in her breast. The EP performed a breast POCUS examination at this visit, which demonstrated an irregular, highly vascularized structure concerning for malignancy (Image 2). Based on this imaging, the patient was secured an urgent follow-up appointment with the breast surgery clinic where she received

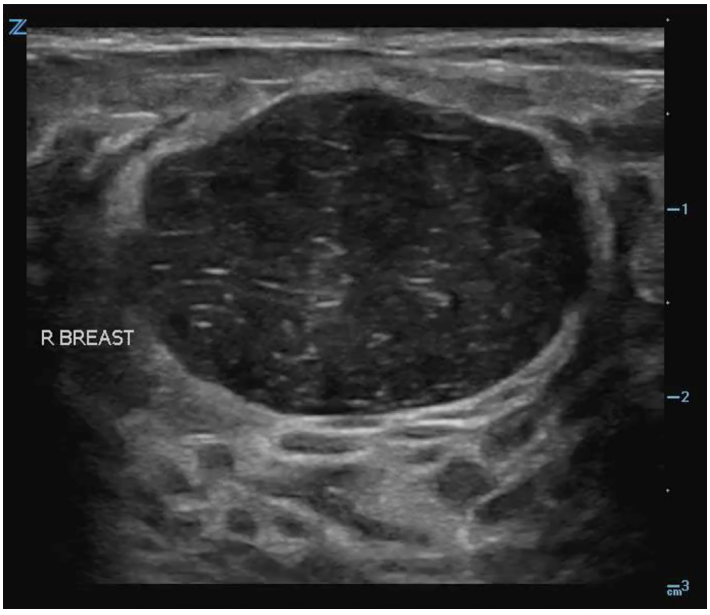


**Image 1.** Solid, well-circumscribed mass found on a breast point-of-care ultrasound examination, later confirmed to be a fibroadenoma.

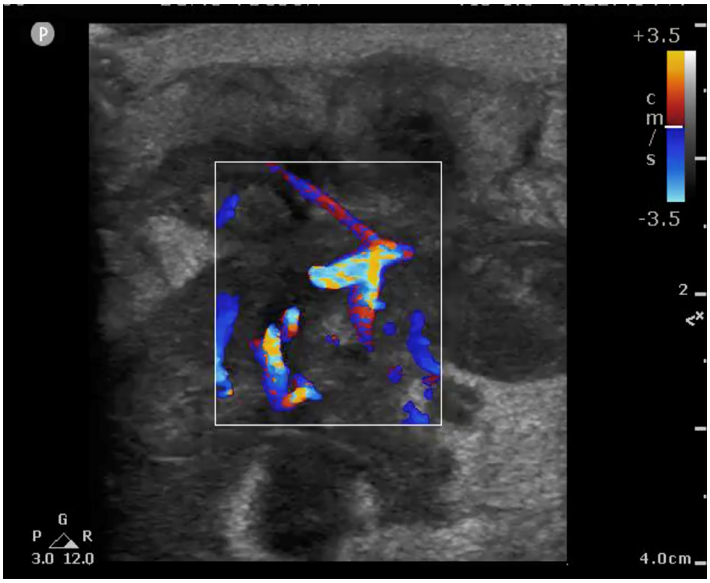


**Image 2.** Irregular, highly vascularized structure found on a breast point-of-care ultrasound examination concerning for malignancy, later confirmed to be invasive ductal carcinoma.

a biopsy confirming invasive ductal carcinoma.

Patients who present to the ED with breast symptoms are often worried that the underlying cause is due to a malignant process. Although most breast concerns have benign, easily treatable causes, breast cancer is the most commonly diagnosed cancer among women and the second leading cause of cancer death in women in the United States.[16,17] It is important that ED providers have an understanding of breast disease and have the ability to thoroughly evaluate and create an appropriate treatment plan.[18] Mammography is the most commonly used modality for breast imaging, especially when screening for malignancy; however, it is not a study that is readily available in the acute care setting. In the ED, ultrasound is more readily available and better tolerated by the patient. But while breast ultrasound might be the mainstay for imaging in the evaluation of the breast in this setting, it is more often performed and interpreted by the department of radiology. This study is unique in that both the examination and interpretation were performed by the treating physician.

In this study, the characteristics of those patients presenting with breast complaints were recorded. Half of the patients who presented had a history of skin or soft tissue infection. All of these patients went on to have findings of a skin or soft tissue infection on POCUS examination. This also held true for the vast majority of diabetic patients. It was also documented whether patients were postpartum or lactating. This represents another important population as breast tissue undergoes significant physiologic changes during pregnancy and lactation. The benign physiological changes that occur during this time naturally lead to a denser parenchyma on imaging. These changes are seen sonographically with fibroglandular tissue that is of mixed echogenicity and disruption of the layered architecture. Emergency physicians may not be as familiar with theses findings on a breast ultrasound.

There are a number of benign, treatable findings commonly seen in postpartum and lactating patients that physicians should be aware of; these include galactoceles, lactating adenomas, mastitis, and abscesses (Image 3),[19] all of which can be evaluated for in the ED using POCUS and guide further management. While approximately 80% of patients will have benign disease, it is important that EPs have the knowledge and ability to screen for more ominous processes in the ED setting.[20-23] In our study, the breast POCUS examination findings in postpartum and lactating patients may have assisted in the medical decision-making process. Consultations were called on 83% of these patients. Several were admitted, with one requiring a same- day visit to the operating room.

Less common patient characteristics were also documented. Charts were reviewed to identify all patients with breast implants, as they may have presented unfamiliar challenges when evaluating for pathology. While there appear to be few studies that evaluate the long-term complications of breast augmentation, some indicate up to a 24% complication rate.[24,25] The most common complication is pain but can also include infection and implant rupture. Prior studies have reported that ultrasound has a low sensitivity of 50-74% for detecting implant rupture, but suggest it may have a role as a screening modality.[25-27] Half of the patients with breast implants who received a breast POCUS exam received a follow-up radiology-performed breast ultrasound. This made up a third of all patients who received follow-up radiology-performed studies in our study. suggesting that perhaps EPs are uncomfortable with performing and interpreting a breast POCUS examination in a patient with implants. However, these patients made up a small percentage (10%) of the patient population, making it difficult to draw any significant conclusions. Similarly, for pediatric and male patients, the sample sizes were too small to be conclusive.

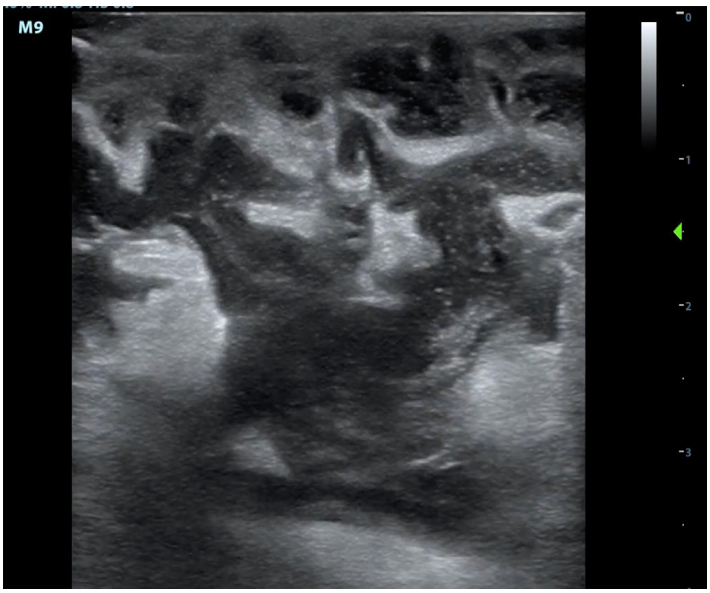


**Image 3.** Breast point-of-care ultrasound examination showing dilated lactating ducts with surrounding abscess that required surgical consultation and drainage.

## LIMITATIONS

This study has several limitations including its retrospective nature and the small sample size. This was not a multicenter study, which potentially limits the generalizability of our results. Another limitation of this study is the selection bias from the convenience sample design, since patients received a breast POCUS only when credentialed EPs were on duty. Additionally, it is likely that there were significantly more patient cases in which POCUS was used to assess a breast complaint, but images were not saved in the QPath database for reviewers to query. Therefore, we cannot say that this group accurately represented the full spectrum of patients presenting to the ED with breast complaints, limiting the generalizability of this study. The chart abstractor was not blinded to the study hypothesis and results; we attempted to reduce the bias in data collection by using a standardized data abstraction form.

Additionally, because there is also an emergency ultrasound fellowship program at this institution, the physicians are not only more experienced but also more driven to perform breast POCUS. Consequently, the practice patterns are not necessarily generalizable to the community ED. Further research showing the impact of breast POCUS is needed to support its application and fully realize its potential benefits on patient care in the ED. A prospective study design and further research that evaluates the diagnostic accuracy of breast POCUS for various pathologies would certainly add to the existing body of literature.

## CONCLUSION

Despite the limitations, our study findings illustrate the utility of point-of-care ultrasound in the evaluation of a variety of breast complaints in the ED. Our study suggests that breast POCUS has the potential to impact patient management in the diagnosis of pathology, in the performance of procedures, and in patient treatment and disposition.

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# Coding of Sexual Assault by Emergency Physicians: A Nationally Representative Study

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**Introduction:** Sexual assault is a public health problem that affects many Americans and has multiple long-lasting effects on victims. Medical evaluation after sexual assault frequently occurs in the emergency department, and documentation of the visit plays a significant role in decisions regarding prosecution and outcomes of legal cases against perpetrators. The American College of Emergency Physicians recommends coding such visits as sexual assault rather than adding modifiers such as "alleged."

**Methods:** This study reviews factors associated with coding of visits as sexual assault compared to suspected sexual assault using the 2016 Nationwide Emergency Department Sample.

**Results:** Younger age, female gender, a larger number of procedure codes, urban hospital location, and lack of concurrent alcohol use are associated with coding for confirmed sexual assault.

**Conclusion:** Implications of this coding are discussed. [West J Emerg Med. 2021;22(2)291-296.]

## INTRODUCTION

Sexual assault and rape remain public health and medical crises in the United States. Empirically documented correlates of sexual victimization include young age, female gender, childhood history of maltreatment, and substance use/abuse.[1] Approximately 20% of women and 2% of men experience rape at some point in their lives, accounting for an estimated 1.2 trillion dollars in direct medical costs and a total of 3.1 trillion dollars when lost productivity and other indirect costs are included (2014 US dollars).[2,3] Despite the deleterious and long-lasting physical and mental health conditions associated with rape and sexual assault, most of these assaults are never reported.[4-6] According to Kimerling, the under-reporting of sexual assault may be attributed to the "private, intimate nature of the assault and pervasive negative social consequences to disclosure."[7] While it is widely accepted that sexual assault and rape are under-reported, medical personnel, law enforcement, the legal system, and society are often skeptical when victims do come forward.

The current legal definition of rape stresses lack of consent and does not require the use of force,[8] and the medical literature is clear that the presence of associated injuries is not required to prove the occurrence of sexual assault.[9-12] The reported incidence of genital and other injuries associated with sexual assault is widely variable and depends on the methods used to detect injuries.[13] However, victims are more likely to report the sexual assault and law enforcement is more likely to pursue investigation if there are associated physical injuries.[14-16] Guidelines developed by the American College of Emergency Physicians recommend coding encounters as

"sexual assault" rather than using modifiers such as "alleged" or "rule-out" sexual assault.[17] Given the importance of medical documentation on future legal proceedings, we sought to determine factors that are associated with coding sexual assault vs alleged sexual assault.

*Population Health Research Capsule*

What do we already know about this issue?
*Guidelines for the care of sexual assault survivors recommend coding visits as "sexual assault" rather than modifiers that imply uncertainty.*

What was the research question?
*What factors are associated with coding of sexual assaults by emergency physicians?*

What was the major finding of the study?
*Less than half of sexual assault visits are coded as "confirmed." Demographic factors and alcohol abuse account for a small percentage of the variation.*

How does this improve population health?
*Sexual assault is underreported. Documentation that casts doubt on survivors may increase stigma, decrease engagement with follow up, and impede criminal justice proceedings.*

## METHODS

This study employed data from the 2016 Nationwide Emergency Department Sample (NEDS) of the Healthcare Cost Utilization Project (HCUP) distributed by the US Department of Health and Human Services Agency for Healthcare Research and Quality (AHRQ).[18-20] The NEDS includes data on approximately 33 million hospital-based ED visits from 953 hospitals approximating a 20% sample of US hospital-owned EDs. The sample is stratified by geographic region, trauma center designation, urban-rural location of the hospital, teaching hospitals, and hospital ownership. HCUP provides the hospital and discharge information necessary to calculate national estimates of ED visits, along with demographic information, reason for ED visit, and charge information. The analytic sample consists of individuals who were discharged from US EDs in 2016 with a diagnostic code of either suspected (n = 5948, weighted n = 26,421; 95% CI, 21,847-30,995) or confirmed sexual abuse (n = 5781, weighted n = 24,627; 95% CI, 21,254-28,000).

### Measures

*Confirmed Sexual Abuse*

Each record contained in the NEDS can include up to 30 *International Classification of Diseases, 10th Revision, Clinical Modification* (ICD-10-CM) (World Health Organization, 1993) diagnostic codes, each representing a different diagnosis. A single dichotomous code was used to identify cases with a diagnosis of confirmed sexual abuse (ICD-10-CM code T74.21).

*Suspected Sexual Abuse*

A single dichotomous code was used to identify cases with a diagnosis of suspected sexual abuse (T76.21).

*Patient Covariates*

Patient characteristics included age in years (>25, 26-35, 36-50, and >50), gender, ZIP code median household income quartile, and insurance status (Medicare, Medicaid, private, and self-pay, no charge, or other). As a marker for more severe injury, we also included the number and types of procedures coded on the patient's discharge record using the Common Procedural Technology (CPT) or Healthcare Common Procedure Coding System (HCPSC) collection of codes.

*Alcohol Use and Abuse*

Dichotomous variables (*yes*, *no*) were created for alcohol use and alcohol abuse diagnostic codes. Patients with the diagnostic code for alcohol use, unspecified (F10.9) were coded as having alcohol use. Patients were coded as having alcohol abuse if they had the F10.1 diagnosis code labeled alcohol abuse.

*Hospital Characteristics*

The hospital's urban-rural designation, trauma level, and teaching status were included in the analyses. The urban-rural status of a hospital is based on the county of the hospital identified by the American Hospital Association (AHA). Hospitals in large metropolitan areas with at least one million residents and those in small metropolitan areas were considered urban. Hospitals in micropolitan and non-urban residual areas were classified as rural in the present analyses. The hospital trauma level designation was obtained from the Trauma Information Exchange Program database. For this study, trauma center Level I or Level II were grouped as trauma centers, and non-trauma centers and Level III were considered non-trauma. Teaching status is classified by the AHA Annual Survey of Hospitals as metropolitan non-teaching, metropolitan teaching, and non-metropolitan hospital. For the present study, we combined metropolitan non-teaching and non-metropolitan hospital into a non-teaching group.

### Analyses

We conducted bivariate analyses to identify the prevalence of a diagnosis of confirmed sexual abuse or suspected sexual abuse among ED patients as well as provide

descriptive statistics for these individuals. Multivariate logistic regression was conducted to investigate sociodemographic and hospital-level differences between individuals with confirmed sexual abuse or suspected sexual abuse. The analyses were weighted to account for the NEDS complex sampling design using the *svyset* command and *svy* prefix in Stata 14.2 (StataCorp, College Station, TX).

## RESULTS

In 2016, there were approximately 26,421 adult discharges from EDs with a diagnostic code for suspected sexual abuse and 24,627 with confirmed sexual abuse. Table 1 presents estimates of the association between suspected sexual abuse and confirmed sexual abuse regarding key sociodemographic and hospital-level factors. With respect to age, those with confirmed sexual abuse were more likely to be younger than 25 compared to any other age group. With respect to gender, those with confirmed sexual abuse were significantly more likely to be female than male (odds ratio [OR], 1.18; 95% confidence interval [CI], 1.02-1.36); however, this difference is no longer significant when adjusting for sociodemographic and hospital factors. Individuals with confirmed sexual abuse are 28% less likely to be diagnosed with alcohol abuse than individuals with suspected abuse (adjusted OR [AOR], 0.72, 95% CI, 0.56-0.93); however, no significant difference was observed between the groups with regard to alcohol use. The number of CPT procedures appears to be slightly higher for individuals with confirmed sexual abuse. No differences were observed for ZIP code median household income quartile.

**Table.** Sociodemographic associations with suspected versus confirmed sexual abuse in United States emergency departments in 2016.

| | Diagnostic code | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Suspected sexual abuse (N = 5,948) | | Confirmed sexual abuse (N = 5,718) | | Unadjusted | | Adjusted | |
| | Row % | 95% CI | Row % | 95% CI | OR | 95% CI | OR | 95% CI |
| Age | | | | | | | | |
| <25 | 49.57 | [44.56-54.59] | 50.43 | [45.41-55.44] | 1.00 | - | 1.00 | - |
| 26-35 | 52.81 | [47.75-57.81] | 47.19 | [42.19-52.25] | **0.88** | **[0.78-0.99]** | **0.86** | **[0.76-0.97]** |
| 36-50 | 52.83 | [48.13-57.49] | 47.17 | [42.51-51.87] | **0.88** | **[0.78-0.99]** | **0.86** | **[0.76-0.97]** |
| >50 | 59.37 | [53.21-65.25] | 40.63 | [34.75-46.79] | **0.67** | **[0.56-0.81]** | **0.67** | **[0.56-0.81]** |
| Gender | | | | | | | | |
| Male | 55.50 | [49.95-60.91] | 44.5 | [39.09-50.05] | 1.00 | - | 1.00 | - |
| Female | 51.45 | [46.72-56.15] | 48.55 | [43.85-53.28] | **1.18** | **[1.02-1.36]** | 1.17 | [1.00-1.37] |
| Insurance status | | | | | | | | |
| Medicare | 57.13 | [52.22-61.90] | 42.87 | [38.10-47.78] | **0.74** | **[0.61-0.89]** | 0.84 | [0.68-1.04] |
| Medicaid | 49.55 | [45.87-53.23] | 50.45 | [46.77-54.13] | 1.00 | - | 1.00 | - |
| Private insurance | 51.90 | [47.59-56.18] | 48.10 | [43.82-52.41] | 0.91 | [0.78-1.06] | 0.89 | [0.75-1.05] |
| Other (self-pay, no charge, other) | 52.60 | [43.98-61.07] | 47.40 | [38.93-56.02] | 0.89 | [0.66-1.19] | 0.88 | [0.65-1.19] |
| Urban-rural | | | | | | | | |
| Rural | 60.67 | [54.98-66.09] | 39.33 | [33.91-45.02] | 1.00 | - | 1.00 | - |
| Urban | 49.95 | [44.54-55.37] | 50.05 | [44.63-55.46] | **1.55** | **[1.12-2.13]** | **1.59** | **[1.15-2.18]** |
| Alcohol use | | | | | | | | |
| No | 51.69 | [46.97-56.37] | 48.31 | [43.63-53.03] | 1.00 | - | 1.00 | - |
| Yes | 60.94 | [39.49-78.86] | 39.06 | [21.14-60.51] | 0.69 | [0.29-1.64] | 0.66 | [0.27-1.64] |
| Alcohol abuse | | | | | | | | |
| No | 51.45 | [46.64-56.23] | 48.55 | [43.77-53.36] | 1.00 | - | 1.00 | - |
| Yes | 59.61 | [54.09-64.88] | 40.39 | [35.12-45.19] | **0.72** | **[0.57-0.91]** | **0.72** | **[0.56-0.93]** |
| Mean number of CPT procedures (SD) | 5.62 (4.83) | | 6.05 (4.97) | | 1.02 | [0.99-1.04] | **1.03** | **[1.01-1.05]** |

Note: Odds ratios adjusted for age, gender, income, and location of hospital (urban or rural). Odds ratios and confidence intervals in bold are significant (P < 0.05).
*CI,* confidence interval; *OR,* odds ratio.

With regard to hospital-level characteristics, individuals with confirmed sexual abuse are significantly more likely to admit to an urban hospital compared to one in a rural area (AOR, 1.59; 95% CI, 1.15-2.18). Teaching status or trauma level of the hospital was not significantly associated with suspected vs confirmed sexual abuse.

## DISCUSSION

Using the NEDS database, we estimated there were 24,627 ED visits for confirmed sexual abuse and 26,421 visits for suspected sexual abuse in 2016, a total of 51,048 ED visits. In the same time period, there were 130,603 rapes reported to the Federal Bureau of Investigation.[21] The most recent National Intimate Partner and Sexual Violence Survey estimated that 1,484,000 women are raped annually.[22] In this context, we sought to determine factors that are associated with coding-confirmed sexual assault vs alleged sexual assault. We found that younger age, female gender, higher number of procedural services, urban hospital location, and lack of associated code for alcohol abuse were significantly associated with a code of confirmed sexual assault.

Regarding age, it is not necessarily surprising that individuals between the ages of 18-24 are more likely to receive a code of confirmed sexual abuse. Extant data suggest that most sexual assaults against females occur prior to the age of 25.[1] Furthermore, the age group of 18-24 is referred to as "emerging adults" characterized by significant life transitions including college attendance and/or entry into the workforce in addition to increased experimentation and participation in unsafe behavior (ie, substance use).[23-25] As a result, this age demographic is particularly vulnerable to both violence and substance use.[25] In recent years, sexual assault on college campuses has garnered significant national attention with increased media coverage and programming and services.[26,27] Provider willingness to code cases with younger victims as sexual assault rather than adding the modifier "alleged" may reflect awareness of and empathy for these vulnerabilities.

In this study, female victims were more likely to be coded as sexual assault than male victims, although this difference was not significant when adjusted for sociodemographic and hospital factors. This finding may be reflective of provider inexperience with sexual assault against males due to the small number of cases. Alternatively, it may be indicative of biases based on gender norms that stigmatize male victims. These biases may serve as barriers to male victims seeking care and perpetuate the myth that males are less likely to experience sexual assault.

Cases coded as confirmed sexual assault had slightly more CPT procedures than cases coded as alleged. However, supplemental analysis of the exact CPT codes used did not suggest more severe injuries in cases coded as sexual assault as billing level/medical complexity and procedures were similar between groups. Hospitals in urban areas were more likely to code for confirmed sexual abuse. Research suggests that rural areas have more geographic and economic barriers to seeking healthcare.[28,29] Furthermore, a lack of Sexual Assault Nurse Examiner (SANE)-trained nurses in rural areas has been empirically documented and may explain the difference in confirmed vs alleged sexual assault coding for sexual abuse between urban and rural hospitals.[30]

Sexual assault victims with a concurrent code for alcohol abuse were less likely to be coded as confirmed. Alcohol intoxication may cause impairment in the ability to give active consent to participate in sexual activity. Additionally, alcohol intoxication may increase uncertainty regarding the events surrounding the assault. Nevertheless, alcohol intoxication does not negate reports of sexual assault. Moreover, alcohol intoxication may lead to delayed presentation to the ED after an assault, for fear of not being credible or facing negative consequences (ie, underage drinking). Delayed help-seeking may affect victims' abilities to have crucial forensic evidence collected (ie, SANE exam).

This study suggests that slightly less than half of ED visits for evaluation after sexual assault are coded as "confirmed." Younger age, female gender, and urban location of hospital were associated with higher rates of coding as confirmed but ORs were low, and it is important to remember that false allegations of rape occur in 2-10% of cases, a rate similar to false reports for other crimes.[31,32] Given the importance of the medical documentation, it is crucial that the ED record reflect the events as reported by the victim, corroborated by physical exam findings when present. Only a small minority of victims present to the ED for evaluation after sexual assault, and a poor interaction with the healthcare system may adversely impact victims' future mental health as well as success of legal proceedings.[33,34]

Similar to findings in Rudman et al's work on coding of domestic violence, providers may be reluctant to code cases as confirmed sexual assault due to fears of stigmatizing the patient, unwillingness to commit to the diagnosis in face of uncertainty, or fear of medicolegal liability.[35] Inadequate experience with sexual assault victims and the forensic exam during residency training may also contribute to uncertainty as to proper coding.[36] This highlights the need for additional training regarding the importance of appropriate documentation and coding of sexual assaults. Directions for future research include qualitative studies of providers' rationale for their documentation and coding practices, evaluation of training programs intended to improve documentation, and use of telehealth to expand access to SANE programs.

## LIMITATIONS

The study relies on the NEDS database with the inherent limitations of use of administrative databases for research

purposes.[37-39] NEDS relies on complete and accurate coding by participating institutions but coding may be incomplete. Rates of diagnostic testing and screening may vary across providers and/or institutions. For example, providers may differ in their use of screening, brief intervention, and referral to treatment for at-risk alcohol use, which could affect the likelihood of being coded as alcohol use vs alcohol abuse. Information about the availability of SANE nurses is not included in the NEDS database and it was not possible to correlate coding to assessment by a SANE nurse.

We identified correlates to coding confirmed sexual assault but such associations cannot determine causality. Additional correlates that may predict providers' willingness to believe victims such as relationship of perpetrator to victim, provider gender, or confirmatory collateral history are not available from the database. Furthermore, data in the study are from 2016. Recent high-profile cases such as the Me Too movement and the outcry against lenient sentences imposed on perpetrators may have changed coding patterns.

## CONCLUSION

Our study underscores the necessity of accessible, accurate, and efficient ways to document sexual assault in EDs. Sexual assault is notoriously under-reported. Provider-level barriers coupled with the fast-paced nature of EDs may explain physicians' reticence to code for sexual assault. Healthcare systems need to develop policies and practices that support ED providers in screening, treating, and providing appropriate referrals for sexual assault, with concerted efforts toward male victims and victims under the influence of alcohol. Rural EDs may ED identification of sexual assault has the potential to link victims to community services through referrals to counseling, victim advocates, and legal services – services that have been empirically documented to improve psychological health and increase social support.

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# Emergency Medicine Intern Education for Best Practices in Opioid Prescribing

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**Introduction:** Opioid exposure has been identified as a contributing factor to the opioid epidemic. Reducing patient exposure, by altering heavy opioid prescribing patterns but appropriately addressing patient pain, may represent one approach to combat this public health issue. Our goal was to create and implement an opioid education program for emergency medicine (EM) interns as a means of establishing foundational best practices for safer and more thoughtful prescribing.

**Methods:** This was a retrospective study at an academic, urban emergency department (ED) comparing ED and discharge opioid prescribing practices over a 12-week time period for two 14-intern EM classes (2016 and 2018) to evaluate an early opioid reduction education program. The education program included opioid prescribing guidelines for common ED disease states associated with moderate pain, clinician talking points, and electronic education modules, and was completed by EM interns in July/August 2018. Opioid prescription rates per shift were calculated and opioid prescribing best practices described. We used chi-squared analysis for comparisons between the 2016 and 2018 classes.

**Results:** Overall, ED and discharge opioid orders prescribed by EM interns were fewer in the 2018 class that received education compared with the 2016 class. ED opioid orders were reduced by 64% (800 vs 291 orders, rate per shift 1.8 vs 0.7 orders) and opioid discharge prescriptions by 75% (279 vs 70 prescriptions, rate per shift 0.7 vs 0.2 prescriptions). The rate of prescribing combination opioid products compared to opioids alone was decreased for ED orders (32% vs 16%, $P < 0.01$) and discharge prescriptions (91% vs 74%, $P < 0.01$) between the groups. Also, the median tablets per discharge prescription (14.5 vs 10) and total tablets prescribed (4305 vs 749) were reduced, $P < 0.01$. There were no differences in selection of opioid product or total morphine milligram equivalents prescribed when an opioid was used.

**Conclusion:** An opioid reduction education program targeting EM interns was associated with a reduction in opioid prescribing in the ED and at discharge. This may be an effective way to influence early prescribing patterns and best practices of EM interns. [West J Emerg Med. 2021;22(2)297–300.]

## INTRODUCTION

Use of prescription opioids in the United States (US) has risen sharply over the past 20 years with sales nearly quadrupling from 1999 to 2014.[1] Similarly, rates of drug overdose deaths increased 140% over the time period 2000-2014 with those resulting from opioid overdose increasing from

about three to nine deaths per 100,000 persons.[2] Over 600,000 people have died as a result of drug overdose since 1996 with about two-thirds involving an opioid.[3] Understanding the role of overall opioid exposure in the population as a driving factor for the epidemic led to recommendations suggesting a focus on safer prescribing practices in the medical community.[2] Although clinicians are concerned about opioid misuse among patients, many also report lack of training regarding opioid prescribing and optimal pain management.[4]

Pain is one of the most common complaints among patients presenting to US emergency departments (ED) and is estimated to be reported by over 50% of patients.[5,6] The percentage of overall ED visits where any opioid analgesic prescribed increased from 20.8% in 2001 to 31% in 2010.[7] The development of chronic pain after an episode of acute pain is concerning as approximately 16% of patients receiving more than a one-week supply of opioids and 6% of patients receiving even a one-day supply reported continued use after one year.[8] Previous investigations have found a reduction in ED opioid use and prescribing after the implementation of formal programs aimed at this goal.[9-11] Recognizing the potential role of ED use/prescribing in the opioid epidemic and the impact that a formal program can provide, we assembled a pharmacist-led, interdisciplinary task force to create and implement an opioid reduction program with the goal of reducing ED opioid orders and discharge prescriptions by 30%. Using the tools from this program, we sought to evaluate the impact of early education incorporated into emergency medicine (EM) resident training on multimodal pain management and smart opioid use.

## METHODS

Our institution is an 886-bed academic, urban, tertiary care center with a 120-bed ED serving over 115,000 patients annually. An ED-focused opioid reduction program was developed and implemented in November 2017.[12] The program included opioid prescribing guidelines and evidence-based pathways for multimodal, stepwise pain management with opioid rescue for common ED disease states associated with moderate pain (musculoskeletal pain, back pain, renal colic, fractures, and headaches). The guidelines recommended morphine instead of hydromorphone or oxycodone for less euphoric effects, oral compared to intravenous opioids when possible, use of opioid agents alone compared to combination products (eg, opioid/ acetaminophen) for optimization of non-opioid adjuncts and more effective multimodal therapy, and no more than a three-day supply if prescribing opioids at discharge. We created talking points related to pain management and smart opioid use and smart phrases in the electronic health record (EHR) for use in the patient discharge summary. To educate current and new staff on the ED opioid reduction program and available materials, electronic education modules were created. Participants would review materials and presentations and then attest that they were reviewed (Table 1).

The EM medical residency program is a three-year program with 14 residents per class. Early in the 2018 education year (July/August), the EM intern class completed this education. To evaluate the impact of this early education, we conducted a retrospective study comparing ED and discharge opioid-prescribing practices for the 2016 and 2018 intern classes (before and after the ED opioid reduction program/ education). Data on opioids prescribed for ED administration or at discharge, including medication name, dose, route of administration, directions, and number of tablets (for discharge prescriptions) was extracted from our EHR for two 12-week time periods, August 12–November 4, 2016 and August 10–

**Table 1.** Opioid reduction education program for emergency medicine interns.

| Electronic Modules | Description |
|---|---|
| ED opioid guidelines | Restrict opioids to moderate/severe pain<br>Opioid risk assessment tool<br>Opioid adverse effects<br>Smart prescribing recommendations – preference of morphine instead of hydromorphone or oxycodone for less euphoric effects; oral instead of IV administration when possible; combination opioid/acetaminophen products not recommended when opioids are used; guidance for lowest effective dose and short treatment duration when discharge opioids are prescribed (3 days or less) |
| Multimodal pain management and disease-specific pathways | Emphasis on acetaminophen and ibuprofen/ketorolac around the clock with opioids as needed (if necessary) for acute pain management<br>Pathways for pain management of nephrolithiasis, fractures/joint dislocation, musculoskeletal pain, chronic abdominal pain/gastroparesis, migraine/headache with non-opioid alternatives and opioid rescue |
| Talking points | Useful phrases to aid in patient and family member discussions related to optimal pain management, risks of opioids, and ED pain plan |
| Lidocaine IV and ketamine IV presentations | Focus on the rationale for use, available literature, indications, dose and administration, and monitoring |

*ED,* emergency department; *IV,* intravenous.

November 2, 2018. From this report, we extracted opioids prescribed by EM interns from the 2016 and 2018 classes.

We used intern schedules to identify shifts worked to calculate prescribing rate. A rate of opioids prescribed per shift was calculated for both ED opioid orders and discharge prescriptions. We used a rate since each intern worked a different number of shifts during the time period. Additional analyses on the prescribing of hydromorphone or oxycodone compared to morphine, total morphine milligram equivalents (MME) prescribed, combination products compared to opioids alone, and number of tablets provided at discharge were compared. We used chi-squared analysis to compare the 2016 and 2018 groups for all endpoints. A *P*-value of $< 0.05$ was considered statistically significant, and all analyses were completed using SAS version 9.4 (SAS Institute, Inc., Cary, NC).

## RESULTS

A total of 28 EM interns were included in the study (14 in each class). Demographic information and shifts worked were similar between the two classes (Table 2). Overall, ED opioid orders were reduced by 64% (800 vs 291 orders, rate per shift 1.8 vs 0.7 orders) and opioid discharge prescriptions by 75% (279 vs 70 prescriptions, rate per shift 0.7 vs 0.2 prescriptions). The rate of prescribing combination products compared with opioids alone was significantly decreased for ED opioid orders (32% vs 16%, $P < 0.01$) and opioid prescriptions at discharge (91% vs 74%, $P < 0.01$) between the 2016 and 2018 groups. Also, the median tablets per discharge prescription were decreased (14.5 vs 10), and total tablets prescribed were reduced by 83% (4305 vs 749) in the study period. There were no differences in hydromorphone/oxycodone prescribing compared to morphine or total MME prescribed when an opioid was ordered.

## DISCUSSION

These data suggest several positive results with education targeting EM interns and influence on opioid prescribing patterns. Specifically, education modules with learning points directly focused on prescribing opioids alone, when needed, compared to a combination product to allow optimization of acetaminophen alone correlated with a reduction in combination product use. We also found substantial reductions in both the number of opioid prescriptions at discharge and median tablets per discharge prescription. This equates to less frequent, shorter courses of opioid analgesics for patients returning to the community and reduces exposure harm that may lead to increased risk of habit formation inherent with more prolonged use.[4,8-11] Fewer tablets available in the community may also decrease the incidence of pill diversion. The lack of notable reduction in hydromorphone and oxycodone prescribing compared to morphine or total MME prescribed, if an opioid was ordered, might be explained by the clinical complexity of the patients seen in our ED, pre-existing comfort of clinicians with certain opioids and doses, or saved EHR preferences.

To our knowledge, this is the first report evaluating focused education at the beginning of medical residency training on actual practice changes and the only one to describe EM trainees. Other reports surveyed surgery or ophthalmology trainee opioid and pain management prescribing practices, perceived influences, and knowledge of prescribing resources.[13-16] Additionally, one report evaluated surgical resident prescribing practices via survey immediately before and after a one-hour didactic training focused on opioid prescribing best practices that found trainees answered with more non-opioid pain management options and reduced tablets prescribed when an opioid was selected to be used.[17]

**Table 2.** Emergency medicine intern demographic information.

| Demographic Variable | 2016 (n = 14) | 2018 (n = 14) |
|---|---|---|
| Age, mean years ± SD | 29.6 ± 4.4 | 29.0 ± 2.1 |
| Gender, No. male (%) | 8 (57) | 9 (64) |
| Degree | | |
| MD, No. (%) | 12 (86) | 12 (86) |
| DO, No. (%) | 2 (14) | 2 (14) |
| Medical school in the United States, No. (%) | 14 (100) | 13 (93) |
| Total ED shifts worked during the study period, No. | 447 | 417 |

*SD,* standard deviation; *MD,* doctor of medicine; *DO,* doctor of osteopathic medicine; *ED,* emergency department.

## LIMITATIONS

One potential limitation is that prescribing changes may have occurred in the setting of the larger landscape of the opioid epidemic, which had come much more into the public eye over the study period. Thus, it is possible that incoming interns in the second cohort (2018) were exposed to external factors that may have influenced their perceptions related to ED pain management and the use of opioid analgesics. We do not speculate there were other influences on the opioid prescribing differences seen between the 2016 and 2018 EM intern classes, as the EM intern learning environment was unchanged. Specifically, staffing patterns in the ED, patient population, number of patients seen/hour, and general patient demographic for whom they were providing care were unchanged over the two-year study period. It is possible that the EM attending prescribing practice changes did influence EM intern prescribing. However, the EM attending is not required to approve ED orders or discharge prescriptions written by EM interns for controlled or non-controlled substances. Although there is a discussion regarding the pain management plan, it is the EM interns who determine the agent(s) prescribed, route of administration, dose, directions, duration, and total tablets prescribed.

Other potential limitations include the number of study subjects, as this was limited by EM intern class size; potential

regional differences in prescribing patterns as these data are from a single medical center; and the fact that chart abstractors were not blinded to the study hypothesis. Also, the study was not designed to evaluate different educational methods or which methods were most effective. Lastly, the greatest impact on prescribing practices may have occurred immediately following education. It it is unclear whether this effect was sustained over time based on the study period.

## CONCLUSION

Early opioid reduction education to EM interns is associated with significant decreases in initial opioid prescribing practice patterns in the ED and at discharge. The use of opioid/acetaminophen combination products and median number of tablets per opioid discharge prescription were also reduced. An opioid reduction education program could be a low-cost, impactful adjunct to early EM intern training to influence prescribing best practices both in the ED and at discharge.

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# Types and Timing of Teaching During Clinical Shifts in an Academic Emergency Department

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**Objectives:** Academic emergency physicians must find ways to teach residents, medical students, and advanced practice providers amidst the myriad demands on their time during clinical shifts. In this study, we sought to characterize in detail what types of teaching occurred, how often they occurred, and how attending teaching styles differed at one academic emergency department (ED).

**Methods:** We conducted this observational study in a large, urban, quaternary care, academic Level I trauma center with an emergency medicine (EM) residency. The on-shift activities of EM attending physicians (attendings) were observed and recorded over 42 hours by a fourth-year EM resident with co-observations by an EM education fellow. Teaching categories were identified, developed iteratively, and validated by the study team. We then characterized the distribution of teaching activities during shifts through the coding of attending activities every 30 seconds during observations. Teaching archetypes were then developed through the synthesis of notes taken during observations.

**Results:** Attendings spent a mean of 25% (standard deviation 7%) of their time engaging in teaching activities during shifts. Of this teaching time 36% consisted of explicit instruction, while the remaining 64% of teaching occurred implicitly through the discussion of cases with learners. The time distribution of on-shift activities varied greatly between attendings, but three archetypes emerged for how attendings coupled patient care and teaching: “in-series”; “in-parallel modeling”; and “in-parallel supervision.”

**Conclusions:** Teaching in this academic ED took many forms, most of which arose organically from patient care. The majority of on-shift teaching occurred through implicit means, rather than explicit instruction. Attendings also spent their time in markedly different ways and embodied distinct teaching archetypes. The impact of this variability on both educational and patient care outcomes warrants further study. [West J Emerg Med. 2021;22(2)301-307.]

## INTRODUCTION

Emergency physicians (EP) face myriad demands for their time on shift, including evaluating patients, performing procedures, reviewing charts, communicating with team members, and documenting in the health record. In academic emergency departments (ED), responsibilities for part of these tasks are shifted to residents, medical students, and advanced practice providers. However, attendings in academic departments are also expected to teach and supervise, creating different and additional demands for their time. Prior research suggests that attendings work just as quickly when paired with medical students and may actually see more patients per hour when working with residents.[1-4] As technology – particularly electronic health records – re-shapes how physicians practice,[5] it is important to understand how on-shift teaching fits into the other activities expected of today’s academic EP.

Prior studies have described the proportion of time that physicians spend on patient care, documentation, and other activities in both community and academic EDs. Academic attendings have been reported to spend anywhere from 6-20% of their shifts teaching.[6,7] However, the definition of teaching in these studies has either been limited in description or defined as all conversations between attendings and learners. While the raw amount of time attendings spend with residents does appear to affect resident learning experience on shift,[8,9] this cannot capture the complex nature of on-shift education in the ED. Indeed, widely varying methods by which expert attendings teach during busy shifts have been described.[10,11] The optimal mode of education in chaotic emergency medicine (EM) environments remains unknown; a more nuanced account of how teaching currently occurs in academic EDs is needed to lay the groundwork for the future study of educational efficacy during shifts.

In this study, we sought to characterize in detail how teaching occurred in one academic ED. We aimed to describe the different forms of teaching that took place during shifts, as well as how teaching interacted with the other activities expected of academic attending physicians. We set out to do this through detailed observations of attending physicians involving quantitative assessments of activity frequencies and qualitative development of teaching-style archetypes.

*Population Health Research Capsule*

What do we already know about this issue?
*Academic emergency physicians (EP) use many techniques to teach during shifts and must balance teaching with other tasks.*

What was the research question?
*How much do academic EPs teach during shifts, what types of teaching occur, and how is teaching paired with clinical care?*

What was the major finding of the study?
*Attendings devoted 25% of their time during shifts to teaching, most of which was implicit through case discussion. Three teaching archetypes were identified.*

How does this improve population health?
*Effective on-shift teaching is essential for training the next generation of EPs. Understanding when and how teaching occurs can help to improve trainee education.*

## METHODS

### Setting

This observational study was conducted in a large, urban, quaternary care, academic Level I trauma center, with an EM residency. It was considered quality improvement by the institutional review board and therefore exempt from review. All observations were conducted in the 25-bed critical care area of the ED. This area sees an average of 52 patients per day; 60% of these patients are admitted. The area is supervised by one attending EP at all times of day, with varying levels of staffing by residents and physician assistants depending on time of day. There is always at least one senior resident working in this area, and there is usually at least one junior resident as well. The levels of additional trainees on shift vary from intern to senior resident; there is nearly always a mix of trainee levels present, but the particular combination changes day to day.

### Data Collection

The primary mode of data collection was direct observations of attending physicians during shifts. The primary observer was a fourth-year EM resident. A total of 42 clinical hours were observed in 10 four-hour blocks and one two-hour block. All observed shifts took place on weekdays, and observation blocks were either 10 AM-2 PM or 3 PM-7 PM (plus one 12-2 PM block), with a near-even distribution between the times. These periods were chosen because they generally have high patient arrival rates, exemplifying the need for attendings to use their time thoughtfully. One attending was observed in each period, and 10 different attendings were observed over the course of the 11 observation blocks (one attending was observed twice).

At the outset of each observation, the primary observer obtained verbal assent from each attending. During assent, attendings were told that their activities would be observed and recorded in writing. Attendings were not informed of the study goals and did not know that educational activities were an outcome of interest. The observer then recorded the activities of the attendings in 30-second increments by writing down each observed activity on a paper template with a line for every 30-second period. If more than one activity occurred in a 30-second period, the dominant activity was recorded. For activities involving an interaction with a learner, the role of the learner was also recorded (learners were defined as either medical students, residents, or physician assistants in this study).

### Defining Activity Categories

We categorized attending activities into teaching and non-teaching-related subcategories. The activity categories were developed iteratively over the course of two observation periods; an initial coding scheme was created based on presupposed categories, and then modified based on actual observed activities. These coding categories were further

refined through iterative discussion by study team members (all of whom are EPs), and then validated through observation by a second observer.

**Assessing Inter-rater Reliability**

The second observer (an EM education fellow) joined the primary observer for two two-hour co-observations sessions to validate the activity codes. During these sessions, each observer independently recorded the activities observed every 30 seconds, choosing from among the previously agreed-upon categories and definitions. Subsequently, observations were compared by 30-second increment, and a Cohen's kappa statistic was calculated to assess inter-rater reliability.

**Developing Archetypes with Flow Diagrams**

In addition to assigning activity categories, the primary observer also took notes during observations on the teaching styles of the observed attendings. During observations it became apparent that different attendings used distinct strategies for coupling teaching and patient care. Using field notes, the primary observer identified three archetypes that encompassed most attending teaching behavior. These archetypes were refined with the second observer and then with the study team. Flow diagrams were created to demonstrate the pattern of teaching and patient care observed with each archetype.

**Outcomes**

The primary outcome was the percentage of time attendings spent in total on the various types of teaching during shifts. The average amount of time spent by attendings on each specific type of teaching was characterized using the teaching categories and coding strategy described above. We also calculated the amount of time spent on other activity categories by similar means. In addition, a box plot was created in the open source statistical program R Studio v1.2.5001 (Boston, MA) to demonstrate the variability in activity distribution across the attending physicians observed. We also assessed the amount of time spent teaching residents vs physician assistants by calculating and comparing the amount of observed teaching time conducted with each type of learner.

## RESULTS

**Inter-rater Reliability**

The two observers achieved a kappa of 0.89. Inter-rater agreement was 90% among the 30-second increments that at least one observer labeled as a teaching activity. Among instances of disagreement, 43% were due to disagreement over the start and end points for an activity, as opposed to how the activity was coded. In 20% of disagreements observers concurred that teaching was occurring, but they disagreed on the teaching subtype. Finally, 37% of disagreements involved the observers coding 30-second increments as entirely different activity categories; 75% of these involved one observer coding an action as a teaching activity when the other observer did not.

**Primary Outcomes**

Overall, teaching activities comprised a mean of 25% (standard deviation [SD] 7%) of attendings' time during the observed periods of this study. We identified two principal categories of teaching: explicit and implicit, with 36% of total teaching time categorized as explicit, and 64% implicit. Implicit teaching occurred through back-and-forth discussions of patient cases with learners but did not involve the attending expressly providing new medical information in a didactic teaching format to the learner, nor clear instruction in how they would proceed in a given case. Often this kind of teaching consisted of asking questions or exploring alternative diagnoses and was observed to blend in with the management of patient care. Explicit teaching occurred when the attending clearly made education the main intent of their words or actions, eg, providing novel information from a recent study to the learner, describing their own personal approach to a difficult situation, or instructing the learner in how to perform a procedure. This explicit teaching was generally observed to be identifiably separate from the routine management of patient care.

Within explicit teaching, four subcategories were identified: case-based teaching; procedural teaching; bedside teaching; and topic-based teaching. Final teaching-related and non-teaching activity subcategories are displayed in Tables 1 and 2, respectively. Case-based teaching was the most common, comprising 52% of explicit teaching. Topic-based teaching was relatively rare, comprising 7% of explicit teaching. See Table 3 for further time breakdown by explicit teaching category.

While the above statistics represent averages, marked variability was observed in the amount of time that different attending physicians spent on teaching activities and all other activities; explicit teaching constituted anywhere from 3-24% of time on shift, while total teaching (implicit and explicit combined) ranged from 17-40% of on-shift time. See Figure 1 and Table 4 for graphical and numerical depictions of activity variability by attending.

**Teaching Archetypes**

Three main archetypes emerged for how attendings coupled patient care and education, with flow diagrams of each depicted in Figure 2. While no attending used exclusively one archetype throughout an observation period, all of them had a dominant style that they employed most of the time. We labeled the three identified archetypes as "in-series," "in-parallel with supervision," and "in-parallel with modeling." The difference between in-series and in-parallel was whether attendings saw patients separately from learners (in-series) or simultaneously with learners (in-parallel).

"In-series" describes a style where attendings let the

learner see a patient first, received a presentation on the case, and then saw the patient separately. This approach often led to implicit teaching during the presentation, followed sometimes by explicit teaching once the attending had seen the patient. This "in-series" style was used in about 40% of total patient encounters throughout the observations, and three of the attendings observed displayed this archetype predominantly.

"In-parallel" approaches were used in approximately 60% of patient encounters and could be enacted in a "supervision style" or a "modeling style." Supervision involved quietly observing as the learner engaged with the patient, interjecting only occasionally as needed to ensure adequate clinical care. Modeling involved the attending engaging directly with the patient and executing most of the history and physical while the learner observed. The in-parallel style was much more likely to involve bedside teaching than the in-series style. Four attendings primarily used in-parallel supervision, while three attendings primarily used in-parallel modeling.

**Time with Residents vs Physician Assistants**

On average, residents spent 3.1 minutes per hour receiving any type of teaching from an attending, while physician assistants spent 2.3 minutes receiving any type of teaching from an attending. Of note, while residents and physician assistants were staffed relatively evenly over the observed time periods (55% residents, 45% physician assistants), over 75% of explicit teaching time was directed toward residents.

**Other Activities**

Across observations, attendings spent a mean of 32% (SD 9%) of their time on direct patient care, 12% (SD 8%) on documentation, 7% (SD 6%) socializing or taking breaks, and 6% (SD 2%) on chart review (Table 5). Attendings saw a median of 2.9 (SD 0.59) patients per hour and spent a median of 5.8 (SD 2.6) minutes in each new patient's room.

**Table 1.** Activity categories recorded for attending interactions with learners.

| |
|---|
| Implicit teaching: |
| Case discussion: The attending actively engages the learner in discussion about a case with back-and-forth conversation, but without didactically imparting new knowledge or providing clear instruction on topics related to a case. |
| Explicit teaching: |
| Case-based teaching: The attending provides clear didactic instruction using content of a case, novel information pertaining to a case, or a description of how they would personally handle a case. |
| Bedside teaching: The attending provides clear educational instruction to the learner at the patient's bedside using the content of the patient's presentation and/or physical exam findings. |
| Procedural teaching: The attending directly teaches and supervises a learner in how to perform a bedside procedure, including ultrasound. |
| Topic-based teaching: The attending provides formal didactic education to a learner about a topic not related to a case seen with that learner. |
| Not considered teaching: |
| Case listening: The attending purely listens to a case presentation from a learner without giving any input. |

**Table 2.** Activity categories recorded for attending activities not involving learners.

| |
|---|
| Documenting: Attending inputs data into the medical chart or dictates to a scribe. |
| Chart review: Attending looks at patient data on the computer or asks a scribe to read data from computer. |
| Initial patient care: The first time the attending enters the patient room. (It was also documented whether the attending saw patients alongside residents or independently.) |
| Re-evaluation patient care: Subsequent times the attending enters a patient room. |
| Emergency medical services' (EMS) report: Attending listens to EMS calls. |
| Break: Attending takes personal time, including using personal phone, e-mail, eating, using restroom. |
| Socializing: Attending speaks with team members about topics unrelated to medical care. |
| Sign-out: Attending takes sign-out from oncoming team. |
| Walking: Attending walks between ED locations while not engaged in another activity. |
| Phone call: Attending is on the phone with consultants or other hospital staff. |
| Team communication: Attending speaks with members of the team other than residents or advanced practice providers (eg, nurses, techs, pharmacists). |

*ED*, emergency department.

**Table 3.** Percentage of total explicit teaching time spent on different teaching subcategories.

| Explicit teaching category | Percentage |
|---|---|
| Case-based | 52% |
| Bedside | 22% |
| Procedural | 18% |
| Topic-based | 7% |

## DISCUSSION

In this academic ED, attending physicians spent 25% of their time on activities involving teaching, with 9% of total time spent on explicit teaching. When explicit teaching occurred, it was most often case-based, followed by bedside and procedural teaching; formal topic-based teaching was rare in our setting. The majority of teaching was implicit, with important lessons transmitted through questions asked and discussions initiated in the normal flow of managing patient care. These conversations did not involve the explicit didactic transmission of new knowledge, but they did provide learners with opportunities to observe how attendings thought about cases, what information attendings found most pertinent, and other implicit features of how attendings approached their work as EPs.

While it was clear to the observers that implicit teaching held potential educational value for learners, it is not known whether attendings or learners experienced these interactions as "teaching." Studies evaluating the aspects of clinical teaching most valued by residents suggest that these characteristics will evolve over the course of residency.[12,13] Previous clinical experience may therefore influence which archetypes learners perceive to be teaching vs supervision without educational value. Our study was not designed to elucidate this nuance, but it will be important for future work to assess perceptions of both attendings and learners about the types of education that occur during shifts.

Our data show there are many ways to structure an attending's time during an academic ED shift; consistent with prior research on EP tasks, there was marked variability in the distribution of both teaching and non-teaching activities between attendings in our study.[14] However, we know relatively little about how the mix of activities chosen by attendings may affect educational quality, documentation quality, and perhaps even patient care quality. At minimum, prior work suggests that the need to manage multiple ED patients in a short period has an impact on bedside teaching, an important part of the "in-parallel" archetype.[15] Future research might further explore the impact on various outcomes of how academic EPs spend their time during shifts.

Attendings also differed in their approach to integrating education and patient care, which in turn affected the types of teaching that occurred. Attendings and learners saw patients either "in parallel" or "in series," with two versions of "in parallel" observed: "supervision" and "modeling." While the level of the learner and the nature of the case may have affected the style chosen, it became clear that most attendings gravitated to one archetype regardless of other factors. Prior research does suggest that as the acuity of patient cases rises, attending's choice of educational strategy narrows;[16] it is, therefore, possible that our critical care area setting influenced the pattern of archetypes we observed.

The archetype embodied by an attending likely affects the experience of the learner, the experience of the patient, and the experience of the attending in providing care. With the "modeling" strategy, learners may benefit from observing how attendings interact with patients but miss out on opportunities for developing autonomy. With this style, the attending can engage with patients themselves, and patients receive care directly from the attending. "Supervision" allows the learner to practice their patient care skills directly and in the best-case scenario, provides an opportunity for the attending to give the learner feedback and conduct resident milestone assessments required by the Accreditation Council for Graduate Medical Education.[17] However, the attending

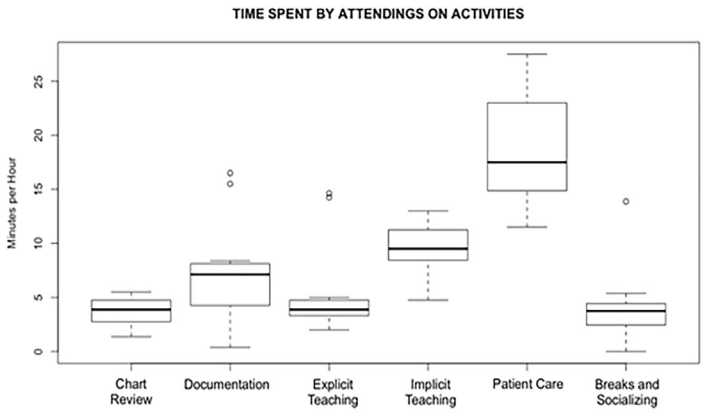


**Figure 1.** Box plot for the distribution of on-shift activities across observations. Bold lines represent median values, solid boxes delineate 25th-75th percentiles, dotted lines delineate the full data range, and circles represent outliers. N = 11.

**Table 4.** Variability in how attendings spent time on shift, with the range between extremes for each activity category.

| Activity | Range of minutes/hour |
|---|---|
| Explicit teaching | 2-15 |
| Implicit teaching | 7.8-19 |
| Direct patient care | 11.5-25 |
| Documentation | 1-16.5 |
| Chart/Data review | 1.3-5.5 |
| Breaks/Socializing | 0-13.8 |

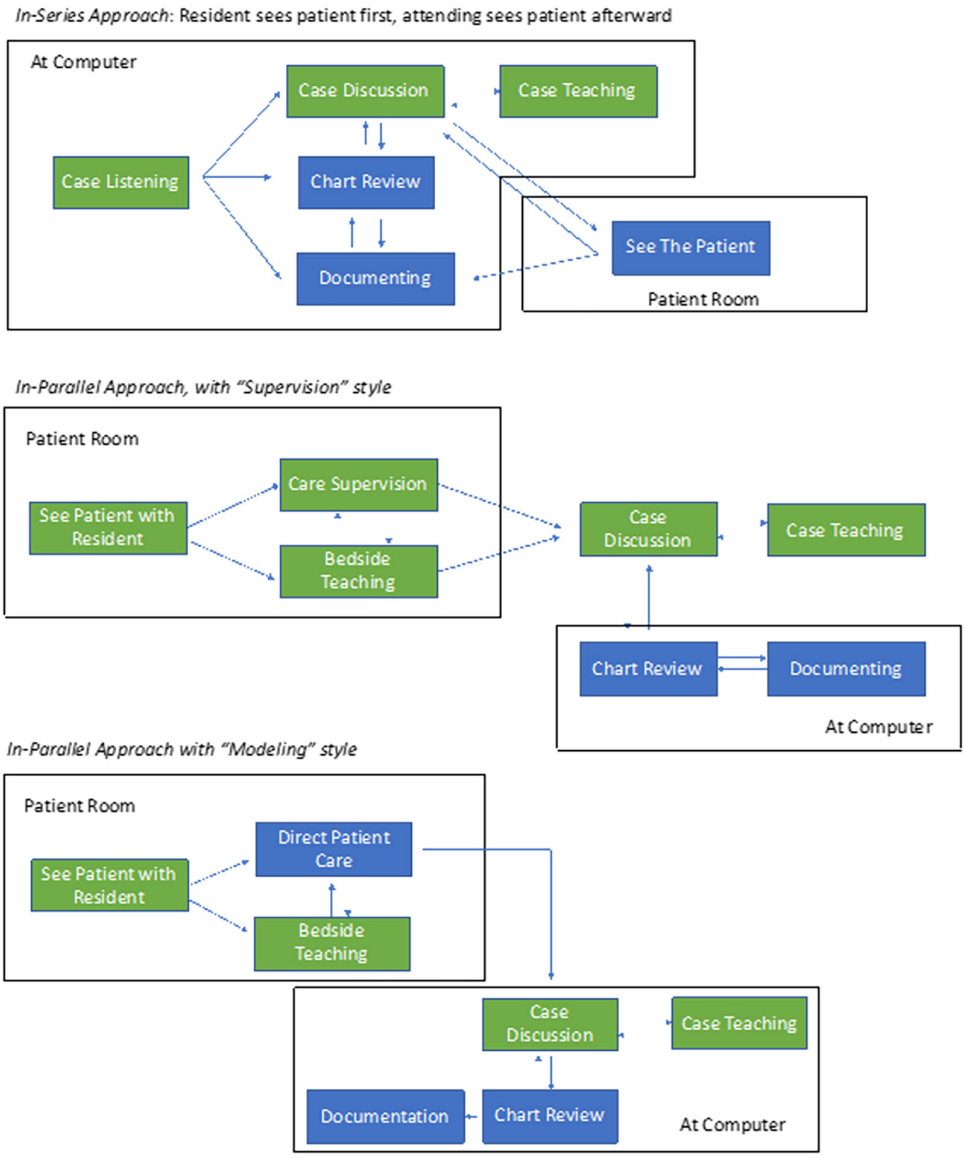


**Figure 2.** Flow diagrams for the three archetypes for how attending physicians see patients and incorporate education. Blue boxes delineate solo activities; green boxes delineate teaching activities.

engages minimally with the patient directly in this style, and the patient interacts mostly with a learner. "In-series" patient care allows learners more independence, which may have its own educational advantages. The attending is also able to engage with the patient directly, but patients must tell their story twice. Each style therefore likely has advantages and disadvantages for education, attending experience, and patient experience. A recent study on "swarming," which maps to the "in-parallel" archetypes here, suggests the practice can have efficiency and educational benefits in a pediatric ED.[18] The impact may be different in the adult ED environment, and the way an attending leads the "swarm" likely matters. Future research might examine the relative effects of the archetypes we observed on educational and patient care outcomes.

## LIMITATIONS

This was a single institution study. Observations occurred only on weekdays at specific times in an acute care area of the ED; time spent on teaching and other activities may have varied at different times of day, on weekends, and with different mixes of cases. Our results were likely affected by the particular ratio of attending to learners in our setting, as well as expectations around patient volumes seen by our attendings; this may limit generalizability to other settings with different staffing structures and expectations. While we observed varied teaching methods, we were not able to assess teaching effectiveness or how learners perceived the educational value of different methods. We were also unable to assess why attendings structured their time in the different ways that we observed.

**Table 5.** Activity distribution for on-shift activities. No standard deviation listed for "Other" as the relative composition of this category varied between observations.

| Activity | Avg min per hour (SD) | Percentage |
|---|---|---|
| Explicit teaching | 5.5 (4.4) | 9% |
| Implicit teaching | 9.6 (2.3) | 16% |
| Direct patient care | 18.9 (5.6) | 32% |
| Documentation | 7.5 (5) | 12% |
| Chart/Data review | 3.6 (1.3) | 6% |
| Receiving sign-out | 3.6 (1.5) | 6% |
| Breaks/Socializing | 4.2 (3.6) | 7% |
| Other (EMS calls, case listening, phone calls, speaking with consultants, walking, team communication) | 6 | 10% |

*Avg*, average; *min*, minute; *SD*, standard deviation; *EMS*, emergency medical services.

## CONCLUSION

Attending physicians in this academic ED spent a quarter of their time teaching, most of it through implicit means. Attendings varied widely in how they spent time during shifts but fit into three distinct archetypes of how education was structured in relation to patient care. Future research should examine the impact of these choices and archetypes on educational and patient-related outcomes.

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# Effect of Implementation of HEART Chest Pain Protocol on Emergency Department Disposition, Testing and Cost

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**Background:** Symptoms concerning for acute coronary syndromes (ACS) such as chest pain and dyspnea are some of the most common reasons for presenting to an emergency department (ED). The HEART score (history, electrocardiogram, age, risk factors and troponin) was developed and has been externally validated in an emergency setting to determine which patients with chest pain are at increased risk for poor outcomes. Our hospital adopted a HEART score-based protocol in late 2015 to facilitate the management and disposition of these patients. In this study we aimed to analyze the effects of the adoption of this protocol. Prior studies have included only patients with chest pain. We included both patients with chest pain and patients with only atypical symptoms.

**Methods:** This was a retrospective chart review of two cohorts. We identified ED charts from six-month periods prior to and after adoption of our HEART score-based protocol. Patients in whom an electrocardiogram and troponin were ordered were eligible for inclusion. We analyzed data for patients with typical symptoms (chest pain) and atypical symptoms both together and separately.

**Results:** We identified 1546 charts in the pre-adoption cohort and 1623 in the post-adoption cohort that met criteria. We analyzed the first 900 charts in each group. Discharges from the ED increased (odds ratio [OR[1.56, P<.001), and admissions for cardiac workup decreased (OR 0.46, P <.001). ED length of stay was 17 minutes shorter (P = .01). Stress testing decreased (OR 0.47, P<.001). We estimate a cost savings for our hospital system of over $4.5 million annually. There was no significant difference in inpatient length of stay or catheterization rate. When analyzing typical and atypical patients separately, these results held true.

**Conclusion:** After adoption of a HEART score-based protocol, discharges from the ED increased with a corresponding decrease in admissions for cardiac evaluations as well as cost. These effects were similar in patients presenting without chest pain but with presentations concerning for ACS. [West J Emerg Med. 2021;22(2)308-318.]

## INTRODUCTION

Acute coronary syndromes (ACS) include myocardial infarction and unstable angina. The most common symptoms in ACS include chest pain, dyspnea, fatigue, and weakness.[1] These symptoms are common reasons for presentation to emergency departments (ED). Chest pain itself accounts for

approximately 8-10% of ED visits each year nationwide for adults aged 15 years and older.[2] Ruling out acute myocardial infarction is generally straightforward, but subsequently identifying which patients are at risk for having a major cardiac event in the near future and arranging appropriate access to further screening can be costly, challenging, and risk prone.[3,4] For chest pain patients, the American Heart Association's 2010 guidelines recommend stress tests to be completed in the first 72 hours of the patient's visit. No formal guidance exists for patients with atypical symptoms.[5] This requirement has led to a high number of inpatient stays for cardiac observation and risk- stratification testing with an associated financial burden.[4]

In a study by DeVon et. al, 65-74% of patients with ACS reported chest pain; of those, only 43-53% reported chest pain or discomfort as a chief complaint.[1] The HEART score was developed for use in an emergency setting for patients presenting with chest pain. The score has been prospectively and externally validated and is widely used to aid in risk stratification and to safely reduce unnecessary inpatient resource utilization.[6-8] A score is calculated from its component elements: history, electrocardiogram [ECG], age, risk factors, and troponin.[9]

The HEART score attempts to distinguish low-risk patients who can be safely discharged from the ED, from patients at a higher risk for a major cardiac event (MACE) defined as death, non-fatal myocardial infarction (MI), or revascularization procedure within a six-week period. The HEART score has been shown to be equal or superior to other scoring systems such as TIMI or GRACE.[10] The HEART score consists of five factors, each assigned a score of 0, 1, or 2 points; the sum of all five comprises the HEART risk score for potential ACS patients (Figure 1).[6,9]

A HEART score of 0-3 is considered low risk and corresponds to a less than 2% risk of MACE within six weeks and supports discharge from the ED without further workup or evaluation; a score of 4-6 is medium risk, corresponding to a 5-20% risk of six-week MACE.[6] Patients with a medium risk HEART score warrant cardiology evaluation for admission for clinical observation and further cardiac workup. A score of ≥ 7 is considered high risk, conveying a 50-72% risk of six-week MACE and supports initiation of invasive treatment with minimal delay.[6,11] In a retrospective, multicenter analysis, patients with HEART scores 0-3 had a 0.99% rate (3/303 cases) of MACE within six weeks of presentation; those with scores 4-6 and 7-10 had rates of 11.6% (48/413) and 65.2% (107/164), respectively.[6] It has been further proposed that using HEART scores in combination with zero and three-hour serial troponin measurements reduced hospital length of stay, increased early discharges, and decreased objective cardiac testing.[7,12] This data would indicate that the HEART score is a reliable noninvasive predictor of outcome in this treatment population and can be a valuable tool for safe and efficient patient management in the EDs.

*Population Health Research Capsule*

What do we already know about this issue?
*Use of the patient's history, electrocardiogram [ECG], age, risk factors, and troponin (HEART) score to help increase discharges and reduce downstream testing has been externally validated in emergency department (ED) patients with chest pain.*

What was the research question?
*Can a HEART-based protocol improve care in patients with both typical and atypical signs of acute coronary syndrome (ACS)?*

What was the major finding of the study?
*Our HEART-based protocol increased ED discharge rates even in patients with only atypical signs of ACS.*

How does this improve population health?
*A HEART score-based pathway has the potential to safely increase ED discharge and reduce downstream testing even among patients with only atypical signs of ACS.*

The Naval Medical Center Portsmouth (NMCP) evaluates over 65,000 patients annually in its 54-bed emergency department (ED). The patient population includes active duty military members, their families, some retirees, and veterans. Generally speaking, the population is younger and healthier than that of the average community ED. In the fall of 2015, the NMCP ED instituted a protocol based on the HEART score. For patients presenting with symptoms believed to be related to possible ACS, an ECG and troponin are performed. STEMI patients are immediately prepared and sent for percutaneous coronary intervention in our catheterization laboratory. NSTEMI patients are admitted for observation and treatment by our cardiology team. The remainder are entered into the HEART score-based protocol.

In accordance with other studies,[6,7,11,12] we slightly modified the original HEART pathway to add a second troponin test three hours after the first for patients who present with less than six hours of chest pain. Patients with HEART scores of three or less are discharged from the ED with primary care or cardiology follow-up within 72 hours. Patients with HEART scores of 4-6 are evaluated by the cardiology team for inpatient admission and evaluation or are placed in an observation status in the ED for risk stratification. Patients

**Figure 1.** Composition of the HEART score.

| Composition of the HEART Score | Score |
|---|---|
| History | |
| Highly suspicious | 2 |
| Moderately suspicious | 1 |
| Slightly suspicious | 0 |
| ECG | |
| Significant ST depression | 2 |
| Nonspecific repolarization disturbance | 1 |
| Normal | 0 |
| Age | |
| >65 | 2 |
| 45-65 | 1 |
| <45 | 0 |
| Risk factors* | |
| ≥3 risk factors | 2 |
| 1-2 risk factors | 1 |
| No risk factors known | 0 |
| Troponin | |
| >2x normal limit | 2 |
| 1-2x normal limit | 1 |
| ≤ normal limit | 0 |

*Risk factors included in HEART: hypertension, hypercholesterolemia, diabetes, obesity (body mass index > 30), smoking (active or quit within 3 months), positive family history (parent or sibling with cardiovascular disease < age 65, and atherosclerotic disease (prior myocardial infarction, percutaneous coronary intervention/coronary artery bypass graft, cerebrovascular accident/transient ischemic attack, or peripheral vascular disease). Adapted from Backus 2010.[6]
*HEART*, history, electrocardiogram, age, risk factors and troponin; *ECG*, electrocardiogram.

with HEART scores greater than 6 are generally admitted for treatment and evaluation.

The purpose of this study was to examine how the implementation of our new institutional HEART score- based protocol affects ED disposition (admission vs discharge). Secondarily, we evaluated ED length of stay (LOS), number of stress tests completed, cardiac catheterization rates, and rates of MACE before and after implementation of the protocol. Our protocol does not specifically address patients with purely atypical symptoms. However, ACS is often a concern and a score is easily calculated for these patients. For analysis, we included all patients in whom a troponin and ECG were ordered by the ED team regardless of their chief complaint or reported symptoms.

## METHODS

This was a retrospective chart review study comparing two six-month periods, one prior to implementation and one after adoption of the HEART score-based chest pain protocol. We used procedures outlined in Kaji's paper on retrospective reviews in the ED as a guide for design and data abstraction.[13]

### Chart Review

We screened medical records using an electronic health record (EHR) (T-system EV, Plano, TX). Records were collected for all patients between the ages of 30-89 who had a troponin test and an ECG ordered in the ED during a six-month period prior to implementation of the chest pain protocol (January 1, 2015–June 30, 2015) and a corresponding annual period after implementation (January 1, 2016– June 30, 2016). The post-implementation period started five months after adoption of the protocol to ensure a washout and standardization period. During both periods, we used two types of non-high sensitivity troponin tests. One is a point of care test (i-STAT cardiac troponin I, Abbott Diagnostics, Chicago, IL), and the other a standard lab assay (Vitros 5600 Troponin I, Ortho-Clinical Diagnostics, Raritan, NJ); the two tests were considered equal for the purposes of the study using their individual reference ranges (normal values for i-STAT < 0.02, and less than 0.034 for laboratory assay).

Using the troponin lab and ECG order as a triggering event in the screening, we identified 1546 records in the pre-implementation group and 1623 in the post-implementation group. The first 900 charts in each cohort were used for analysis. For each group, trained data abstractors manually abstracted required data elements from the EHR and entered this information in a password-protected spreadsheet (Microsoft Excel, Redmond WA). Data was abstracted from the ED EHR), the outpatient EHR (AHLTA, Unissant Inc, Herndon, VA) and the inpatient EHR (Essentris, CliniComp, Intl, San Diego, CA) to complete the password-protected dataset. Data abstractors were not blinded to study objectives. Patient names were de-identified with a separately held subject ID key. Patients who were diagnosed with ST-elevation myocardial infarction (STEMI) or non-ST elevation myocardial infarction (NSTEMI) were excluded, as were those whose troponin results and ECGs were missing from the EHR system (Figure 1). The included records were evaluated by a physician who used a modified spreadsheet containing a randomized listing of the patient's chief complaint and history of present illness (HPI) to calculate a score for the history portion of the HEART score. This physician was blinded to the patient's group (pre or post). We used the original and validation studies of the HEART score as a guide for scoring the history.[6,11] If the chief complaint or the HPI included chest pain, pressure or discomfort, the patient was included in the typical group. Otherwise, the patient was placed in the atypical group for analysis.

ECG interpretations, age, risk factors, and troponin were taken directly from the chart. If the ECG interpretation was not available in the chart, the actual ECG was evaluated and scored by a physician blinded to the patient's cohort and medical

record according to the HEART algorithm. Zero points were assigned to ECGs that were normal, one point if there were non-specific repolarization disturbances.

### Outcomes

The primary outcome was patient disposition (admission vs discharge). For the purpose of this study, "admission" was defined as a transfer of care to ED observation, inpatient internal medicine, or the cardiology service. Secondary outcomes included ED LOS, number of stress tests performed, number of catheterizations performed (and the results), and rate of MACE. We indirectly estimated cost savings by using standard costs obtained by our business affairs department for cardiac admissions, floor admissions, cardiology outpatient follow-up, stress testing, and catheterizations.

### Analysis

We assumed alpha 0.05 and beta 0.2 for our sample size estimate. To determine a 10% difference in ED discharge rates (two-sided), 380 subjects per group were required. To determine a 5% difference (two-sided), 1320 subjects per group were required. We performed interim power analysis after 900 records had been collected for each side, and the numbers collected were deemed sufficient.

Baseline patient characteristics (history, age, EKG, risk factors, troponin category) were converted into categorical data based on the HEART score (Figure 1). Results were compared before and after implementation of the HEART-based chest pain protocol. For categorical data, differences between the groups were evaluated using chi-square and Fisher's exact tests. We evaluated continuous data using two-sided Student's T tests. We performed logistic regression analysis to control for potential confounders including differences in HEART scores between the pre- and post-protocol groups.

We examined the reason for visit, which was recorded by the front desk staff, the chief complaints entered by the nurse and physician, and the HPI sections in the EHR. The HPI section also included a basic review of systems. If there was any mention of chest pain, pressure or discomfort (eg, chest + "pain," "discomfort," "pressure," "squeezing," or "heaviness") the patient was placed in the typical category. Otherwise, the patient was placed in the atypical category.

## RESULTS

### Chart Review

We analyzed 900 records in the pre-implementation group and 900 seasonally matched records in the post-implementation group. To directly compare our study to similar studies, we grouped our records into two main categories. Patients with typical symptoms and atypical symptoms were analyzed together and separately. Pre-protocol, we excluded two patients with STEMI and eight patients with NSTEMI. We also excluded 16 patients for missing troponins, 26 patients for missing ECGs, and four patients who left against medical advice (AMA). Post-protocol, we excluded seven patients with STEMI and 13 patients with NSTEMI. We also excluded nine patients for missing troponins, four patients for missing ECGs and six patients who left AMA. This left 844 patients in the pre-protocol cohort, 434 of whom demonstrated typical ACS symptoms and 410 with atypical symptoms. In the post-protocol cohort, we included 861 records, 482 of which demonstrated typical symptoms and 379 with atypical symptoms (Figure 2).

Patients in the pre-protocol cohort were more likely to have normal ECGs, were older, had more risk factors, and were more likely to have a positive troponin. When combined into a total HEART score, there were more low-risk patients in the post cohort but this did not reach statistical significance ($p = .06$). We adjusted for these differences using logistic regression to account for the HEART score category, which takes the differences seen in age, troponin, and risk factors into account. The regression dampened some findings but did not significantly change results in any outcome and are included in the respective outcome sections.

Typical vs atypical symptoms: About half of patients in each cohort presented with chest pain as a chief complaint (51%, 56%). Within our exclusions for NSTEMI, 7/21 presented with atypical symptoms (33%). For STEMI

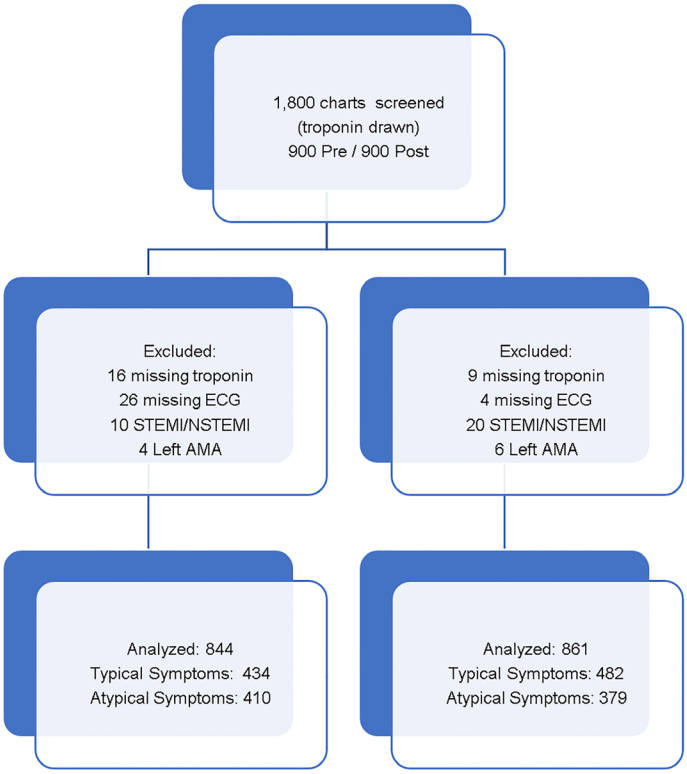


**Figure 2.** Inclusion criteria flow chart.
*ECG*, electrocardiogram; *STEMI*, ST-segment elevation myocardial infarction; *NSTEMI*, non-ST-segment elevation myocardial infarction; *AMA*, against medical advice.

patients who were excluded, 1/9 (11%) presented with atypical symptoms (dyspnea). Atypical patients were more likely to be scored as 0 for the history portion of the HEART score. This was consistent between cohorts (39% typical vs 86% atypical pre; 39% typical vs 88% atypical post) (Table 1).

*Primary Outcomes: Patient Disposition*

ED discharge rates: For all patients, the discharge rate from the ED increased by 10.8% absolute (odds ratio [OR] 1.56, 1.49 adjusted, $p<.0001$). This trend held true whether the patient had typical chest pain or atypical symptoms (Table 2).

Hospital admission rates: Admissions to the cardiology service decreased by 11.6% absolute, (OR 0.46, 0.45, $p<.0001$). Admissions to other services increased by 1.5% absolute (OR 1.10, 1.15, $p = .5$). This represents a trend but did not reach statistical significance. When analyzed by symptoms, the trend seemed more profound for patients with typical symptoms (OR 1.52) vs atypical symptoms (OR

**Table 1.** Baseline characteristics pre- and post-adoption of HEART-based protocol.

| Characteristic | Pre-implementation | Post-implementation | *p*-value |
|---|---|---|---|
| Patients | | | |
| All | 844 | 861 | NA |
| Typical/atypical | 434/410 (51%)/(49%) | 482/379 (56%)/(44%) | 0.07 |
| Gender | | | |
| All | Male: 442 (52%)<br>Female: 402 (48%) | Male: 412 (48%)<br>Female: 449 (52%) | 0.07 |
| Typical/atypical | Male: 218/224 (50%/55%)<br>Female: 216/186 (50%/45%) | Male: 230/182 (48%/48%)<br>Female: 252/197 (52%/52%) | 0.5/ 0.07 |
| History | | | |
| All | | | |
| 0 | 522 (62%) | 519 (60%) | 0.5 |
| 1 | 302 (36%) | 320 (37%) | |
| 2 | 20 (2%) | 22 (3%) | |
| Typical/atypical | | | |
| 0 | 169/353 (39%/86%) | 186/333 (39%/88%) | 0.9/0.2 |
| 1 | 245/57 (56%/14%) | 276/44 (57%/12%) | |
| 2 | 20/0 (5%/0%) | 20/2 (4%/0%) | |
| ECG | | | |
| All | | | |
| 0 | 658 (78%) | 636 (74%) | 0.02 |
| 1 | 183 (22%) | 225 (26%) | |
| 2 | 3 (0%) | 0 (0%) | |
| Typical/atypical | | | |
| 0 | 356/302 (82%/74%) | 369/267 (77%/70%) | 0.06/0.2 |
| 1 | 77/106 (18%/26%) | 113/112 (23%/30%) | |
| 2 | 1/2 (0%/0%) | 0/0 (0%/0%) | |
| Age | | | |
| All | | | |
| 0 (<45) | 183 (21%) | 240 (28%) | 0.01 |
| 1 (45-64) | 460 (55%) | 443 (51%) | |
| 2 (≥65) | 201 (24%) | 178 (21%) | |
| Typical/atypical | | | |
| 0 (<45) | 136/47 (31%/11%) | 179/61 (37%/16%) | 0.2/0.2 |
| 1 (45-64) | 237/223 (55%/54%) | 245/198 (51%/52%) | |
| 2 (≥65) | 61/140 (14%/34%) | 58/120 (12%/32%) | |

**Table 1.** Continued.

| Characteristic | Pre-implementation | Post-implementation | *p*-value |
|---|---|---|---|
| Risk Factors | | | |
| All | | | |
| 0 | 201 (24%) | 257 (30%) | 0.009 |
| 1 | 390 (46%) | 387 (45%) | |
| 2 | 253 (30%) | 217 (25%) | |
| Typical/atypical | | | |
| 0 | 113/88 (26%/21%) | 175/82 (36%/22%) | 0.004/0.3 |
| 1 | 201/189 (46%/46%) | 195/192 (40%/51%) | |
| 2 | 120/133 (28%/32%) | 112/105 (23%/28%) | |
| Troponin category | | | |
| All | | | |
| 0 | 757 (90%) | 808 (94%) | 0.007 |
| 1 | 64 (7%) | 41 (5%) | |
| 2 | 23 (3%) | 12 (1%) | |
| Typical/atypical | | | |
| 0 | 404/353 (93%/86%) | 461/347 (96%/91%) | 0.01/0.05 |
| 1 | 23/41 (5%/10%) | 19/22 (4%/6%) | |
| 2 | 7/16 (2%/4%) | 2/10 (0/3%) | |
| HEART score | | | |
| All | | | |
| 0-3 (Low risk) | 577 (68%) | 632 (73%) | 0.06 |
| 4-6 (Medium risk) | 256 (30%) | 222 (26%) | |
| ≥7 (High risk) | 11 (1%) | 7 (1%) | |
| Typical/atypical | | | |
| 0-3 (Low risk) | 300/277 (69%/68%) | 364/268 (75%/71%) | 0.10/0.5 |
| 4-6 (Medium risk) | 129/127 (30%/31%) | 114/108 (24%/28%) | |
| ≥7 (High risk) | 5/6 (1%/1%) | 4/3 (1%/1%) | |

For characteristics that are part of the HEART score, the HEART score category is included. All differences were analyzed using chi-square testing. Each characteristic is also shown according to whether they presented with typical or atypical symptoms.
*ECG*, electrocardiogram.

1.13), but again these differences did not reach statistical significance ($p$= .1 typical, $p$= .5 atypical) (Table 2).

**Secondary Outcomes: Length of stay, stress tests, catheterizations, MACE, and cost**

ED LOS: We analyzed two different ED LOS categories for discharged patients. Overall LOS included time in the waiting room. Room to discharge time eliminated the time in the waiting room from analysis. For all discharged patients, overall LOS was 13 minutes shorter in the post-protocol group but this did not meet statistical significance ($p$= .07). Room to discharge time for discharged patients was 17 minutes shorter for all patients ($p$= .012). For typical chest pain patients, room to discharge time was 19 minutes shorter ($p$= .037). For patients with atypical symptoms, ED LOS was 13 minutes shorter but was not statistically significant ($p$= .17) (Table 3).

Inpatient LOS: We analyzed inpatient LOS for all admitted patients. We grouped all admits together to include those admitted to ED observation, those admitted to the cardiology service, and those admitted to other services. If a patient was admitted and discharged on the same day, we considered them admitted for one day. Otherwise we calculated the number of days between admission and discharge. There was a small but significant decrease in inpatient LOS from pre to post (2.62 days to 2.17 days, $p$= .02). Admissions for atypical symptoms were about a day longer than for typical symptoms in both groups (Table 3).

Number of stress tests performed: The number of stress tests performed (which include treadmill/exercise stress tests, stress echocardiograms, and chemical stress tests) decreased by half from pre-protocol to post-protocol (16% to 8%, OR 0.47, $p$<.001). This trend held true when analyzed by symptoms.

For typical symptoms, stress tests decreased by 13% absolute (26% to 13%, OR 0.43, $p<.001$). For atypical patients, stress tests decreased by 4% absolute but numbers were low overall (6% to 2%, or 0.36, $p= .02$). Across all groups, the percentage of positive stress tests did not increase or decrease significantly (14% vs 15%, OR 0.99, $p= 1.0$) (Table 4).

Cardiac catheterization rates and results: The number of cardiac catheterizations performed was low for both cohorts and did not change significantly from pre to post (4% vs 3%). Of the catheterizations performed, a greater portion were positive post-protocol (53% vs 77%), but this did not reach statistical significance (Table 4).

MACE: Among the 1705 patients included in the final analysis, six-week follow-up data could not be confirmed for 8% (134 patients). Loss to follow-up was consistent in both groups (7.7% pre, 8.0% post). Follow-up was done by looking through outpatient records for repeat visits more than six weeks after the index visit. Patients with primary care or cardiology care outside of our facility (which is not uncommon) would not be expected to be found in this way. This limited our ability to draw significant conclusions regarding MACE. Among the 92% of patients for whom follow-up was available, there were no missed MACE cases. There were four deaths within the six-week period, but all were admitted to the hospital at the index visit.

Healthcare costs: To calculate savings or cost of the protocol to the hospital, we requested cost information from the hospital business office. We were provided with a list of average costs for various services. In the pre-protocol cohort, the first 900 patients presented over 109 days, and over 98 days for the post-implementation cohort. We calculated the number of events per day over these periods and calculated an annual cost based on these numbers. This method accounts for an increase in visits in the post-protocol period. For cardiology visits, we assumed all extra discharges had a visit with a cardiologist and therefore that the number of outpatient cardiology visits increased. This is likely a significant overestimation, as many low-risk patients follow up only with their primary care provider. This method appropriately biases against our intervention. Cost information is presented in Table 5.

## DISCUSSION

Our study is similar to a study by Hyams in 2018, which showed a similar resource-utilization benefit to a HEART-based protocol. Hyams' and all other HEART studies to date have included only patients presenting with chest pain.[8] In this study, by including all patients where an ECG and troponin

**Table 2.** Disposition for patients pre- and post-adoption of HEART-based protocol.

| Disposition | Pre-cohort | Post-cohort | Percent change absolute | OR -*adj |
|---|---|---|---|---|
| Discharged | | | | |
| All | 428 (50.7%) | 530 (61.6%) | 10.8 | 1.56,*1.49 (P<0.001) |
| Typical | 244 (56.2%) | 326 (67.6%) | 11.4 | 1.63,*1.57 (P<0.001) |
| Atypical | 184 (44.9%) | 204 (53.8%) | 8.9 | 1.43, *1.38 (P = 0.01) |
| Admit cardiac | | | | |
| All | 208 (24.6%) | 112 (13.0%) | -11.6 | 0.46, *0.47 (P<0.001) |
| Typical | 130 (30.0%) | 79 (16.4%) | -13.6 | 0.46, *0.44(P<0.001) |
| Atypical | 78 (19.0%) | 33 (8.7%) | -10.3 | 0.41, *0.43(P<0.001) |
| Admit to other service | | | | |
| All | 161 (19.1%) | 177 (20.6%) | 1.5 | 1.10, *1.15 (P = 0.5) |
| Typical | 25 (5.76%) | 41 (8.5%) | 2.7 | 1.52, *1.51 (P = 0.1) |
| Atypical | 136 (33.2%) | 136 (35.9%) | 2.7 | 1.13, *1.18 (P = 0.5) |
| ED observation | | | | |
| All | 35 (4.1%) | 35 (4.1%) | -0.1 | 0.98,*0.98 (P = 1.0) |
| Typical | 33 (7.6%) | 33 (6.8%) | -0.8 | 0.89,*0.90 (P = 0.7) |
| Atypical | 2 (0.5%) | 2 (0.5%) | 0 | 1.08,*1.13 (P = 1.0) |
| Transfer | | | | |
| All | 12 (1.4%) | 7 (0.8%) | -0.6 | 0.57,*0.57 (P = 0.3) |
| Typical | 2 (0.4%) | 3 (0.6%) | 0.2 | 1.35,*1.40 (P = 1) |
| Atypical | 10 (2.4%) | 4 (1.1%) | -1.4 | 0.43,*0.42 (P = 0.2) |

Admission to other service was an admission which was not to the cardiology service (almost always internal medicine). Odds ratios calculated from raw data and (*) corrected for difference in baseline HEART scores for the pre-and post-protocols using logistic regression. Statistical significance evaluated with Fisher's exact test.
*HEART*, history, electrocardiogram, age, risk factors, troponin; *ED*, emergency department; *OR adj*; odds ratio adjusted.

**Table 3.** Length of stay pre- and post-adoption of HEART-based protocol.

| Length of stay | Pre-Implementation | Post-implementation | Difference | *p*-value |
|---|---|---|---|---|
| Discharges (n) | 428 | 530 | | |
| Total ED time (minutes) | | | | |
| All | 274 ± 5.5 | 261 ± 4.4 | 13 | 0.07 |
| Typical | 273 ± 7.9 | 259 ± 5.8 | 14 | 0.1 |
| Atypical | 275 ± 7.5 | 265 ± 6.7 | 10 | 0.3 |
| ED room to disposition | | | | |
| All | 248 ± 5.3 | 231 ± 4.3 | 17 | 0.01 |
| Typical | 248 ± 7.6 | 229 ± 5.8 | 19 | 0.04 |
| Atypical | 248 ± 7.1 | 235 ± 6.5 | 13 | 0.2 |
| Admits (n) | 404 | 324 | | |
| Inpatient days | | | | |
| All | 2.62 ± 0.15 | 2.17 ± 0.13 | 0.45 | 0.02 |
| Typical | 1.85 ± 0.16 | 1.54 ± 0.12 | 0.31 | 0.1 |
| Atypical | 3.30 ± 0.23 | 2.73 ± 0.22 | 0.51 | 0.07 |

Length of stay for discharged patients is evaluated in two ways. Total ED time is time from check-in until discharge. ED room to disposition excludes waiting room time from length of stay. Inpatient length of stay is in days and includes patients dispositioned to ED observation, cardiac admission and admissions to other services. Data is included as means ± SEM. P-values were calculated using two-sided Student's t test.
*HEART*, history, electrocardiogram, age, risk factors, troponin; *ED,* emergency department.

were ordered, we included and analyzed data from patients presenting with only atypical symptoms of ACS. As far as we know, this is the first study to look at this population. ACS is considered a "can't miss" diagnosis in the ED. Chest pain is the most common symptom of ACS but is by no means universal.[1] Ruling out ACS in patients with only atypical symptoms is challenging. In our study, 44-49% of ECGs and troponins were ordered on patients without chest pain, pressure, or discomfort as a chief complaint or anywhere in the history of present illness. This demonstrates a real-world ED approach to evaluating for cardiac ischemia. In our population, 33% of NSTEMI diagnoses resulted from investigation of atypical symptoms. Nine of the 37 (24%) abnormal catheterizations occurred in the subgroup with only atypical ACS symptoms.

Our HEART protocol simplifies ED evaluation and decreases unnecessary hospital admissions for low-risk patients. The protocol enables more rapid disposition and decreased resource utilization for those in whom MI is ruled out. The discharge rate for chest pain improved by 10.8% absolute (48% relative). Our study corroborates prior studies, demonstrating an OR of 0.46 for admission (vs 0.48 in the Hyams study).[8] Our facility serves primarily active duty military and their families with a smaller portion of retirees. As expected, the percentage of patients with low HEART scores was higher in our population (63-69%) than in other studies (31%, Mahler 2018).[14] Additionally, our medical system differs significantly from a civilian setting with increased access to care and significantly reduced patient-borne costs that may lower patient threshold to present for care.

ED room to disposition times were 17 minutes shorter after implementation of the protocol. Over a year and over 1500 visits this added up to a significant time savings and improvement in patient flow. Given the frequency of cardiac evaluations in any ED, higher discharge rates and shorter stays help reduce waiting room delays and improve patient access to care. Inpatient LOS decreased slightly as well (0.45 days), but these data are a bit less reliable given that we were only able to consider full days and not portions of days in the analysis. In 2011 Mahler et al suggested that the HEART score could reduce stress testing and cardiac imaging.[15] Our study shows a similar significant reduction in stress testing. Interestingly, there was a lower proportion of abnormal stress tests in the atypical population in the post cohort (13% vs 30%) although numbers were quite low and differences were not statistically significant. Considering the inherent imperfections in stress testing this may not be an indication of the HEART protocol missing cases. Cardiac catheterization procedures in the pre and post cohorts were also low and not statistically significant but a higher positive catheterization rate (77% vs 53%) in the post cohort may indicate better patient selection.

Although our cost data is indirect and incomplete, based on saving admissions to the cardiac care unit, increasing ED discharges and decreasing admissions and stress tests resulted in an estimated cost savings to our military medical center of approximately $4.5 million annually.

**Table 4.** Cardiac testing. Stress testing and cardiac catheterizations performed pre- and post-adoption of HEART- based protocol.

| Testing | Pre-cohort | Post-cohort | OR -*adj | *p*-value |
|---|---|---|---|---|
| Stress testing | | | | |
| Performed | | | | |
| All | 138 (16%) | 72 (8%) | 0.47,*0.49 | <0.001 |
| Typical | 115 (26%) | 64 (13%) | 0.43,*.0.44 | <0.001 |
| Atypical | 23 (6%) | 8 (2%) | 0.36,*0.38 | 0.02 |
| Abnormal result | | | | |
| All | 20 (14%) | 11 (15%) | 0.99,*0.95 | 1.0 |
| Typical | 13 (11%) | 10 (16%) | 1.34,*1.30 | 0.6 |
| Atypical | 7 (30%) | 1 (13%) | 0.34,*0.29 | 0.6 |
| Catheterizations | | | | |
| Performed | | | | |
| All | 32 (4%) | 26 (3%) | 0.79,*0.90 | 0.4 |
| Typical | 24 (6%) | 17 (4%) | 0.63,*0.67 | 0.2 |
| Atypical | 8 (2%) | 9 (2%) | 1.23,*1.46 | 0.8 |
| Abnormal (%) | | | | |
| All | 17 (53%) | 20 (77%) | 2.89,*1.91 | 0.1 |
| Typical | 14 (58%) | 14 (82%) | 3.24,*2.38 | 0.2 |
| Atypical | 3 (38%) | 6 (67%) | 3.09,*1.78 | 0.3 |

Odds ratios calculated from raw data and (*) corrected for total HEART scores for the pre and post protocols using logistic regression. Statistical significance was evaluated with Fisher's exact test.
*HEART*, history, electrocardiogram, age, risk factors, troponin.

## LIMITATIONS

There were several limitations to our study, with the primary being the retrospective chart review design conducted over a two-year timespan. Other confounding variables may exist if other ED or hospital-wide improvements were made during the study period, although we are unaware of any major changes in patient care. The study was conducted by providers in the subject ED, which could have introduced bias.[13] Some resident physicians served as data abstractors and were not blinded to study objectives. In addition, there is a trend toward more outpatient evaluation for coronary artery disease in general, which influenced our results in unclear ways. Risk factors such as obesity and smoking are tremendously under-reported in our EHR but likely consistent between cohorts.

The HEART score was derived and validated for chest pain patients. The history portion of the score is designed for chest pain patients and as expected was lower in the atypical group. This may bias the score against patients with only atypical symptoms, as it is more difficult to get a higher score for history in this group. Future studies need to have better follow up and determine the MACE rates for patients in this category.

We used the ordering of troponin and an ECG as our inclusion criteria. There are other reasons for ordering these tests together (eg, determining the physiologic burden of pulmonary embolism) but underlying cardiac disease is the primary reason for ordering these tests in the majority of these cases, even when the primary diagnosis being considered is arrhythmia, stroke, or another non-cardiac cause.[16] Inclusion of patients where ECG and troponin were ordered when there was no concern for ACS is possible but numbers are likely low and equal between cohorts.

There was a difference in the overall health of the pre- and post-protocol populations with the pre-protocol population tending to be older with more cardiac risk factors. This was accounted for by using logistic regression to account for HEART score category (low, medium, high). This effectively controls for differences in the components of the HEART score such as age and risk factors. Results after logistic regression were slightly dampened but remained statistically and clinically significant. It is unclear as to why the populations differed. It is possible that the threshold for ordering troponin and ECGs has decreased in recent years or that our population has developed a lower threshold for presenting to the ED with mild symptoms. The decreased severity of risk factors was consistent with previous studies.[8] It is well known that fewer patients are smoking over time, and recent publications also note a recent decrease in chest pain patients with hyperlipidemia and diabetes.[8]

Lack of follow-up occurred at a rate of 8%. This is unlikely to have changed our results substantially, particularly because rate of follow-up was similar between the two groups. The loss to follow-up hindered our ability to draw conclusions

**Table 5.** Healthcare cost pre and post adoption of HEART-based protocol.

| Event | Cost per | Pre (annual) | Post (annual) | Annual change | Savings (cost) |
|---|---|---|---|---|---|
| Cardiac admit | $22,257 | 208 (696) | 112 (417) | -279 | $6,217,958 |
| General admit | $9,111 | 161 (539) | 177 (659) | +120 | ($1,094,288) |
| Cardiology visit | $297 | 428 (1433) | 530 (1974) | +541 | ($586,272) |
| Stress test | $277 | 138 (462) | 72 (268) | -194 | $53,723 |
| Total | | | | | $ 4,591,121 |

Estimates of healthcare costs based on changes on admission rate, stress testing, catheterizations, etc.

about MACE. However, external validation has previously demonstrated the safety of a HEART based protocol.[17,18]

### *Areas for Future Research*

A rule for assisting with disposition of patients with atypical symptoms of ACS is desirable. The HEART score is a good starting point. Based on our study, minor modifications to the history portion of the HEART score may be all that is required to make it more applicable to patients with only atypical symptoms. Such modification may require new derivation and validation studies. We would also encourage current and future researchers to include data on atypical patients when publishing on HEART and other cardiac risk stratification tools.

## CONCLUSIONS

After adoption of a HEART score-based protocol, discharges from the ED increased with a corresponding decrease in admissions for cardiac evaluations as well as cost. These effects were similar in patients presenting without chest pain but with presentations concerning for acute coronary syndrome.

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# Examining the Timeliness of ST-elevation Myocardial Infarction Transfers

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**Introduction:** Despite large-scale quality improvement initiatives, substantial proportions of patients with ST-elevation myocardial infarction (STEMI) transferred to percutaneous coronary intervention centers do not receive percutaneous coronary intervention within the recommended 120 minutes. We sought to examine the contributory role of emergency medical services (EMS) activation relative to percutaneous coronary intervention center activation in the timeliness of care for patients transferred with STEMI.

**Methods:** We conducted a retrospective analysis of interfacility transfers from emergency departments (ED) to a single percutaneous coronary intervention center between 2011–2014. We included emergency department (ED) patients transferred to the percutaneous coronary intervention center and excluded scene transfers and those given fibrinolytics. We calculated descriptive statistics and used multivariable linear regression to model the association of variables with ED time intervals (arrival to electrocardiogram [ECG], ECG-to-EMS activation, and ECG-to-STEMI alert) adjusting for patient age, gender, mode of arrival, weekday hour presentation, facility transfers in the past year, and transferring facility distance.

**Results:** We identified 159 patients who met inclusion criteria. Subjects were a mean of 59 years old (standard deviation 13), 22% female, and 93% White; 59% arrived by private vehicle, and 24% presented after weekday hours. EDs transferred a median of 9 STEMIs (interquartile range [IQR] 3, 15) in the past year and a median of 65 miles (IQR 35, 90) from the percutaneous coronary intervention center. Median ED length of stay was 65 minutes (IQR 51, 85). Among component intervals, arrival to ECG was 6%, ECG-to-EMS activation 32%, and ECG-to-STEMI alert was 49% of overall ED length of stay. Only 18% of transfers had EMS activation earlier than STEMI alert. ECG-to-EMS activation was shorter in EDs achieving length of stay ≤60 minutes compared to those >60 minutes (12 vs 31 minutes, P<0.001). Multivariable modeling showed that after-hours presentation was associated with longer ECG-to-EMS activation (adjusted relative risk [RR] 1.05, P<0.001). Female gender (adjusted RR 0.81, P<0.001), prior facility transfers (adjusted RR 0.84, P<0.001), and initial ambulance presentation (adjusted RR 0.93, P = 0.02) were associated with shorter ECG-to-EMS activation.

**Conclusion:** In STEMI transfers, faster EMS activation was more likely to achieve a shorter ED length of stay than a rapid, percutaneous coronary intervention center STEMI alert. Large-scale quality improvement efforts such as the American Heart Association's Mission Lifeline that were designed to regionalize STEMI have improved the timeliness of reperfusion, but major gaps, particularly in interfacility transfers, remain. While the transferring EDs are recognized as the primary source of delay during interfacility STEMI transfers, the contributions to delays at transferring EDs remain poorly understood. [West J Emerg Med. 2021;22(2)319–325.]

## INTRODUCTION

There is evidence that early initiation of emergency medical services (EMS) prior to activation of the cardiac catheterization laboratory at the percutaneous coronary intervention center may reduce the time spent at transferring emergency departments (ED).[4] However, the role that EMS plays in transfer timeliness compared with other ST-elevation myocardial infarction (STEMI) transfer processes is unclear. With EMS agencies and percutaneous coronary intervention centers requiring separate activation during a STEMI, the transferring ED must choose which process step to perform first. Thus, we sought to evaluate this decision and how the timing of transferring ED activation of EMS when compared with percutaneous coronary intervention center activation influenced the timeliness of interfacility transfers for patients with suspected STEMI.

*Population Health Research Capsule*

What do we already know about this issue?
*Inter-facility transfer of patients with ST-elevation myocardial infarction (STEMI) are often prolonged due to coordination with emergency medical service (EMS) agencies and percutaneous coronary intervention (PCI) centers and impact patient outcomes.*

What was the research question?
*What is the contributory role of EMS versus PCI center activation in the timeliness of care for patients transferred with STEMI?*

What was the major finding of the study?
*Time spent at transferring EDs for patients with STEMI is more dependent on EMS activation than activation of the PCI center.*

How does this improve population health?
*Encouraging early EMS activation and incorporating this activity into formal policies may improve transfer timeliness for patients with STEMI.*

## METHODS

### Study Design and Population

Vanderbilt University Medical Center (VUMC) is a quaternary care center for cardiovascular services in Middle Tennessee that provides 24/7 primary percutaneous coronary intervention capabilities and medical and surgical management of cardiovascular conditions. VUMC has a catchment area over 65,000 square miles and receives interfacility transfers from dozens of referring EDs in the region. Primary percutaneous coronary intervention activation at VUMC activates the cardiac catheterization team and prepares the laboratory for intervention. After hours, staff must be available onsite within 30 minutes. For the transferring ED, EMS must be activated separately and no formal policy exists regarding the order of such decisions.

In this study we sought to examine the contributory role of each activity to overall STEMI transfer timeliness. We included patients with suspected STEMI who experienced interfacility transfer from an outside ED to VUMC between January 1, 2011–December 31, 2014. We excluded the following patients: 1) those who received fibrinolytics, which are recommended when the patient presents to a non-percutaneous coronary intervention facility and the anticipated delay to primary percutaneous coronary intervention is ≥120 minutes (class I, level of evidence A)[8]; 2) those who were transported directly to VUMC from the field; 3) were initially transferred for reasons other than STEMI; 4) did not receive a cardiac catheterization; and 5) were missing transfer ED health records or had incomplete transferring ED operational data (eg, arrival timestamp). This study was approved by the VUMC Institutional Review Board.

### Data Collection

We developed a data dictionary and performed dual abstractor data collection using REDCap, a secure, browser-based, metadata-driven electronic data capture tool.[9] Data were abstracted from health records from transferring EDs that are regularly collected and stored in VUMC's electronic health record. Operational data included the following: transferring hospital; transferring ED timestamps (arrival, diagnostic electrocardiogram [ECG]; physician evaluation; percutaneous coronary intervention center activation; EMS activation; EMS arrival, exit); percutaneous coronary intervention center arrival; and percutaneous coronary intervention start (ie, initiation of cardiac catheterization). We also classified facilities as rural/urban using the Rural Urban Commuting Area codes,[10] presence in the middle Tennessee regional STEMI network, and driving distance to VUMC (using Google Maps). Clinical data included presenting symptoms, demographics, comorbidities, and 30-day mortality.

### Data Analysis

We calculated time intervals as the difference between two ED operational timestamps (identified above). When referencing ECGs, we used the ECG diagnostic of STEMI triggering the transfer. As some diagnostic ECGs may be performed by EMS prior to ED arrival, we set the arrival to ECG equal to zero as these visits had access to the diagnostic ECG upon arrival. Since we were using patients with suspected STEMI, and not all patients may have had stent placement, we used the timestamp for initiation of the percutaneous coronary intervention procedure, which was required for inclusion.

We calculated descriptive statistics for patient and facility characteristics, time intervals, and proportion of time intervals

of the overall ED length of stay for the overall population, by EMS activation status (before vs after percutaneous coronary intervention activation) and by ED length of stay (≤60 minutes vs >60 minutes). We selected 60 minutes as the cutoff as this was the duration used internally for quality improvement purposes. Group comparisons were conducted using Wilcoxon rank-sum tests for continuous variables and chi-square tests for categorical variables. We used generalized linear models with log link function to quantify relative model ED time intervals of interest (ECG-to-EMS activation) adjusting for patient and facility characteristics, which included patient age, gender, ED mode of arrival (private vs emergency medical services), ED presentation after hours (>5 PM and on weekends), number of facility transfers to VUMC for suspected STEMI in the past year at the time of transfer, and transferring ED facility distance. Analyses were conducted using *R 3.5.1* (R Foundation for Statistical Computing, Vienna, Austria).

## RESULTS

From an initial group of 439 subjects, we identified 159 patients who met inclusion criteria **(**Figure 1). Subjects were

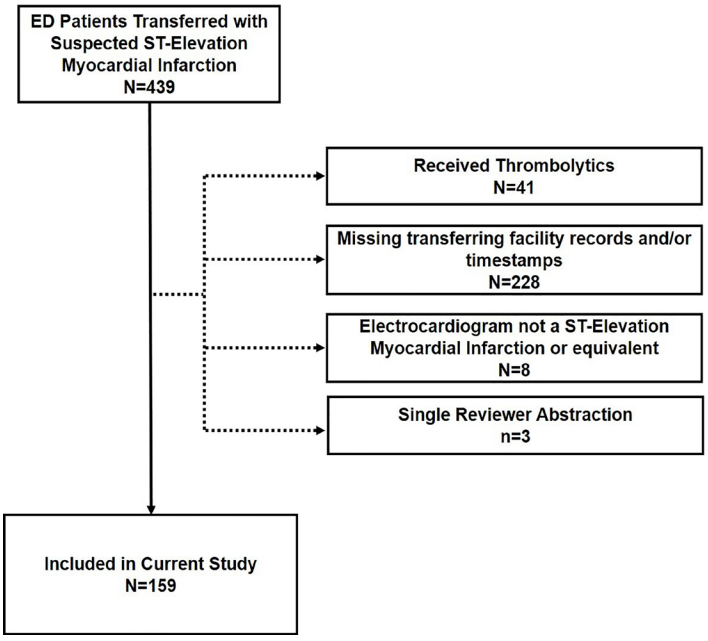


**Figure 1.** CONSORT Diagram for study population.
*ED,* emergency department.

a median of 58 years old (interquartile range [IQR]50, 67), 78% male, and 93% White; 59% arrived to the ED by private vehicle, and 75% presented after hours (Tables 1-2). The median ECG-to-EMS activation interval was 20 minutes (IQR 11, 36), whereas ECG-to-percutaneous coronary intervention activation was 28 minutes (IQR 18, 44) representing 32%, and 46% of the overall ED length of stay, respectively. Transfers with EMS activation first had an 11-minute shorter ECG-to-ED exit interval (61 vs 72 minutes, $P = 0.047$). However, ED arrival-to-percutaneous coronary intervention start was not different when EMS was activated first (108 vs 118 minutes, $P = 0.07$). Among transfers with an ED length of stay ≤60 minutes, 75% (N = 66) had an ECG-to-EMS activation ≤20 minutes. However, only 50% (N = 33) of such transfers with an ED length of stay ≤60 had an ECG-to-percutaneous coronary intervention activation that was ≤20 minutes. Figure 2 shows the relative distribution of these two intervals.

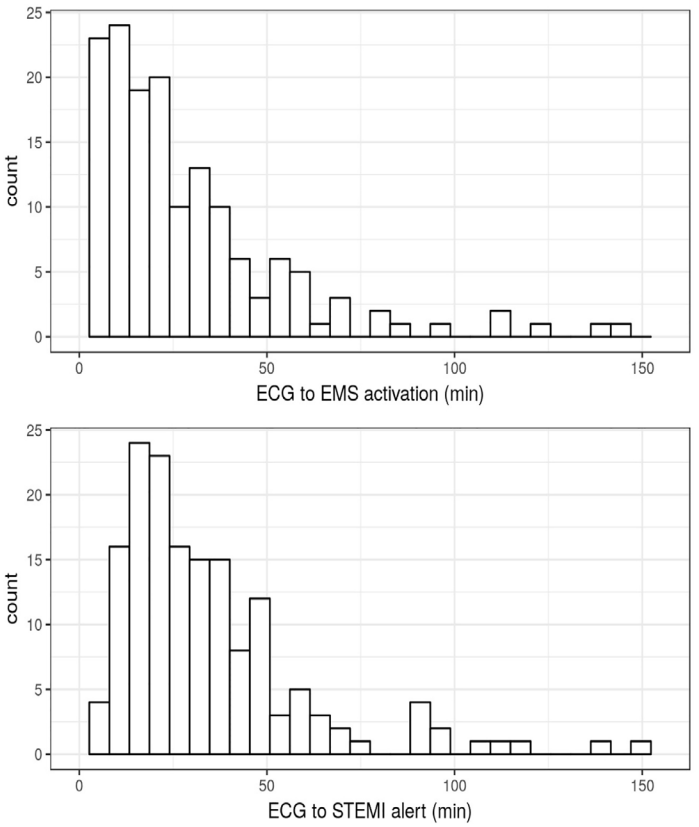


**Figure 2.** Histogram of electrocardiogram (ECG)-to-emergency medical services activation and ECG-to-percutaneous coronary intervention activation intervals. ECGs used were those diagnostic of ST-elevation myocardial infarction (STEMI).
*min,* minutes.

### Multivariable Modeling

Given the relative importance of the ECG-to-EMS activation interval in reducing the ED length of stay, we focused on this interval for the multivariable generalized linear model. Multivariable modeling showed that after-hours presentation was associated with shorter ECG-to-EMS activation (adjusted relative risk [RR] 0.81, 95% confidence interval [CI], 0.76, 0.87, $P<0.001$). Similarly, female gender (adjusted RR 0.82, 95% CI, 0.76, 0.89, $P<0.001$) and

**Table 1.** Descriptive statistics of percutaneous coronary intervention activation timing relative to emergency medical services activation, and for those transfers above and below 60 minutes by patient demographics.

| Variable | EMS Activation After PCI Activation N=28 | EMS Activation Before PCI Activation N=131 | P-value | ED LOS ≤ 60 min N=66 | ED LOS > 60 min N=93 | Combined N=159 | P-value |
|---|---|---|---|---|---|---|---|
| Demographics* | | | | | | | |
| Age, median (IQR)** | 55 (48,60) | 59 (50,68) | 0.11 | 56 (50,65) | 59 (50,67) | 58 (50,67) | 0.6 |
| Female gender | 0.14 (4) | 0.24 (31) | 0.28 | 0.21 (14) | 0.23 (21) | 0.22 (35) | 0.84 |
| Race | | | 0.38 | | | | 0.72 |
| White | 0.89 (25) | 0.94 (123) | | 0.94 (62) | 0.92 (86) | 0.93 (148) | |
| Black or African American | 0.11 (3) | 0.06 (8) | | 0.06 (4) | 0.08 (7) | 0.07 (11) | |
| Insurance | | | 0.57 | | | | 0.37 |
| Private | 0.46 (13) | 0.36 (47) | | 0.39 (26) | 0.37 (34) | 0.38 (60) | |
| Medicare | 0.32 (9) | 0.36 (47) | | 0.29 (19) | 0.40 (37) | 0.35 (56) | |
| Medicaid | 0.07 (2) | 0.05 (6) | | 0.08 (5) | 0.03 (3) | 0.05 (8) | |
| None | 0.14 (4) | 0.24 (31) | | 0.24 (16) | 0.20 (19) | 0.22 (35) | |
| Private vehicle arrival to ED | 0.71 (20) | 0.56 (74) | 0.14 | 0.55 (36) | 0.62 (58) | 0.59 (94) | 0.32 |
| Transfers in the past year | 9 (3,12) | 11 (3,16) | 0.25 | 14.0 (9.0,20.5) | 5.0 (2.0,13.0) | 10.0 (3.0,16.0) | <0.001 |
| After-hours presentation | 0.86 (24) | 0.73 (96) | 0.17 | 0.73 (48) | 0.77 (72) | 0.75 (120) | 0.5 |
| Comorbidities | | | | | | | |
| Hypertension | 0.71 (20) | 0.68 (89) | 0.72 | 0.70 (46) | 0.68 (63) | 0.69 (109) | 0.79 |
| Smoker | 0.43 (12) | 0.54 (71) | 0.28 | 0.53 (35) | 0.52 (48) | 0.52 (83) | 0.86 |
| Dyslipidemia | 0.68 (19) | 0.41 (54) | 0.01 | 0.48 (32) | 0.44 (41) | 0.46 (73) | 0.58 |
| Diabetes | 0.39 (11) | 0.25 (33) | 0.13 | 0.24 (16) | 0.30 (28) | 0.28 (44) | 0.41 |
| Prior PCI | 0.32 (9) | 0.16 (21) | 0.048 | 0.14 (9) | 0.23 (21) | 0.19 (30) | 0.15 |
| Prior CABG | 0.07 (2) | 0.11 (14) | 0.57 | 0.08 (5) | 0.12 (11) | 0.10 (16) | 0.38 |
| Peripheral Artery Disease | 0.18 (5) | 0.06 (8) | 0.039 | 0.06 (4) | 0.10 (9) | 0.08 (13) | 0.41 |
| Heart Failure | 0.04 (1) | 0.08 (10) | 0.44 | 0.05 (3) | 0.09 (8) | 0.07 (11) | 0.32 |
| Dialysis | 0.00 (0) | 0.02 (2) | 0.51 | 0.02 (1) | 0.01 (1) | 0.01 (2) | 0.81 |
| 30-Day Mortality | 0.04 (1) | 0.11 (14) | 0.24 | 0.11 (7) | 0.09 (8) | 0.09 (15) | 0.67 |

*Demographics are reported in proportion with sample size in parentheses.
**Time intervals are presented in medians with interquartile ranges in parentheses.
*EMS,* emergency medical services; *PCI,* percutaneous coronary intervention; *CABG,* coronary artery bypass graft; *ED,* emergency department; *LOS,* length of stay; *IQR,* interquartile range.

increased interfacility transfers in the past year (adjusted RR 0.75, 95% CI 0.71, 0.80, $P<0.001$) were associated with shorter ECG-to-EMS activation (Table 3).

## DISCUSSION

This work advances our understanding of ED interfacility transfer for suspected STEMI patients through two key findings: 1) activating EMS earlier is more likely to reduce the amount of time spent at the transferring ED than percutaneous coronary intervention center activation; and 2) higher transfer volume in the past year, female gender, and after-hours presentations were associated with improved timeliness of EMS activation. These findings support policies that prioritize rapid EMS activation at the transferring ED. Further, these findings suggest that the increased interfacility familiarity that accompanies higher transfer volume may be a modifiable target for intervention to reduce STEMI transfer delays. Through reduction of transfer delays we seek to improve the timeliness of reperfusion as this is essential to optimizing patient outcomes.

Our findings have practical implications for emergency clinicians who must transfer a patient with a suspected STEMI. This research provides evidence to support the clinician's decision to activate EMS (ie, transportation) prior to calling the percutaneous coronary intervention center. We found that EMS activation can be an important

**Table 2.** Descriptive statistics of percutaneous coronary intervention activation timing relative to emergency medical services activation, and for those transfers above and below 60 minutes by time intervals.

| Variable | N | EMS activation after PCI activation N=28 | EMS activation before PCI activation N=131 | P-value | ED LOS ≤ 60 min N=66 | ED LOS > 60 min N=93 | Combined N=159 | P-value |
|---|---|---|---|---|---|---|---|---|
| Time intervals | | | | | | | | |
| Total ED LOS | 159 | 68 (59,101) | 65 (50,79) | 0.083 | 48.0 (40.0,53.8) | 79.0 (68.0,102.0) | 65.0 (50.5,84.5) | <0.001 |
| ED arrival to ECG | 159 | 6 (0.25,9.25) | 4.00 (0.00,9.00) | 0.47 | 3.00 (-10.75,6.75) | 6.00 (2.00,10.00) | 5.00 (0.00,9.00) | <0.001 |
| ECG to EMS activation | 159 | 38 (17,61) | 19 (9,32) | <0.001 | 12.0 (7.2,20.0) | 31.0 (17.0,51.0) | 11.0 (20.0,36.5) | <0.001 |
| ECG to PCI activation | 159 | 32 (17,46) | 28 (18,42) | 0.85 | 20 (14,26) | 38 (27,53) | 28 (18,44) | <0.001 |
| EMS activation to ED exit | 159 | 35 (22,41) | 40 (32,49) | 0.005 | 33.5 (28.2,39.0) | 45.0 (38.0,52.0) | 39.0 (30.5,47.5) | <0.001 |
| PCI activation to ED exit | 159 | 39 (30,46) | 30 (22,39) | 0.002 | 26 (18,34) | 37 (26,48) | 32 (23,39) | <0.001 |
| PCI activation to EMS activation | 159 | 4.5 (0.0,10.2) | -9.0 (-13.0,-5.0) | <0.001 | -7.0 (-10.8,-4.0) | -7.0 (-12.0,-2.0) | -7.0 (-12.0,-3.0) | 0.86 |
| ECG to ED exit | 159 | 72 (56,91) | 61 (46,78) | 0.047 | 46 (40,52) | 78 (63,96) | 62 (48,82) | <0.001 |
| ED exit to PCI center arrival | 159 | 22 (17,36) | 23 (19,32) | 0.94 | 22 (16,27) | 25 (20,37) | 23 (18,33) | 0.007 |
| PCI center arrival to PCI start | 158 | 20 (14,24) | 19 (15,24) | 0.79 | 19.0 (16.0,23.8) | 19.0 (14.0,24.0) | 19.0 (15.0, 24.0) | 0.74 |
| ED arrival to PCI start | 158 | 122 (100,158) | 112 (93,132) | 0.076 | 89 (77,100) | 132 (116,158) | 113 (94,140) | <0.001 |

*Time intervals are presented in medians with interquartile ranges in parentheses.
*EMS,* emergency medical services; *PCI,* percutaneous coronary intervention; *ED,* emergency department; *LOS,* length of stay; *ECG,* electrocardiogram.

rate-limiting step in the timely transfer of patients with suspected STEMI. Three quarters of all transfers that had an ED length of stay less than 60 minutes had EMS activated in 20 minutes or less. This finding provides additional evidence supporting the use of early EMS activation in clinical practice.[4]

The activation of EMS likely plays such an important role in the transfer process because the patient cannot leave until EMS arrives to physically transport the patient. On the other hand, while percutaneous coronary intervention center activation is important and necessary, the timing of this process appears to be less consequential. Although no formal policy exists at this study setting regarding the activation of EMS, in other settings, some EMS agencies still require an accepting physician name prior to transportation. Auto-acceptance protocols may work by simplifying the transfer process and improving the relationship between organizations by enhancing the likelihood that potential transfers will be accepted by the percutaneous coronary intervention center. As seen in this study, activating EMS prior to the percutaneous coronary intervention center activation was common practice despite no formal policy existing. In settings in which no formal policy exists regarding activating EMS prior to contacting the percutaneous coronary intervention center, incorporating such guidance into transfer center policies and protocols could be a strategy to enhance uptake of early EMS activation.

We also identified that higher transfer volumes in the past year may also have reduced the time to activate EMS. More transfers may indirectly enhance the working relationship between facilities through organizational learning and improved timeliness. Research on interorganizational relationships also suggests that system membership and frequency of transfers may be related with timeliness of care.[11,12] However, with a decreasing incidence of STEMIs,[13] volume may no longer be sufficient to maintain preparedness and efficiency for transfers. Building higher quality interorganizational relationships may be an alternative strategy in the absence of a sufficient volume

**Table 3.** Results from the generalized linear regression models investigating the association of the electrocardiogram-to-emergency medical services activation interval to a priori selected covariates.

| | Univariate | | | Multivariable | | |
|---|---|---|---|---|---|---|
| Covariate | aOR | 95% CI | P | aOR | 95% CI | P |
| Age | 0.99 | (0.95, 1.03) | 0.64 | 1.02 | (0.98, 1.06) | 0.39 |
| Transfers to PCI center in past year | 0.77 | (0.73, 0.81) | <0.001 | 0.75 | (0.71, 0.80) | <0.001 |
| Distance from PCI center | 1.17 | (1.11, 1.23) | <0.001 | 1.01 | (0.94, 1.07) | 0.87 |
| Gender: female vs male (ref) | 0.86 | (0.80, 0.93) | <0.001 | 0.82 | (0.76, 0.89) | <0.001 |
| Presentation time: after hours vs weekday (ref) | 0.82 | (0.77, 0.88) | <0.001 | 0.81 | (0.76, 0.87) | <0.001 |
| Mode of transport to ED: EMS vs personal (ref) | 0.93 | (0.87, 0.99) | 0.01 | 0.94 | (0.89, 1.00) | 0.06 |

*Unless otherwise noted, odds ratios for continuous variables are comparing a change from the 25th to the 75th percentile.
*aOR,* adjusted odds ratio; *CI,* confidence interval; *PCI,* percutaneous coronary intervention; *ED,* emergency department; *EMS,* emergency medical services.

of patients who may benefit from timely transfers. Such strategies may include meeting staff/leadership from partner facilities, post-event communication (eg, patient outcome reports), and video communication to enhance interaction.[14]

## LIMITATIONS

Some limitations of this work should be considered. First, we conducted a retrospective analysis of patients with suspected STEMI transferred for primary percutaneous coronary intervention. Not all patients were ultimately diagnosed with STEMI, but the transferring ED and receiving percutaneous coronary intervention center operated as if it were a STEMI. This may, in part, account for our finding of improved timeliness in EMS activation for female patients who typically are less likely to receive percutaneous coronary intervention due to atypical presentations. Further, lack of severity at presentation may confound this finding. To enhance the quality of the retrospective data collection, we used dual abstractor review; however, transferring records might not have been available or potentially conflicting because organizational documentation and charting requirements might have been different (Figure 1). For example, some may have required the collection of specific data elements (eg, physician conversation time) or have a charting template for STEMI. To handle this, we established a hierarchy of quality of evidence. Finally, our study used a single percutaneous coronary intervention center with more than 40 transferring EDs. Evaluation of our findings in other settings is needed to enhance their generalizability and representativeness.

## CONCLUSION

Time spent at transferring EDs for patients with ST-elevation myocardial infarction is more dependent on activating emergency medical services rather than activation of the percutaneous coronary intervention center. Emphasizing this process and formally incorporating it into operational policies may improve transfer timeliness and subsequently reperfusion times.

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# Suicide Among the Emergency Medical Systems Occupation in the United States

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**Introduction:** Suicide claimed 47,173 lives in 2017 and is the second leading cause of death for individuals 15-34 years old. In 2017, rates of suicide in the United States (US) were double the rates of homicide. Despite significant research funding toward suicide prevention, rates of suicide have increased 38% from 2009 to 2017. Recent data suggests that emergency medical services (EMS) workers are at a higher risk of suicidal ideation and suicide attempts compared to the general public. The objective of this study was to determine the proportionate mortality ratio (PMR) of suicide among firefighters and emergency medical technicians (EMT) compared to the general US working population.

**Methods:** We analyzed over five million adult decedent death records from the National Occupational Mortality Surveillance database for 26 states over a 10-year non-consecutive period including 1999, 2003–2004, and 2007–2013. Categorizing firefighters and EMTs by census industry and occupation code lists, we used the underlying cause of death to calculate the PMRs compared to the general US decedent population with a recorded occupation.

**Results:** Overall, 298 firefighter and 84 EMT suicides were identified in our study. Firefighters died in significantly greater proportion from suicide compared to the US.working population with a PMR of 172 (95% confidence interval [CI], 153-193, P<0.01). EMTs also died from suicide in greater proportion with an elevated PMR of 124 (95% CI, 99-153), but this did not reach statistical significance. Among all subgroups, firefighters ages 65-90 were found to have the highest PMR of 234 (95% CI, 186-290), P<0.01) while the highest among EMTs was in the age group 18-64 with a PMR of 126 (95% CI, 100-156, P<0.05).

**Conclusion:** In this multi-state study, we found that firefighters and EMTs had significantly higher proportionate mortality ratios for suicide compared to the general US working population. Firefighters ages 65-90 had a PMR more than double that of the general working population. Development of a more robust database is needed to identify EMS workers at greatest risk of suicide during their career and lifetime. [West J Emerg Med. 2021;22(2):326-332.]

## INTRODUCTION

Suicide is a leading cause of death in the United States (US), claiming the lives of over 47,000 Americans in 2017.[1] Suicide is the 10th leading cause of death for all ages in the US and the second leading cause of death for people ages 15–34. In 2017, rates of suicide in the US were double the rates of homicide.[1] In an attempt to address this public health problem, the National Institutes of Health increased funding

for suicide prevention from $39 million in 2008 to $103 million in 2017.[1] Despite these efforts, rates of suicide have increased 38% since 1999 from 10.48 per 100,000 to 14.48 per 100,000 in 2017.[1]

In an attempt to address increasing suicide rates in the US, researchers have sought to identify leading risk factors of suicide as well as populations at greatest risk.[1-6] National surveys suggest that emergency medical services (EMS) workers, including firefighters and emergency medical technicians (EMT), are at higher risk of experiencing suicidal ideation and suicide attempts compared to the general public.[7-10] These elevated levels of suicidal ideation and suicide attempts are hypothesized to be the result of the occupational hazards associated with the EMS profession, which include routine exposure to high levels of physical and psychological stress.[2,3,11]

While several studies have quantified individual risk factors among EMS workers, there is scant published research on completed suicide in this population. We analyzed the National Occupational Mortality Surveillance (NOMS) database to examine the proportion of death by suicide among firefighters and EMTs compared to other US decedents with a recorded occupation.

*Population Health Research Capsule*

What do we already know about this issue?
*Emergency medical services (EMS) workers have a higher risk of suicidal ideation and attempts compared to the general public, possibly the result of occupational exposures.*

What was the research question?
*Do EMS workers commit suicide at a higher proportion compared to the general US working population?*

What was the major finding of the study?
*Suicide among EMS workers was proportionately higher than the general US working population.*

How does this improve population health?
*Identifying those at highest risk of suicide during their lifetime is a critical step in developing crucial prevention strategies and resources.*

## METHODS

### *Study Design*

This was a retrospective study of 10 years of mortality data from the NOMS database. The NOMS database is maintained by the National Institute for Occupational Safety and Health (NIOSH) and is used to periodically monitor causes of death across occupations and industries to facilitate occupational mortality surveillance over time.[12] The database collects mortality records for decedents ages 18-90 with a recorded occupation. The dataset used in our analysis includes 5,070,335 adults, ages 18-90, whose records of death were collected from state-level vital statistics offices over 10 non-consecutive years during 1999, 2003-2004, and 2007-2013.[12]

We used proportionate mortality ratio (PMR) analysis to determine the pattern of suicide by occupation.[13] A PMR indicates whether a proportion of deaths due to a specific cause is high or low for a particular population and therefore approximates the death rate. We chose the PMR to assess risk for this study instead of other estimations of risk due to the difficulty in accurately estimating the at-risk population for a given year based on job code. The PMR Query System calculates PMRs by occupation by comparing the proportion of deaths from a specific cause within a specific occupation with the proportion of deaths due to that cause across all occupations (multiplied by 100). This can be further stratified by age, race, and gender. A PMR of greater than 100 is considered elevated over all other occupations combined.[12] A regulatory determination that this study was not human subjects research, as defined by 45 CFR 46.102(f), was approved by the University of Arizona Human Subjects Protection Program institutional review board.

### *Study Setting and Population*

A total of 26 states contributed mortality data to the NOMS dataset used in our analysis. Death certificates were completed by funeral directors and medical certifiers and contained unique fields including the cause of death, usual occupation, and demographic information. Underlying cause of death mortality data were coded utsing the International Classification of Diseases, 10th Edition (ICD–10).[14] We collected records of decedents with a known occupation from Colorado, Florida, Georgia, Hawaii, Idaho, Indiana, Kansas, Kentucky, Louisiana, Michigan, North Carolina, North Dakota, Nebraska, New Hampshire, New Jersey, New Mexico, Nevada, Ohio, Rhode Island, South Carolina, Texas, Utah, Vermont, Washington, Wisconsin, and West Virginia. The population at risk includes all men and women ages 18–90 with a known occupation who were at risk of dying over the study period. Access to PMRs, methods, and further information is available at https://www.cdc.gov/niosh/topics/noms.[15]

### *Data Collection and Processing*

We collected NOMS data from the NOMS electronic PMR Query System.[16] The NOMS dataset included age, race, gender, underlying cause of death, and occupation. EMS occupations used in this study included firefighters and EMTs. EMT deaths were inclusive of paramedic death records in accordance with current US Centers for Disease Control and Prevention occupational coding. Occupation fields were coded using the

NIOSH 1990 or 2000 census industry occupation code lists based on the year of death. Firefighters were categorized using the 1990 census occupation codes 413 (supervisors, firefighting, and fire prevention occupations) and 417 (firefighting occupations) or 2000 census occupation codes 372 (first-line supervisors/managers of firefighting and prevention workers) and 374 (firefighters).

The 2000 census established occupation code 340 (EMTs and paramedics), which was used to categorize EMTs and paramedics in this study.[12] Prior to the 2000 census, EMTs and paramedic deaths were not recorded with a unique occupation code. Due to the inability to identify EMT deaths prior to the incorporation of the 2000 census industry and occupation code list, our study did not include EMT deaths prior to the year 2000. For this study, suicide was defined as ICD-10 codes X60-X84 and Y87.0.[14] We excluded decedents who were students, volunteers, unemployed, or had an unknown occupation or industry.

*Data Analysis*

We calculated PMRs for groups stratified by race (White, Black, all races combined), age (18-64, 65-90, 18-90), and gender (male, female) using the PMR Query System developed by NIOSH.[17] PMRs are calculated when the total population at risk is not known and rates of death or standardized mortality ratios (SMR) cannot be calculated.[18] A rate of death or SMR could not be calculated for this occupation-based analysis due to the total number of workers in EMS being unknown. We calculated 95% confidence intervals (CI) for the observed PMRs. If the observed number of deaths for an occupation was 1000 or less, we calculated the 95% CI based on the Poisson distribution, while for occupations with greater than 1000 deaths CIs were calculated using the Mantel and Haenszel chi-square test.[19,20] Due to confidentiality agreements with the reporting states, the number of deaths are reported in tables as "<5," when a cell is based on fewer than five deaths.

## RESULTS

There were 5,070,335 deaths entered into the NOMS database during the study period. Of those deaths, there were 298 firefighter and 84 EMT deaths attributed to suicide (Table 1). The PMR for firefighters ages 18–90 was 172 (95% CI, 153–193, $P<0.01$] compared to the general US working population (Table 2). When stratified for age the PMR for firefighters 18-64 years old was 157 (95% CI, 136–179), $P<0.01$), and 65-90 years old was 234 (95% CI, 186–290, $P<0.01$) (Table 2). A trend toward elevated PMR for EMTs was observed compared to the general US working population with a PMR of 124 (95% CI, 99-153), however, this trend did not reach statistical significance (Table 3). When stratified for age, the PMR for EMTs 18-64 years old was 126 (95% CI, 100–156, $P<0.05$) (Table 3). PMR for EMTs 65-90 years old could not be calculated due to confidentiality agreements with suicides <5. The PMR for White male firefighters ages 18–90 was 130 (95% CI, 114–147, $P<0.01$], ages

**Table 1.** Suicide in US working firefighters and emergency medical technicians ages 18–90 NIOSH surveillance, 1999, 2003–2004, 2007–2013.

| Age group | Firefighter suicides | EMT suicides |
|---|---|---|
| 18-90 | 298 | 84 |
| 18-64 | 215 | 83 |
| 65-90 | 83 | <5* |

*Due to confidentiality agreements with states, the number of deaths are reported in tables as "<5" when a cell is based on less than five deaths.
*NIOSH,* National Institute for Occupational Safety and Health; *EMT,* emergency medical technician.

**Table 2.** Proportionate Mortality Ratios (PMR)[A] for Suicide: Firefighters by age, gender, and race ages 18–90, vs. U.S. working population NIOSH National Occupational Mortality Surveillance (NOMS), 1999, 2003–2004, 2007–2013.

| | Suicides | PMR | 95% CI |
|---|---|---|---|
| Firefighters | | | |
| Age group | | | |
| 18–90 years old | 298 | 172** | 153–193 |
| 18–64 years old | 215 | 157** | 136–179 |
| 65–90 years old | 83 | 234** | 186–290 |
| White males | | | |
| 18–90 years old | 258 | 130** | 114–147 |
| 18–64 years old | 177 | 126** | 108–146 |
| 65–90 years old | 81 | 139** | 111–173 |
| Black males | | | |
| 18–90 years old | 8 | 160 | 69–316 |
| 18–64 years old | 8 | 177 | 77–349 |
| 65–90 years old | <5[B] | – | – |
| White females | | | |
| 18–90 years old | 8 | 175 | 76–345 |
| 18–64 years old | 8 | 184 | 80–363 |
| 65–90 years old | <5[B] | – | – |
| Black females | | | |
| 18–90 years old | <5[B] | – | – |
| 18–64 years old | <5[B] | – | – |
| 65–90 years old | <5[B] | – | – |

A. A PMR greater than 100 is considered elevated over the average compared to the general United State's working population.
B. Due to confidentiality agreements with states, the number of deaths are reported in tables as '<5' when a cell is based on less than 5 deaths, making the exact calculation of death in that category impossible.
* indicates a significance (P-value) < 0.05
** indicates a significance (P-value) < 0.01
*PMR,* proportionate mortality ratio; *CI,* confidence interval.

**Table 3.** Proportionate Mortality Ratios (PMR)[A] for Suicide: EMTs by age, gender, and race Ages 18–90, vs. U.S. working population NIOSH National Occupational Mortality Surveillance (NOMS), 1999, 2003–2004, 2007–2013.

| | Suicides | PMR | 95% CI |
|---|---|---|---|
| EMTs | | | |
| Age Group | | | |
| 18–90 years old | 84 | 124 | 99–153 |
| 18–64 years old | 83 | 126* | 100–156 |
| 65–90 years old | <5[B] | – | – |
| White Males | | | |
| 18–90 years old | 62 | 102 | 78–131 |
| 18–64 years old | 61 | 103 | 79–133 |
| 65–90 years old | <5[B] | – | – |
| Black Males | | | |
| 18–90 years old | <5[B] | – | – |
| 18–64 years old | <5[B] | – | – |
| 65–90 years old | <5[B] | – | – |
| White Females | | | |
| 18–90 years old | 17 | 132 | 77–212 |
| 18–64 years old | 17 | 135 | 79–217 |
| 65–90 years old | <5[B] | – | – |
| Black Females | | | |
| 18–90 years old | <5[B] | – | – |
| 18–64 years old | <5[B] | – | – |
| 65–90 years old | <5[B] | – | – |

A. A PMR greater than 100 is considered elevated over the average compared to the general United State's working population.
B. Due to confidentiality agreements with states, the number of deaths are reported in tables as '<5' when a cell is based on less than 5 deaths, making the exact calculation of death in that category impossible.
* indicates a significance (P-value) < 0.05
** indicates a significance (P-value) < 0.01
*PMR,* proportionate mortality ratio; *CI,* confidence interval.

18–64 was 126 (95% CI, 108–146, $P<0.01$], and ages 65–90 was 139 (95% CI, 111–173, $P<0.01$]) (Table 2).

## DISCUSSION

Our study identified a significantly higher proportion of completed suicides in firefighters ages 18-90 and EMTs ages 18-64 compared to the general US working population. Although there is previous research showing increased firefighter and EMT risk for suicidal ideation, this is the first multi-state study to our knowledge suggesting a higher rate of completed suicide for EMTs and firefighters.

While there are multiple studies examining law enforcement suicide, there is a paucity of data regarding this topic in firefighters and EMTs.[21-23] Those studies available suggest that firefighters have an increased prevalence of suicidal ideation, plans, and attempts (46.8%, 19.2%, and 15.5%,) compared to the general population (13.5%, 3.9%, and 4.6%).[7,22,24] Despite increased suicide risk factors, five previous mortality studies found a decreased SMR for suicide among firefighters during the period 1915-1999, which is in contrast to our results.[25-29] The era in which the mortality data for these studies were collected may provide insight into our differing conclusions. Vigil et al (2018) identified changes to the role of a firefighter from fire suppression to emergency medical aid in the later 20th century, with the development of the modern-day EMS system.[2] In the modern-day EMS system firefighters are often dispatched as the closest available first responder in addition to a transport-capable EMS unit, and frequently arrive up to several minutes prior to a transport-capable EMS unit.[30] From 1999 to 2013 fire calls decreased nationally by 31% from 1,823,000 to 1,240,000, while medical aid calls have increased by 198% from 11,484,000 to 22,750,500.[31]

Although studies prior to 1999 do not show elevated suicide mortality ratios among firefighters, a more recent study from Arizona found that EMS providers are significantly more likely to die from suicide than the general population.[2] EMTs had an odds ratio of 1.39 for suicide over a seven-year period from 2009-2015.[2] While this was a single-state study, the results are consistent with our findings on the national level.

EMS personnel are exposed to many stressors and traumatic events that have been shown to place them at greater risk for mental health disorders and suicidal behavior.[32,33] These often comorbid risk factors include alcohol use, sleep disturbances, post-traumatic stress, and chronic exposure to stress in the workplace.[34-38] An important modifiable stressor that members of EMS regularly encounter is chronic sleep deprivation, which has been found to increase rates of suicide.[39-41] Chronic sleep deprivation among EMS workers is common, and workers are required to respond to urgent calls disrupting normal sleep patterns.[42-44] Sleep deprivation has also been shown to exacerbate comorbid risk factors for suicide such as post-traumatic stress disorder (PTSD) and depression, which is prevalent among EMS workers.[45,46] Those with PTSD have reported sleep disturbances as high as 91% and nightmares as high as 71%.[47]

Furthermore, alcohol abuse may play a role in the elevated risk of suicide among EMS providers. Researchers hypothesize that firefighters may drink excessive amounts of alcohol in an attempt to suppress the symptoms of PTSD.[50] In a survey of 656 firefighters, more than 50% reported recent heavy or binge drinking, while 9% reported driving while intoxicated.[51,52] The combination of alcohol and PTSD significantly increases the likelihood of suicidal behavior.[50]

Repeated exposures to traumatic events may also place EMS providers at increased risk of suicide. In a recent survey of 1789 EMS workers, 69% reported experiencing violence directed at them in the prior 12 months.[48] Of particular importance, exposure to suicides has been shown to independently increase the risk of suicidal ideation.[49] Kimbrel

et al (2016) found that 100% of firefighter respondents reported at least one suicide exposure, and found that firefighters with 12 or more suicide exposures had a lifetime suicidal ideation rate of 61.1% compared to 31.6% for those with 11 or fewer.[49] Additionally, stressful situations with a low threshold for failure have been proposed as a cause for increased suicide rates in EMS workers.[37] These situations place firefighters and EMTs at risk for increased rates of anxiety and depression, both of which have been implicated in increased risk for suicide.[36]

Our findings, combined with the multiple suicide risk factors previously found among EMS workers, highlights the urgent need for further research among this at-risk cohort. In addition to further exploration of suicide in EMS workers, focused investigation of retirement age (65-90) firefighters is needed. Our study's finding of a PMR of 234 within this subgroup may indicate that the elevated risk of suicide in this occupation may extend far beyond the time one leaves the job. Additionally, EMS workers may benefit from identification and implementation of effective interventions to reduce the risk of suicide.

## LIMITATIONS

We have identified several limitations in our study. First, the use of PMRs are susceptible to biases including regression to the null, "Healthy Worker Effect," and over- or under-representation of mortality from other causes of death.[23,53,54] Our study used the PMR because the total at-risk (currently living) population of firefighters and EMTs was unknown.

There are limitations when working with census data and occupational death reporting. As we stated above, EMT and paramedic job codes were not included on occupational death certificates prior to 2000, this could be a reason that the PMR for EMT suicide we observed did not achieve statistical significance. Misclassification of occupation may have occurred because information on death certificates was recorded by funeral directors and medical certifiers. However, Petersen et al (1974) reported an 80% accuracy of occupations listed on death certificates compared to surviving family-member interviews.[55,56] Death records assign a single occupation to each decedent, potentially under-representing EMTs and firefighters with second careers. Suicides may have been misclassified as a non-suicide resulting in fewer reported suicides as has been demonstrated with suicide among police officers.[57] A final possible confounding factor with occupational death reporting of this nature is that the decedent's place of residence may not accurately represent the same locality as their place of work.

## CONCLUSION

In this multi-state study, firefighters and EMTs had significantly higher proportionate mortality ratios for suicide compared to the general US working population. Firefighters ages 65-90 had a PMR more than double that of the general working population. Development of a more robust database is needed to identify EMS workers at greatest risk of suicide during their career and lifetime.

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# Emergency Department and Urgent Care Medical Malpractice Claims 2001–15

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**Introduction:** This study reviews malpractice, also called medical professional liability (MPL), claims involving adult patients cared for in emergency departments (ED) and urgent care settings.

**Methods:** We conducted a retrospective review of closed MPL claims of adults over 18 years, from the Medical Professional Liability Association's Data Sharing Project database from 2001–2015, identifying 6,779 closed claims. Data included the total amount, origin, top medical specialties named, chief medical factors, top medical conditions, severity of injury, resolution, average indemnity, and defense costs of closed claims.

**Results:** Of 6,779 closed claims, 65.9% were dropped, withdrawn, or dismissed. Another 22.8% of claims settled for an average indemnity of $297,709. Of the 515 (7.6%) cases that went to trial, juries returned verdicts for the defendant in 92.6% of cases (477/515). The remaining 7.4% of cases (38/515) were jury verdicts for the plaintiff, with an average indemnity of $816,909. The most common resulting medical condition cited in paid claims was cardiac or cardiorespiratory arrest (10.4%). Error in diagnosis was the most common chief medical error cited in closed claims. Death was the most common level of severity listed in closed (38.5%) and paid (42.8%) claims. Claims reporting major permanent injury had the highest paid-to-closed ratio, and those reporting grave injury had the highest average indemnity of $686,239.

**Conclusion:** This retrospective review updates the body of knowledge surrounding medical professional liability and represents the most recent analysis of claims in emergency medicine. As the majority of emergency providers will be named in a MPL claim during their career, it is essential to have a better understanding of the most common factors resulting in MPL claims. [West J Emerg Med. 2021;22(2):333–338.]

## INTRODUCTION

Among the challenges in emergency departments (ED) is providing quality care to patients with high-risk diagnoses under the pressures of limited information and increasing demands on time. This complex environment inherently lends itself to potential medical errors and possible resulting litigation. The threat of a malpractice lawsuit partially drives physicians' clinical decision-making in such environments. A survey performed by the Harvard School of Public Health and Columbia Law School found that 93% of physicians in high-risk specialties change their clinical decision-making due to concern of a malpractice suit, a behavior commonly referred to as "defensive medicine."[1]

A prior study by Brown et al. in 2010 examined 11,529 closed medical professional liability (MPL) claims originating

from EDs for adult patients between 1987–2007 using a database from the Physician Insurers Association of America (the former name of the MPL Association).[2] The changing landscape of MPL due to tort reform, fluctuations in malpractice insurance premiums, and regulatory interference underscores the need for a more contemporary analysis of the MPL data. This study reviewed MPL claims involving adult patients (over 18 years old) cared for in ED and urgent care settings and provides an update of characteristics in closed MPL claims from 2001–2015.

*Population Health Research Capsule*

What do we already know about this issue?
*Approximately 75% of emergency physicians will be named in a malpractice suit during their career and the average time to resolution is 16.7 months per claim.*

What was the research question?
*We sought to characterize closed claims involving adults originating from emergency departments or urgent care centers.*

What was the major finding of the study?
*A total of 65.9% of claims were dropped, 22.8% settled, 7.6% went to trial, 3.3% by private contract, and 0.4% unknown.*

How does this improve population health?
*Understanding the most common factors in recent closed malpractice claims provides important context to improve the care of adults treated in emergency settings.*

## METHODS

In this retrospective review of closed adult MPL claims reported to the Data Sharing Project (DSP) of the MPL Association during a 15-year period (2001–2015), we reviewed 135,490 closed claims. The DSP is the largest independent database of MPL claims and lawsuits, comprised of aggregated and de-identified information from voluntarily participating member insurance companies. The MPL Association represents more than two-thirds of physicians in private practice.

We queried the DSP for MPL claims involving adult patients (older than 18 years) with claims arising from care received in a United States hospital-based ED or ambulatory urgent care center. Information obtained included the medical specialty involved, top resulting medical conditions, chief medical factor, and severity of resulting injury. We analyzed the outcomes of these claims (i.e., dropped, settled, judgment for plaintiff or defendant, etc.), as well as the amount of the award to the plaintiffs and the total defense fees. We summarized data using summary statistics. This study of de-identified data was not considered human subjects research by our institutional review board.

## RESULTS

Of 135,490 MPL claims and lawsuits closed between 2001–2015, 6,779 (5%) involved adult patients over 18 years old in a US hospital-based ED or ambulatory urgent care setting (Figure) (Table 1). The ED represented 5.2% of adult claims from all facilities, and urgent cares represented 0.9% of claims. Of hospital-based origins, the ED was the third most common origin (9.1%) for a claim, following operating rooms (40.7%) and inpatient rooms (15.8%).

Of the 6,779 total claims, 65.9% were dropped, withdrawn or dismissed. Another 22.8% were settled for an average indemnity of $297,709 and an average defense expense of $55,260. Of the 515 (7.6%) cases that went to trial, juries returned verdicts finding for the defendant in 92.6% of cases (477/515). The average defense cost for a verdict in favor of the defendant was $111,446. The remaining 7.4% of cases (38/515) where juries returned verdicts for the plaintiff had an average indemnity of $816,909 and an average defense expense of $159,716. There were 222 claims (3.3%) that resulted in alternative dispute resolution (ADR) or private contract. There were 30 claims (0.4%) with an unknown outcome (Table 2).

Emergency physicians were the primary specialty named in 33.5% of the 6,779 closed claims, followed by internal medicine (12.4%), family practice (9.6%), radiology (7.3%), and general surgery (7.1%).

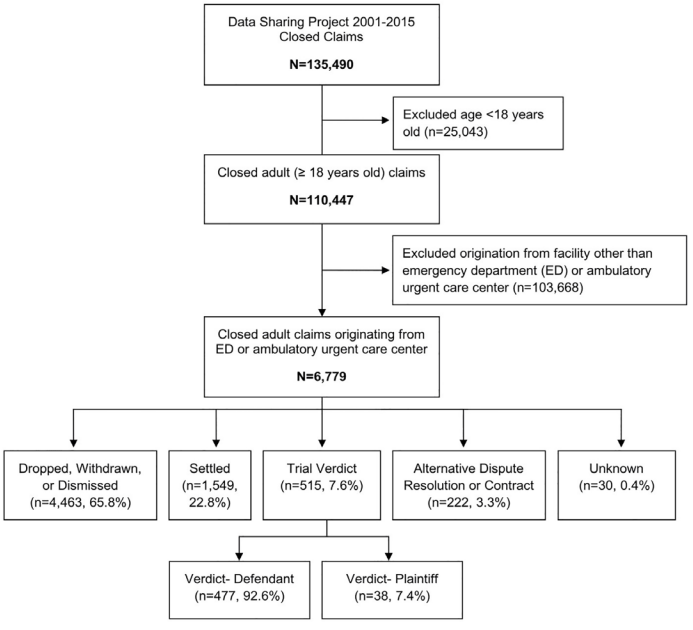


**Figure 1.** Claim resolution of closed claims in adult emergency departments or urgent care settings.

For the 27.1% of closed MPL claims culminating in an indemnity payment (trial verdicts, verdicts for the

**Table 1.** Summary of claims submitted to the Data Sharing Project of the Medical Professional Liability Association during a 15-year period (2001-2015).

| Description | Closed claims | Paid claims | % Paid-to-closed | Average Indemnity | Average defense expense | % of all closed claims | % of all paid claims |
|---|---|---|---|---|---|---|---|
| All claims for patients 18+ years | 110,447 | 30,720 | 27.8 | $308,083 | $41,033 | 81.5% | 85.2% |
| Emergency Department and Urgent Care Claims | 6,779 | 1,799 | 26.5 | $309,908 | $41,047 | 5.0% | 5.0% |
| Emergency Department | 5,737 | 1,499 | 26.1 | $321,034 | $42,602 | 5.2% | 4.2% |
| Urgent Care | 1,042 | 300 | 28.8 | $254,315 | $32,484 | 0.9% | 0.8% |

plaintiff, ADR/contracts, and unknown), the resulting medical conditions most commonly cited were cardiac or cardiorespiratory arrest (9.1%), acute myocardial infarction (4.0%), aortic aneurysm (2.3%), pulmonary embolism (2.2%), and appendicitis (2.0%). Of these, acute myocardial infarction had the highest paid-to-closed ratio with 39% resulting in a payment. Claims for aortic aneurysms generated the highest average indemnity of $369,872 per claim (Table 3).

The chief medical errors cited in MPL closed claims, seen in Table 4, were errors in diagnosis (36.4%); no medical misadventure (19.2%); improper performance (17.7%); failure to supervise or monitor case (5.2%); and medication errors (3.4%).

As seen in Table 5, death was the most common severity of injury cited in closed adult MPL claims, listed in 38.5% of closed claims and 42.8% of paid claims. Claims reporting major permanent injury had the highest percent of paid-to-closed claims (38.3%), and grave injury had the highest average indemnity of $686,239. Emotional injury was the least likely severity of injury to be listed, comprising 0.9% of total claims, in addition to having the lowest paid-to-closed ratio at 11.7%.

## DISCUSSION

Making time-sensitive healthcare decisions for patients with myriad and complex conditions based on limited information is routine for emergency physicians (EP), but not without risk. Compared to other specialties where physicians may avoid caring for high-risk patients in order to mitigate medical liability, EPs are limited in their ability to choose their patient population.[1] The American Medical Association found that 8.7% of respondents in emergency medicine faced a MPL claim in the prior year alone,[3] and it is estimated that over 75% of EPs will be named in a malpractice suit by the end of their career.[4]

In the early 2000s, tort reform "intended to protect physicians who are practicing with incomplete information in high-intensity care settings"[5] changed the definition of when physicians can be named in MPL and the manner in which those claims are resolved. For instance, the definition of malpractice in some states changed from "a deviation in standard care" to "gross negligence,"[5] and over the same time period, nine states set a new cap on damages in MPL cases.[6] Proponents of tort reform argue that these increased protections will result in decreased overall healthcare spending by assuaging physicians' fears and changing their practice patterns; however, that has yet to be borne out in the literature. One analysis of MPL in three states (TX, GA, and SC) in the years immediately before and after tort reform observed no change in three proxies of defensive medicine practices: ordering computed tomography (CT) and magnetic resonance imaging (MRI); hospital admission;, and total charges for ED visits.[5] Similarly, a retrospective study of EPs recently named in a malpractice suit compared to similar, unnamed peers found no difference in what they called care intensity (measured as admission rate or relative value units (RVU) per visit as a proxy for increased testing) or speed (measured as RVUs per hour or length of stay).[7]

Brown et al. examined closed MPL claims originating from

**Table 2.** Resolution and outcomes of closed claims in adult emergency departments or urgent care settings.

| Resolution | Closed claims | Paid claims | % Paid-to-closed | Average indemnity | Average defense expense | % of all closed claims | % of all paid claims |
|---|---|---|---|---|---|---|---|
| Dropped, withdrawn, or dismissed | 4,463 | - | - | $0 | $25,996 | 65.9% | 0.0% |
| Settled | 1,549 | 1,549 | 100.0 | $297,709 | $55,260 | 22.8% | 86.1% |
| Verdict-defendant | 477 | - | - | $0 | $111,446 | 7.0% | 0.0% |
| Verdict-plaintiff | 38 | 38 | 100.0 | $816,909 | $159,716 | 0.6% | 2.1% |
| Alternative dispute resolution/ Contract | 222 | 193 | 86.9 | $279,380 | $70,986 | 3.3% | 10.7% |
| Unknown | 30 | 19 | 63.3 | $600,526 | $55,001 | 0.4% | 1.1% |
| TOTAL | 6,779 | 1,799 | 26.5 | | | | |

**Table 3.** Outcomes of the top five resulting medical conditions cited in closed claims in adult emergency departments or urgent care settings.

| Top 5 resulting medical conditions | Closed claims | Paid claims | % Paid-to-closed | Average indemnity | Average defense expense | % of all closed claims | % of all paid claims |
|---|---|---|---|---|---|---|---|
| Cardiac or cardiorespiratory arrest | 617 | 187 | 30.3 | $340,622 | $54,410 | 9.1% | 10.4% |
| Myocardial infarction, acute | 269 | 105 | 39.0 | $306,487 | $46,447 | 4.0% | 5.8% |
| Aortic aneurysm | 153 | 47 | 30.7 | $369,872 | $43,163 | 2.3% | 2.6% |
| Pulmonary embolism | 147 | 50 | 34.0 | $302,996 | $29,819 | 2.2% | 2.8% |
| Appendicitis | 134 | 39 | 29.1 | $159,815 | $28,432 | 2.0% | 2.2% |

EDs for adult patients from 1987–2007 using an overlapping but different data set. They found an average indemnity of $175,545 in settled claims and an average indemnity of $393,350 in verdicts found for the plaintiff. Of the 11,529 claims identified by their dataset, 64% were withdrawn, dropped, or dismissed with no payment paid to the plaintiff. Error in diagnosis was the most common category of error. Acute myocardial infarction was both the most common specific diagnosis cited and had the highest paid-to-closed ratio in their dataset, with 42% of all claims resulting in a payment.[2]

While there have been previous analyses of MPL, including Brown et al., the source data means no direct comparisons can be made. This retrospective review updates the body of knowledge surrounding medical liability and represents the most recent analysis of claims for adults treated in emergency or urgent care settings. Average indemnity of settled claims in our study (2001–2015) was $297,709, and average indemnity of claims where the plaintiff prevailed was $816,909. The majority of cases (92.6%) that proceeded to trial were found in favor of the defendant. The average defense fee when the verdict found for the defendant was $111,446. Even claims that were dropped, dismissed, or withdrawn had average defense fees of $25,996.

While we did not analyze trends over our study period, a review of all specialties during a similar time range (2004–2016) found an inflation-adjusted increase in all indemnity, with payments related to diagnosis-related errors increasing by 31.2%.[8]

Studies have estimated that EPs face an average time to resolution of 16.7 months for each open claim.[9] This extended period of time has consequences for parties on either side of the claim. Plaintiffs and their families potentially face a delay in compensation, loss of work, and emotional repercussions of a protracted resolution. For physicians among all specialties, 50% of claims that ultimately resulted in no payment took more than one year to be resolved.[9] Lost clinical time,[10] in addition to defense fees and value of lost reputation,[11] may negatively impact physicians, their careers, and their families.

Errors in diagnosis was the most common reason for a claim in this dataset, consistent with other adult[2,12] and pediatric[13,14] emergency medicine studies. Research focusing on the processes leading to an error in diagnosis in the ED identified four main categories: failure to order tests (58%); inadequate medical history and physical examination (42%); incorrect interpretation of tests (37%); and failure to request a consultation (33%).[15]

To avoid medical errors, EPs' rapid access to most imaging and testing modalities without having to obtain prior authorization may contribute to costly and unnecessary utilization of resources. A survey of EPs' most recent act of defensive medicine found that 63% of respondents ordered imaging (CT, MRI, or radiograph) that was not clinically indicated.[1] Overtesting and overimaging is not without risk either; one MPL study of imaging in the ED found that 37% of diagnostic errors resulting in patient harm involved the misinterpretation of diagnostic testing, with plain radiographs being the most common at 52%.[15]

"No medical misadventure" was the second most common chief medical factor cited in claims. According to the MPL Association, "'No medical misadventure" is a code used in the absence of a medical mishap. If a claim has no medical misadventure but is felt to have legal merit, there is an appropriate associated issue designated in the database. These can be problems with records, consent issues, laboratory issues

**Table 4.** Outcomes based on top five chief medical factors cited in closed claims in adult emergency departments or urgent care settings.

| Top 5 chief medical factors | Closed claims | Paid claims | % Paid-to-closed | Average Indemnity | Average defense expense | % of all closed claims | % of all paid claims |
|---|---|---|---|---|---|---|---|
| Errors in diagnosis | 2,466 | 854 | 34.6 | $338,362 | $43,600 | 36.4% | 47.5% |
| No medical misadventure | 1,301 | 43 | 3.3 | $294,140 | $35,588 | 19.2% | 2.4% |
| Improper performance | 1,197 | 356 | 29.7 | $289,941 | $36,185 | 17.7% | 19.8% |
| Failure to supervise or monitor case | 352 | 119 | 33.8 | $296,551 | $41,761 | 5.2% | 6.6% |
| Medication errors | 232 | 58 | 25.0 | $170,148 | $33,834 | 3.4% | 3.2% |

**Table 5.** Outcomes according to severity of injury cited in closed claims in adult emergency departments or urgent care settings.

| Severity of injury | Closed claims | Paid claims | % Paid-to-closed | Average indemnity | Average defense expense | % of all closed claims | % of all paid claims |
|---|---|---|---|---|---|---|---|
| Death | 2,613 | 770 | 29.5 | $326,350 | $45,588 | 38.5% | 42.8% |
| Grave injury | 201 | 65 | 32.3 | $686,239 | $66,722 | 3.0% | 3.6% |
| Major permanent injury | 410 | 157 | 38.3 | $505,965 | $67,025 | 6.0% | 8.7% |
| Significant permanent injury | 617 | 162 | 26.3 | $334,723 | $47,168 | 9.1% | 9.0% |
| Minor permanent injury | 658 | 163 | 24.8 | $248,662 | $34,226 | 9.7% | 9.1% |
| Major temporary injury | 937 | 251 | 26.8 | $215,244 | $33,821 | 13.8% | 14.0% |
| Minor temporary injury | 1,027 | 188 | 18.3 | $152,810 | $27,376 | 15.1% | 10.5% |
| Insignificant injury | 179 | 27 | 15.1 | $89,726 | $14,914 | 2.6% | 1.5% |

or assault/battery, abandonment, etc."[16] Despite being the second most common cited reason for bringing a claim, only 3.3% of claims citing "no medical misadventure" resulted in a payout, and represented only 2.4% of total paid claims.

In our analysis, claims listing grave injury had more than double the average indemnity as paid claims listing death as the resulting injury ($686,239 vs $326,350). Death was the most common (38.5%) injury cited in all closed adult MPL claims, followed by minor temporary injury (15.1%) and major temporary injury (13.8%). A prior study examining MPL claim outcomes and time to resolution found that the more severe the injury listed in the claim, the longer the time to resolution.[9] Among all specialties, 51% of claims with emotional injury only took at least six months to resolve. In 62% of claims listing death or permanent disability, the time to resolution was over one year, with 3% lasting longer than five years.[9]

Acute myocardial infarction was the diagnosis with the highest ratio of paid-to-closed claims. Chest pain continues to be one of the most common chief complaints in the hospital, representing 8-10 million visits per year,[17] with acute ST-elevation myocardial infarctions (STEMI) representing an estimated 0.26% of ED visits.[17] Risk stratification in this population may be aided by the introduction of high-sensitivity troponin and evidence-based decision tools; however, diagnosis of acute myocardial infarction is also affected by subjective interpretation of electrocardiograms that may vary between providers. The overall incidence of STEMIs seen in the ED has been decreasing in recent years. Both the push to improve time to reperfusion and the pre-hospital recognition of STEMIs may have contributed to this decrease, allowing patients to bypass EDs and present directly to catheterization labs. Ward et al. speculated that atypical presenting STEMIs that are more difficult to diagnose and treat may still present to the ED, while classically presenting STEMIs are more likely to proceed directly to the catheterization lab.[18]

Emergency medicine was the most commonly named specialty in our study, followed by internal medicine, family practice, radiology, and general surgery. EPs might view requesting a consult from another specialty as a way of mitigating risk. For example, a review of MPL involving point-of-care ultrasound found that 40% of those imaging studies were performed by radiology, even though both the study and its interpretation were within EPs' scope of practice.[19] A consulting physician-patient relationship must occur through "an overt or implied agreement to participate in a patient's care, or by reviewing specific tests or studies for the purpose of diagnosis and treatment."[20] The case law surrounding shared liability underscores the challenge of delineating when a formal consultation has been made and highlights various occasions when EPs incorrectly presume that a formal consult (and therefore shared liability) was established.

It is our hope that these findings based on these MPL data may help to inform emergency providers about risks and outcomes, and may provide important context to improving the care of adults treated in emergency or urgent care settings.

## LIMITATIONS

This study has several limitations. While the DSP is the largest independent database of MPL claims and lawsuits, it does not capture all closed claims during the study period and may not be representative. In addition, because DSP data were in aggregate to ensure confidentiality, we were not able to obtain information about individual cases or trend claim-specific data over time from 2001–2015. Prior work on EP demographics has suggested that total number of years in practice and total visits seen were associated with increased risk of MPL;[21] similarly, due to the aggregate data, we did not analyze demographics of individual physicians in this study. Additionally, average monetary values did not account for inflation rates, and were averaged over the 15-year period. We were unable to differentiate between types of aortic aneurysm in resulting medical condition, and this category comprises thoracic, abdominal, and thoracoabdominal. Very few medical errors result in litigation,[22,23] and this analysis of closed-claims data found in the DSP provides only one perspective of the intricacies involved in clinical practice and medical negligence in emergency medicine.

## CONCLUSION

Of the 6,779 closed medical professional liability claims originating from ED or urgent care centers over a 15-year period, 65.9% were dropped, withdrawn, or dismissed; 22.8% settled for an average indemnity of $297,709; 7.6% went to trial; and 3.7% resolved by alternative dispute resolution/contract/unknown. In those that went to trial, juries returned verdicts for the defendant 92.6% of the time; however, claims where the jury returned verdicts for the plaintiff had the highest average indemnity of $816,909 of any claim resolution type. Acute myocardial infarction was the diagnosis with the highest ratio of paid-to-closed claims. Death was the most common outcome listed in closed claims; however, outcomes listing grave injury had more than double the average indemnity as paid claims listing death as the resulting injury ($686,239 vs $326,350).

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# Nobody Wants to Be Narcan'd: A Pilot Qualitative Analysis of Drug Users' Perspectives on Naloxone

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**Introduction:** Bystander naloxone distribution is an important component of public health initiatives to decrease opioid-related deaths. While there is evidence supporting naloxone distribution programs, the effects of increasing naloxone availability on the behavior of people who use drugs have not been adequately delineated. In this study we sought to 1) evaluate whether individuals' drug use patterns have changed due to naloxone availability; and 2) explore individuals' knowledge of, access to, experiences with, and perceptions of naloxone.

**Methods:** We conducted a pilot study of adults presenting to the emergency department whose medical history included non-medical opioid use. Semi-structured interviews were conducted with participants and thematic analysis was used to code and analyze interview transcripts.

**Results:** Ten participants completed the study. All were aware of naloxone by brand name (Narcan) and had been trained in its use, and all but one had either currently or previously possessed a kit. Barriers to naloxone administration included fear of legal repercussions, not having it available, and a desire to avoid interrupting another user's "high." Of the eight participants who reported being revived with naloxone at least once during their lifetime, all described experiencing a noxious physical response and expressed a desire to avoid receiving it again. Furthermore, participants did not report increasing their use of opioids when naloxone was available.

**Conclusions:** Participants were accepting of and knowledgeable about naloxone, and were willing to administer naloxone to save a life. Participants tended to use opioids more cautiously when naloxone was present due to fears of experiencing precipitated withdrawal. This study provides preliminary evidence countering the unsubstantiated narrative that increased naloxone availability begets more high-risk opioid use and further supports increasing naloxone access. [West J Emerg Med. 2021;22(2)339-345.]

## INTRODUCTION

### Background

Bystander naloxone distribution is an evidence-based public health intervention.[1,2] The Surgeon General of the United States has emphasized the importance of the opioid overdose reversal agent, stating succinctly and unambiguously, "knowing how to use naloxone and keeping it within reach can save a life."[3] However, efforts to enhance naloxone availability have been hampered by stigma surrounding opioid use disorder (OUD), cost and availability

issues, and the unproven assertion that naloxone increases high-risk drug use.[4-7] To evaluate perceptions of naloxone uptake and use in our population, we piloted a semi-structured interview developed in conjunction with the National Drug Early Warning System (NDEWS) workgroup.[8]

**Importance**

Although studies have demonstrated that increased availability of naloxone has reduced the rate of opioid overdose fatalities in some communities, there is a paucity of data on whether it has also impacted drug use behaviors. Data regarding knowledge of and attitudes toward naloxone among people who use drugs (PWUD), and the impact of naloxone availability on drug-use behaviors, are urgently needed. In this pilot study, we explored the knowledge and perceptions of naloxone among PWUD in order to obtain more nuanced data to guide public health interventions aimed at decreasing opioid overdose deaths.

**Goals of This Investigation**

This study sought to 1) explore individuals' knowledge of, access to, experiences with, and perceptions of naloxone; and 2) characterize reported changes in individuals' drug use patterns and attitudes as a result of naloxone accessibility.

*Population Health Research Capsule*

What do we already know about this issue?
*Bystander naloxone is an evidence-based public health intervention. Increasing naloxone availability is a cornerstone of efforts to combat opioid overdose deaths.*

What was the research question?
*How is bystander naloxone perceived by opioid users? Has naloxone availability affected opioid use behaviors?*

What was the major finding of the study?
*Participants were familiar with naloxone and did not report increased opioid use when naloxone was available.*

How does this improve population health?
*This study affirms that bystander naloxone is acceptable to its intended audience and suggests that naloxone availability does not increase high-risk opioid use.*

## METHODS

**Study Design and Setting**

This pilot study was part of a larger multisite effort by the NDEWS workgroup to validate a qualitative interview agenda regarding knowledge and perceptions of bystander naloxone among PWUD. During the trial period (March-April 2019), we enrolled a convenience sample of 10 adult patients who presented to the University of Massachusetts Memorial Medical Center emergency department (ED) with an opioid-related chief complaint (eg, drug overdose, cutaneous abscess, etc) and history of non-medical opioid use. Among the three sites in the study, ours was distinct in that we focused on individuals who presented for evaluation in the emergency care setting rather than in an outpatient clinic. This protocol was approved by the University of Massachusetts Medical School Institutional Review Board. A Certificate of Confidentiality was obtained to provide an additional layer of participant protection.

**Selection of Participants**

Study investigators screened the electronic health record ED tracking board for individuals meeting inclusion criteria and approached them once they were deemed medically stable by the provider overseeing their clinical care. Eligible participants were 18-65 years of age, had presented to the ED with an opioid-related chief complaint, had a history of non-medical opioid use, were English-speaking, and were able to provide informed consent. Individuals were excluded if they had previously participated in this study or were in police custody. A study investigator obtained verbal informed consent from participants, who were brought to a private room in the ED for the duration of the interview. Participants were compensated for their time with a $10 gift card to a local retail store.

**Interventions**

Two investigators were present during study interviews, with one taking the lead role as facilitator and the other functioning as a notetaker. Investigators administered a brief questionnaire regarding demographic characteristics, as well as a semi-structured interview developed by the NDEWS workgroup, which contained open-ended questions regarding naloxone. A written agenda was used to guide each interview, ensuring that the same key questions were asked of all participants. This allowed each individual to answer in his/her own words, and to describe relevant experiences. The agenda included questions about access to, knowledge of, attitudes about, and experiences with naloxone, as well as each participant's prior history of drug overdose. Participants were asked to respond based on their own thoughts and experiences, as well as provide insight on their perceptions of what other people who use opioids think about naloxone, and whether the availability of naloxone has changed how other users conceptualize drug use.

**Analysis**

We tabulated and entered demographic data into Research Electronic Data Capture (REDCap), a secure web-based application for building and managing online surveys and databases.[9,10] Semi-structured interviews were audio-recorded on a digital voice recorder and transcribed by trained study staff or by a transcription service compliant with the Health Insurance Portability and Accountability Act. Study staff reviewed each transcription to ensure accuracy and to deidentify qualitative data.

Two researchers (BC and MT) independently coded the first two transcripts, creating deductive codes based on questions in the semi-structured qualitative agenda and inductive codes for emergent topics raised by participants. The initial codes were reviewed by the research team, resulting in a preliminary thematic coding scheme. This framework was applied to all transcripts, which were independently coded by both researchers (BC and MT). New codes were created as needed when adjustments were made to accommodate topics in subsequently coded transcripts, which were then retroactively applied to initially coded transcripts as well. Upon completion of independent coding, both researchers met to review differences in coding, which were discussed and refined until agreement between the researchers was reached. After five interviews no further changes were made to the codes. We entered the agreed-upon codes into NVivo 12 Plus (QSR International, Burlington, MA) to complete the thematic analysis, and then reviewed them in aggregate to create summaries of key topic areas.

**RESULTS**

A total of 28 individuals were screened for recruitment during the study period. Of those, 12 were unable to be enrolled as they either eloped (n = 4), were unable to provide consent (n = 1), had no non-medical opioid use in the prior six months (n = 6), or reason was not documented (n = 1). Of the 16 potential participants who were approached, six declined to participate in the study: three identified as female and three as male, and ages ranged from 28-35 years with a median age of 32 years. Ten participants were enrolled in this study; the demographics of the study participants are detailed in Table 1. The sample was predominantly young, White males who had been in treatment for OUD on at least one occasion. The majority had previously received naloxone. The sample varied on education, employment, and housing status.

Analysis of semi-structured interviews revealed several themes, which are described in detail below. Additional illustrative quotations are included for each theme (Table 2).

**Familiarity with Narcan (mechanism and use)**

All participants were familiar with the brand name "Narcan," but some were not familiar with the generic term "naloxone." One individual mistook naloxone for naltrexone. A single participant had never heard the term "naloxone" before. All participants reported having formal naloxone training from sites including local treatment facilities and harm-reduction organizations. Most reported first hearing about naloxone through treatment programs (eg, detox, Alcoholics Anonymous meetings) or correctional facilities, from other people who use opioids for non-medical purposes, and from occasions where they had received it for overdose reversal. Two participants informed study staff that they could not recall how they first learned about naloxone because they had "known about it for so long."

Most participants understood the general purpose of naloxone to be reversing an opioid overdose, yet there were varying degrees of knowledge about the exact underlying mechanisms. The majority of participants used specific terminology implying blockade or antagonism when describing how naloxone works (eg, "receptor," "blocker," and "reversant"). Most participants identified naloxone's specificity for opioids, but there were two participants who also questioned its utility for other substances, such as alcohol.

All but one participant reported that they currently or previously possessed a naloxone kit. Of those nine, three participants reported that their reasoning for carrying a kit was to save the lives of others. One participant stated, "If someone needed it, I would rather have it than be powerless." The majority of participants reported obtaining naloxone kits that contained the newer, "easy" plunger-style nasal spray. Three participants mentioned that they had previously obtained the more "difficult to use" older version that required assembly.

**Naloxone Is Available and Easy to Obtain**

Participants universally agreed that naloxone kits were available and easy to obtain from a variety of organizations (eg, pharmacies, treatment facilities). All participants knew the process for obtaining a naloxone kit, and several reported obtaining it from a harm-reduction agency (eg, needle exchange) that distributed it for free and provided training. When asked how programs that distribute naloxone could improve their services, some participants suggested increasing access by providing naloxone kits by default whenever someone visits a needle exchange or leaves a treatment program, and by implementing mobile programs of outreach workers to distribute it within the community.

**Naloxone Availability Is Viewed Positively**

Participants perceived naloxone as a life-saving drug and were thankful for its presence in the community. One participant stated, "[I] think it's an amazing drug. I've seen it save people's lives." Some participants reported feeling empowered by carrying naloxone and said they would use it to revive someone. When asked how individuals who had been revived by naloxone were perceived by other people who use opioids, many participants responded by saying they were "lucky." Some participants stated that they themselves felt lucky after being revived with naloxone.

**Table 1.** Participant demographics.

| | N=10 |
|---|---|
| Median age, years (range) | 33 (20-56) |
| Sex, N | |
| Male | 8 |
| Female | 2 |
| Race and ethnicity, N | |
| White, neither Hispanic nor Latino | 8 |
| Native Hawaiian or other Pacific Islander, Hispanic or Latino | 1 |
| Multiracial, neither Hispanic nor Latino | 1 |
| Married or have significant other, N | |
| Yes | 5 |
| No | 5 |
| Number of children, N | |
| None | 5 |
| 1-2 | 3 |
| 3+ | 2 |
| Highest level of education completed, N | |
| Less than high school | 1 |
| High school diploma or equivalent | 1 |
| Some college, no degree | 5 |
| Associate degree | 3 |
| Primary employment status (past 12 months), N | |
| Unemployed | 2 |
| Employed full-time | 3 |
| Student | 1 |
| Employed full-time and student | 1 |
| Retired/disabled | 3 |
| Primary housing situation (past 12 months), N | |
| Homeless | 2 |
| Apartment | 3 |
| House | 3 |
| Sober living house | 2 |
| Chief complaint for this ED visit, N | |
| Suspected opioid overdose, naloxone administered | 4 |
| Other opioid-related chief complaint | 6 |
| Received naloxone (lifetime), N | |
| Yes | 8 |
| No | 2 |
| Been in treatment for substance use (lifetime), N | |
| Yes | 10 |
| No | 0 |
| Number of prior drug-related ED encounters (lifetime), N | |
| None | 2 |
| 2-5 encounters | 5 |
| 6+ encounters | 3 |

*ED*, emergency department.

**Naloxone Produces Aversive Symptoms During Reversal**

All participants who had previously been revived with naloxone reported experiencing extraordinarily unpleasant physical responses consistent with severe opioid withdrawal (eg, nausea, vomiting, diffuse body pain). One participant described it as the worst pain he had ever experienced. When these participants were asked about their emotional response, several disclosed that they felt embarrassed or experienced feelings of depression and anxiety regarding their return to opioid use. Participants acknowledged that receiving naloxone was an experience that they would go to great lengths to avoid. However, in the event that they were to overdose and require naloxone to save their life, they hoped someone would administer it.

**Availability of Naloxone Does Not Increase Risky Drug-use Behavior**

Participants were unanimous that their decision to use opioids did not depend on naloxone availability. While participants speculated vaguely that a hypothetical "other" group of people who use opioids might adopt riskier drug use behavior due to the availability of naloxone (such as taking bigger doses or using more often), all participants explicitly denied that they themselves engaged in riskier behavior and/or increased their opioid use in any way due to the availability of naloxone. Several participants reported that they had recently experienced a return-to-use event, but none identified naloxone availability as playing any role in this occurrence.

Several participants stated that they had heard of or had seen others using heroin/fentanyl immediately after being revived with naloxone to mitigate withdrawal symptoms. One participant reported doing this herself, while simultaneously noting that this was "messed up." Participants reported that people are using in groups as a harm reduction strategy and likened using alone to a death sentence.

**Barriers to Carrying Naloxone Are Primarily Related to Potential Social and Legal Consequences**

Participants described several potential barriers when speculating why an individual might choose not to administer naloxone: fear of legal repercussions; not having naloxone available at that moment; and not wanting to interrupt the

individual's euphoric experience ("high"). Interestingly, some participants felt that having naloxone on their person would be perceived by other people as an admission that their recovery might not be successful, and that this decreased their desire to carry it. Of note, two participants expressed concern that carrying naloxone might be interpreted specifically by authority figures (eg, parole officers) as a return to drug use, which would potentially result in legal repercussions. None of the participants had ever self-administered naloxone or knew of anyone who had; all believed that it was impossible or very difficult to do so when indicated.

Good Samaritan laws, which vary by state, protect individuals from prosecution for drug possession if they seek emergency services assistance for a suspected overdose.[11] Nine participants expressed some understanding of the Good Samaritan Law in Massachusetts, but there was variable comprehension about what this law covers. Several participants also expressed concern over whether law enforcement agencies would adhere to these laws.

**Additional Novel Findings**

Most participants shared the belief that the majority/all of the current "heroin" supply in their community is actually fentanyl, and that obtaining "real heroin" was a difficult thing to do. Fentanyl was reportedly less desirable because it was perceived as more dangerous and shorter-acting than heroin, requiring more frequent dosing. Most participants identified cyanosis as the major indicator differentiating the desired opioid effect from an overdose. These participants described the presence of a skin "color change" to blue as the signal to administer naloxone.

## DISCUSSION

Our participants were familiar with and accepting of naloxone. They were also willing to administer this medication to someone who had overdosed. However, participants tended to rely upon the presence of cyanosis, a late finding in overdose, as the indication for naloxone administration. Despite a willingness to carry and use naloxone, we found that some

**Table 2.** Illustrative comments from study participants.

| Theme | Quotes |
|---|---|
| Familiarity with Narcan (mechanism and use) | "[Narcan] basically pulls the opiate out of the receptor." |
| | "[Narcan is] a reversant of heroin overdose." |
| | "I want to help others; I'm not walking around with [Narcan] just for the hell of it; I'm gonna try to save a life." |
| Naloxone is available and easy to obtain | "I get [Narcan] for free, I never paid one dollar for it. There's plenty of programs that give it out for free." |
| | "[Narcan]'s not hard to get, so no excuse. Nothing to prevent them from getting it." |
| Naloxone availability is viewed positively | "[I] think [Narcan is] an amazing drug. I seen it save people's lives." |
| | "You could probably walk to the corner and you always see someone out [overdosed]... If someone needed [Narcan], I would rather have it than be powerless." |
| | "[Narcan is] the best tool to have. It's the best tool to use." |
| Naloxone produces aversive symptoms during reversal | "Nobody wants to be Narcan'd." |
| | "[Receiving Narcan feels like] instant withdrawal, but the worst withdrawal you ever felt in your life. Like you feel like your legs are broken, your head's screaming." |
| | "[Receiving Narcan is] kind of embarrassing and degrading and you know it's upsetting." |
| | "[When receiving Narcan for an overdose], it's better to feel the pain than die." |
| The availability of naloxone does not increase risky drug use behavior | "It's not like we use heroin because we have naloxone...I've never seen anyone that wouldn't already do heroin, do heroin because they have naloxone." |
| | "Maybe people are using [heroin] more in groups now because obviously they're not going to administer naloxone on their dead body." |
| Barriers to carrying naloxone are primarily related to potential social and legal consequences | "Trust me, the cops don't follow the Good Samaritan law. They don't have to...They're supposed to, but it doesn't mean they do." |
| • Knowledge of Good Samaritan Laws | "It's if-if you get caught with somebody, if-if they're both high and you... are using [drugs], and he is using, [the police] can't arrest you." |
| • Barriers to reviving others | "Say you needed Narcan, and I was gonna be the one to give it, maybe I'd be hesitant 'cause I'm like, 'I don't know, I don't wanna ruin his high.'" |
| | "[After giving someone Narcan,] now you have someone who's sick who wants your dope... So they're not highly regarded." |

participants associated possession of naloxone with feelings of weakness or potential failure. We found that participants denied engaging in riskier opioid use behaviors when naloxone was available. In fact, some individuals who had previously overdosed and received naloxone held such a strong aversion to the experience of precipitated opioid withdrawal that they reported subsequently using less drug to decrease their overdose risk. Although our data set was small, we did establish thematic saturation for a preliminary study with respect to the question of whether naloxone facilitated riskier drug use: Our participants were unanimous in reporting that they did not decide to use opioids nor increase their opioid use because of increased naloxone availability.

Previous studies have indicated that non-opioid users hold overall positive opinions of naloxone.[12-14] A survey of lay persons found that while only 61% of respondents had heard of naloxone, most respondents (88%) felt naloxone was beneficial in preventing accidental opioid overdoses.[12] Both medical professionals and state government agencies support efforts to increase naloxone availability due to demonstrated benefits in reducing opioid overdose mortality.[15,16] However, an oft-repeated criticism of naloxone distribution efforts lies in the idea that naloxone availability enables individuals to use opioids without the fear of death, thereby encouraging high-risk drug use behaviors.[17] A majority of the lay public felt that naloxone was only necessary for people who misuse opioids, and that the availability of naloxone enabled these individuals to increase their opioid use.[12] Lay media reports have perpetuated the idea of "Narcan parties" or "Lazarus parties," where people intentionally use large amounts of opioid to overdose with the expectation that they will subsequently be revived by naloxone administration.[4,5]

Despite the persistence of these views in popular opinion, our data and the available literature contradict the supposition that enhanced availability of naloxone leads to increased opioid use.[1,4,18] Our participants reported no increase in their drug use in spite of widespread availability of naloxone. Instead, they actively attempted to avoid naloxone reversal due to the associated adverse effects and were somewhat reluctant to administer it to others unless they were sure they needed it. Although our sample is small, it consists of a relatively experienced group of people who use opioids, as evidenced by prior treatment attempts for OUD and number of drug-related ED visits. Our preliminary finding that this group did not report adopting riskier drug-use patterns in the context of increased naloxone availability suggests that proliferation of bystander naloxone programs does not beget increased opioid use.

Overall, many of our participants had a high degree of functional knowledge regarding naloxone, held a generally positive view of naloxone, and expressed a willingness to administer naloxone when necessary. Despite traumatic experiences associated with receiving naloxone, participants perceived naloxone as a life-saving medication. Contrary to the popular belief that individuals increase their drug use when naloxone is available, some participants reported that they used less opioids to avoid being administered naloxone. Additionally, our participants described using in groups as a contingency plan to mitigate the risk of overdose, and do not view naloxone as a facilitator of riskier drug use.

Our results suggest several areas that can be targeted to enhance public health interventions. There was widespread thought among participants that the presence of cyanosis ("color change") in an individual is the primary indicator of overdose and the need for naloxone administration. Future naloxone education efforts targeted to PWUD, as well as the lay public, should stress that cyanosis is a late finding and emphasize indicators that differentiate "high" from overdose, such as shallow or slowed breathing. Our participants suggested that visits to needle exchanges and discharges from treatment programs are high-value times to ensure that PWUD are equipped with naloxone. Furthermore, they identified mobile outreach programs as a desirable community-based harm-reduction service. Public health initiatives should also work to address concerns that carrying naloxone may signal unsuccessful recovery, and instead rebrand bystander naloxone as a willingness to save others' lives. It may further be beneficial to increase public awareness that naloxone is not for self-administration.

## LIMITATIONS

The limitations of this pilot study include a small sample size (n = 10) and the fact that it was conducted in a single community where several groups were over-represented (eg, male, White, prior naloxone resuscitation, prior treatment for OUD). Although our study population was fairly homogenous and not representative of PWUD on a national scale, it is a typical sample for PWUD in our region in terms of demographics and experience with drug use. We did not appreciate a difference in characteristics between approached vs enrolled patients. Nevertheless, this may detract from generalizability to other settings where the demographics may differ and individuals may have cultural differences or less familiarity with opioid use, opioid antagonists, and treatment modalities for OUD.

That our study was conducted in an urban ED at the epicenter of the North American opioid epidemic likely does skew our study population to favor individuals with more experience and health literacy surrounding their substance use disorder, as evidenced by a majority having previously received naloxone for overdose reversal and treatment for OUD. Furthermore, our state government's progressive response to the opioid epidemic likely enhances our PWUD population's familiarity with naloxone. Additionally, although all study staff are trained in qualitative interview techniques, inadvertent use of leading questions could have led to interviewer bias.

Since the data were analyzed by the qualitative interviewers, there was no ability to blind the coders. This could have resulted

in bias when assigning the thematic codes, which is why two independent reviewers coded the data and analysis was reviewed by all researchers. Moreover, we were unable to administer the interview in languages other than English, resulting in the exclusion of several individuals who were otherwise eligible for participation. Finally, our study used self-report of an illegal and stigmatized behavior, rather than direct observations of how naloxone availability affected drug use behaviors; the results may therefore be influenced by recall bias and social desirability bias. These factors limit the generalizability of our findings to other demographic groups and locales.

## CONCLUSION

We found that participants were accepting of, knowledgeable about, and willing to use naloxone. Furthermore, we discovered that participants did not increase their use of opioids when naloxone was available, but rather tended to use opioids more cautiously due to fears of experiencing precipitated withdrawal from naloxone administration. These findings further support the need for increasing access of naloxone to help prevent opioid overdose deaths.

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# The Psychological Impact of COVID-19 on Hospital Staff

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**Introduction:** The coronavirus 2019 (COVID-19) pandemic has created a mental health crisis among hospital staff who have been mentally and physically exhausted by uncertainty and unexpected stressors. However, the mental health challenges and complexities faced by hospital staff in the United States has not been fully elucidated. To address this gap, we conducted this study to examine the prevalence and correlates of depression and anxiety among hospital staff in light of the COVID-19 pandemic.

**Methods:** The design is a single-center, cross-sectional, online survey evaluating depression and anxiety among all hospital employees (n = 3,500) at a safety-net hospital with a moderate cumulative COVID-19 hospitalization rate between April 30–May 22, 2020. We assessed depression with the Patient Health Questionnaire-9. Anxiety was measured with the Generalized Anxiety Disorder-7 scale. Logistic regression analyses were calculated to identify associations with depression and anxiety.

**Results:** Of 3,500 hospital employees, 1,246 (36%) responded to the survey. We included 1,232 individuals in the final analysis. Overall, psychological distress was common among the respondents: 21% and 33% of staff reported significant depression and anxiety, respectively, while 46% experienced overwhelming stress due to COVID-19. Notably, staff members overwhelmed by the stress of COVID-19 were seven and nine times more likely to suffer from depression and anxiety, respectively. In addition to stress, individuals with six to nine years of work experience were two times more likely to report moderate or severe depression compared to those with 10 or more years of work experience. Moreover, ancillary staff with direct patient contact (odds ratio [OR] 8.9, confidence interval (CI), 1.46, 173.03) as well as administrative and ancillary staff with indirect patient contact (OR 5.9, CI, 1.06, 111.01) were more likely to be depressed than physicians and advanced providers.

**Conclusion:** We found that a considerable proportion of staff were suffering from psychological distress. COVID-19-associated depression and anxiety was widespread among hospital staff even in settings with comparatively lower COVID-19 hospitalization rates. Ancillary staff, administrative staff, staff with less job experience, and staff overwhelmed by the stress of COVID-19 are particularly susceptible to negative mental health outcomes. These findings will help inform hospital policymakers on best practices to develop interventions to reduce the mental health burden associated with COVID-19 in vulnerable hospital staff. [West J Emerg Med. 2021;22(2)346-352.]

## INTRODUCTION

In December 2019, a cluster of idiopathic pneumonia cases linked to a seafood market emerged in Wuhan, China.[1] Genomic sequencing analysis revealed that a novel coronavirus strain, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was the causative agent that resulted in coronavirus disease 2019 (COVID-19).[2] Epidemiological investigations determined that SARS-CoV-2 is highly contagious and primarily spread through person-to-person contact.[3] The virus spread at an alarming rate infecting millions of people, and as a result governments around the world enforced lockdown measures to mitigate community transmission. On March 11, 2020, the World Health Organization declared COVID-19 a pandemic, signaling that the viral illness was a global emergency.[4]

The COVID-19 pandemic has created a parallel mental health crisis in the United States (US). Preliminary results indicate that prevalence rates of depression and anxiety have tripled in the US since the inception of the pandemic.[5] In particular, healthcare workers have been psychologically burdened by high levels of work-related COVID-19 stress.[6,7] Emerging data suggests that up to 50% of healthcare workers will experience moderate to severe depression and anxiety.[8] Moreover, healthcare workers are at a heightened risk of developing stress-related disorders due to experiencing or witnessing human suffering and trauma. Initial studies project that up to 60% of healthcare workers treating patients with COVID-19 will develop symptoms of acute stress disorder.[9] Factors contributing to mental health distress range from psychological and social stressors intrinsic to a novel pandemic to shortages of personal protective equipment.[10] The demands of COVID-19 will undoubtedly further strain the mental health wellbeing of healthcare workers. For this reason, expert panels have requested a call for action to understand the psychological effects of COVID-19.[11]

A handful of observational studies have examined the psychological consequences of COVID-19. A meta-analysis reported that the prevalence of anxiety ranged between 22.6-36.3% and depression between 16.5-48.3% in healthcare workers.[12] The studies included in the meta-analysis primarily focused on healthcare workers providing care in regions of China severely affected by the pandemic. It is important to bear in mind that mental health outcomes among healthcare workers may differ based on region, infection rate, and COVID-19-associated hospitalization rates. Nevertheless, it is likely that the untoward psychological effects of COVID-19 are systemic across the entire health workforce. To date, little is known about the mental health needs of healthcare workers in light of the unprecedented pressures faced by hospitals. To address this gap, we sought in this study to understand the scope of depression and anxiety among staff at a safety-net hospital with a moderate cumulative COVID-19 hospitalization rate. We aimed to determine the prevalence of depression and anxiety, and to elucidate associations between sociodemographic variables, depression, and anxiety.

*Population Health Research Capsule*

What do we already know about this issue?
*The COVID-19 pandemic has created a parallel mental health crisis among hospital staff who are experiencing burnout and stress-related disorders.*

What was the research question?
*Our goal was to examine the prevalence and correlates of depression and anxiety among staff at a general medical hospital.*

What was the major finding of the study?
*Overall, 21% and 33% of staff reported significant depression and anxiety, respectively, especially ancillary and administrative staff and those with less job experience,.*

How does this improve population health?
*Psychological interventions are needed at the hospital organizational level to improve mental health outcomes and the wellbeing of staff.*

## METHODS

### Study Design and Participants

The study, which was approved by the institutional review board at our institution, is a cross-sectional, anonymous, Internet-based survey conducted at a safety-net hospital in San Bernardino County, California, between April 30–May 22, 2020 During the study period, the number of confirmed COVID-19 cases doubled from 2,058 to 4,146 in the county, and a total of 146 patients were treated for COVID-19 at the hospital site. We developed the survey using SurveyMonkey (San Mateo, CA), and the survey web link was emailed to all hospital employees (n = 3500) biweekly. All staff employed by the hospital were asked to participate. Inclusion criteria were as follows: 1) older than 18 years; 2) hospital staff; 3) willing and able to give informed consent; and 4) able to complete the survey in English.

### Measures

Voluntary electronic informed consent was provided by participants prior to beginning the survey. The survey was anonymous, and no identifying information such as name, email address, or Internet-provider information was collected. Participants were permitted to withdraw from the survey at any time. Occupation was classified into four groups: 1) physicians and advanced providers; 2) nursing staff; 3) ancillary staff with direct patient contact; and 4) administrative and ancillary staff with indirect patient contact.

Age was classified into three groups: 1) millennials (20-39 years); 2) generation X (40-55 years); and 3) baby boomers (56-75 years). Zhu and colleagues found that 10 or more years of work experience was a risk factor for COVID-related depression and anxiety among healthcare workers. Accordingly, in our study we categorized years of work experience as follows: 1) zero to five years, 2) six to nine years, and 3) ≥10 years.[13]

To measure perceived stress participants were asked, "Have you been overwhelmed by the stress of the COVID-19 pandemic?" (Y/N). Studies have validated that perceptions of stress can be measured by asking individuals how overwhelmed they are by a situation.[14] To assess whether staff were front-line or second-line we asked, "Have you been in contact with a patient either suspected to have COVID-19 or confirmed to have COVID-19?" (Y/N). Staff who answered "Yes" were classified as front-line and those who answered "No" were classified as second-line. The Patient Health Questionnaire (PHQ)-9 and General Anxiety Disorder (GAD)-7 were completed to measure depressive and anxious symptomatology, respectively.

**Outcomes**

The primary outcome measures were the PHQ-9 score (range, 0-27), and GAD-7 score (range, 0-21). Patient Health Questionnaire-9: This self-reported measure consists of nine questions to measure the frequency of depressive symptoms over the prior two weeks on a four-point Likert-scale ranging from 0 (not at all) to 3 (nearly every day). The scores are interpreted as follows: normal (0-4); mild (5-9); moderate (10-14); moderately severe (15-19); and severe (20-27). A PHQ-9 score ≥10 is 88% sensitive and 88% specific for a diagnosis of major depression.[15] Accordingly, we grouped PHQ-9 scores into two categories: PHQ-9 score <10; PHQ-9 score≥10.

General Anxiety Disorder-7: A self-reported measure that consists of seven questions to measure the severity of anxiety symptoms over the prior two weeks on a four-point Likert-scale ranging from 0 (not at all) to 3 (nearly every day). The scores are interpreted as follows: normal (0-4); mild (5-9); moderate (10-14); and severe (15-21). The GAD-7 is a well-validated tool for assessing anxiety disorders; generalized anxiety disorder (sensitivity of 89%, specificity of 82%); panic disorder (sensitivity of 74%, specificity of 81%); social anxiety disorder (sensitivity of 72%, specificity of 80%); and post-traumatic stress disorder (sensitivity of 66%, specificity of 81%).[16] Accordingly, GAD-7 scores were grouped into two categories: GAD-7 score <8; GAD-7 score ≥ 8.

*Statistical Analysis*

We conducted all statistical analyses using the SAS software for Windows version 9.3 (SAS Institute, Cary, NC). Descriptive statistics are presented as means and standard deviations for continuous variables, and frequencies and proportions for categorical variables. Chi-square statistics were conducted comparing whether staff were overwhelmed by the stress of COVID-19 between sociodemographic factors and scores on the PHQ-9 and GAD-7. Logistic regression analyses were conducted to examine predictors for a PHQ-9 score ≥10 and a GAD-7 score ≥8. These predictors included occupation, age, gender, years in current position, being overwhelmed by the stress of COVID-19, and being in contact with a patient either suspected to have COVID-19 or confirmed to have COVID-19. All statistical analyses were two-sided. $p$-value ≤ 0.05 was considered to be statistically significant.

**RESULTS**

Out of 3,500 staff 1246 (36%) responded to the survey. Among the 1,246 staff who completed the survey, eight refused to participate and six did not indicate whether they consented to participate in the survey. We included a total of 1232 staff in the final analysis. Descriptive statistics are summarized in Table 1. Overall, 21% of respondents were depressed, 33% had anxiety, and 46% were overwhelmed by the stress of COVID-19. Chi-square analysis was conducted to compare staff stressed and not stressed by COVID-19. The results of the chi-square analysis are presented in Table 2. Occupation ($P$<0.001), gender ($P$<0.001), front-line vs second-line staff ($P$ = 0.013), age ($P$ = 0.036), depression severity ($P$ <0.001), and anxiety severity ($P$<0.001) impacted stress perceptions.

We calculated the first logistic regression analysis to examine predictors for staff with a PHQ-9 score ≥10. The results of the logistic regression analysis are presented in Table 3. Ancillary staff with direct patient contact (odds ratio [OR] 8.9; confidence interval [CI], 1.46,173.03), and administrative and ancillary staff with indirect patient contact (OR 5.9; CI,1.06, 111.01) were more likely to be depressed than physicians and advanced providers. Compared to staff with 10 or more years of work experience, staff working six to nine years were more likely to be depressed (OR 2.08; CI, 1.24, 3.5). Stress was also associated with depression; staff overwhelmed by the stress of COVID-19 were more likely to report significant depressive symptoms compared to staff not overwhelmed by the stress of COVID-19 (OR, 7.06; CI, 4.8, 10.63).

We calculated the second logistic regression analysis to examine predictors for staff with a GAD-7 score ≥8. The results of the logistic regression analysis are presented in Table 4. Staff overwhelmed by the stress of COVID-19 were more likely to experience significant anxiety compared to staff not overwhelmed by the stress of COVID-19 (OR 9; CI, 6.49, 12.65).

**DISCUSSION**

We examined the prevalence and correlates of depression and anxiety among hospital staff during the COVID-19 pandemic. This is one of the largest studies in the US examining psychological consequences among hospital staff during the COVID-19 pandemic. Overall, 21% and 33% of staff

**Table 1.** Hospital staff characteristics.

| Variable | Frequency | Percent |
|---|---|---|
| Gender | | |
| Female | 959 | 77.8% |
| Male | 273 | 22.2% |
| Age | | |
| Millennials (20-39 years) | 500 | 44.2% |
| Generation X (40-55 years) | 426 | 37.6% |
| Baby boomers (56-75 years) | 206 | 18.2% |
| Occupation | | |
| Admin + ancillary staff with indirect patient care | 491 | 42.2% |
| Ancillary staff with direct medical care | 68 | 5.8% |
| Nursing staff | 463 | 39.8% |
| Physician + advanced practitioner | 142 | 12.2% |
| Years In current position? | | |
| 0-5 years | 506 | 49.0% |
| 6-9 years | 157 | 15.2% |
| 10+ years | 370 | 35.8% |
| Overwhelmed by the stress of COVID-19? | | |
| No | 624 | 54.2% |
| Yes | 527 | 45.8% |
| Contact with a patient suspected or confirmed to have COVID-19? | | |
| No | 632 | 55.2% |
| Yes | 514 | 44.9% |
| PHQ-9 | | |
| PHQ-9 score <10 | 872 | 79.3% |
| PHQ-9 score ≥10 | 227 | 20.7% |
| GAD-7 | | |
| GAD7 score<8 | 743 | 67.6% |
| GAD7 score≥8 | 357 | 32.5% |

*PHQ-9*, Patient Health Questionnaire; *GAD-7*, General Anxiety Disorder.

reported significant depression and anxiety, respectively. These findings support that depression and anxiety are pervasive among hospital staff even in settings with comparatively lower COVID-19 hospitalization rates. Published studies from the epicenter of the pandemic have reported slightly higher rates of depression and anxiety.[8] A similar study examining the psychological effects of COVID-19 reported comparable rates of anxiety among healthcare workers caring for patients in New York City at the peak of COVID-19.[9]

Our hospital is not considered a COVID-19 designated center, and the results are conceivably more reflective of the general mental health experience of hospital staff. However, it is important to highlight that we may not be able to draw broad inferences considering the low survey-response rate and single-center design. By virtue of the low survey-response rate, it may be expected that our data overstates the prevalence of depression and anxiety because of non-response bias. Furthermore, a limitation of the single-center design is difficulty extrapolating the results to other settings and populations.

Our results indicate that certain hospital staff members were prone to more severe depressive symptoms. Specifically, ancillary and administrative staff were especially burdened with greater depressive symptomatology. On the contrary, physicians and advanced providers experienced less depression compared to ancillary staff providing direct patient care. Similarly to our findings, Zhu and colleagues found that physicians were less likely to report distress compared to medical technicians.[13] A potential explanation is that ancillary staff directly interacting with patients are mentally exhausted by greater workloads and closer contact time with patients, evoking a fear of contagion.[17] Hospital staff providing indirect-care functions are also increasingly burdened by challenges as never before the pandemic. In our study, administrative and ancillary staff with indirect patient contact reported more severe depressive symptoms than physicians and advanced providers. The etiology of depression is multifactorial, and it is plausible that distress among staff not directly interacting with patients is situational and triggered by institutional concerns, lack of social support, and isolation.[18] Altogether, hospital staff are navigating high-intensity stressful situations, which may potentially induce adverse psychological changes.[19]

Stress is highly prevalent among individuals with depression and anxiety.[20] In our study, 46% of staff experienced overwhelming stress during the COVID-19 pandemic. As anticipated, staff stressed over COVID-19 experienced considerable anxiety and depression. Moreover, staff with substantial anxiety and depression reported heightened stress about the COVID-19 outbreak. Causal relationships could not be fully elucidated as this was a cross-sectional study. However, these findings support that almost half of the hospital staff respondents experienced a substantial psychological burden during the COVID-19 crisis. Importantly, research has shown that pandemic-related stress has deleterious effects on health-related quality of life.[21] In view of these findings, there is a critical need for hospital systems to develop interventions to mitigate adverse mental health consequences and to improve the psychological resiliency of staff.

Another significant finding was that staff with 10 or more years of work experience reported lower levels of depression than staff with six to nine years of work experience. Factors that may explain why staff with more years of work experience reported less depressive symptoms include the following:1) practical experience navigating complex situations; 2) experience managing patients during prior epidemics; 3) the development of adaptive coping skills over time; 4) robust social supports; and 5) job security. These results are in contrast to a similar study by Zhu and colleagues

who found that increasing years of work experience was associated with more severe depressive symptoms among healthcare workers during the COVID-19 pandemic.[13] Discrepancies between work experience and depression may be attributed to confounding variables that were not accounted for; our broad inclusion criteria consisting of a wide range of hospital occupations; and cultural differences.

## LIMITATIONS

There are several limitations of this study: 1) the data is cross-sectional and we could not establish causality; 2) selection bias as we used a web-based survey that was voluntary; 3) self-selection bias as more females voluntarily participated than males; 4) there was no data on participants' mental health prior to the COVID-19 outbreak; 5) the low survey-response rate; 6) the lack of screening questionnaires specific for acute stress disorder; 7) the results of the screening questionnaires were not confirmed with comprehensive diagnostic assessments; 8) the results are from a single center and might not be generalizable; and 9) our findings may not be representative of the entire hospital work force as a greater proportion of staff with indirect compared to direct patient contact participated in the study.

## CONCLUSION

In this study, we found that depression and anxiety were pervasive among hospital staff. Our results identified specific groups of hospital staff experiencing depression and anxiety. Ancillary staff, administrative staff, and staff with less job experience are particularly vulnerable to negative mental health outcomes. The COVID-19 pandemic has been overwhelming, and a considerable proportion of staff reported stress as a result of COVID-19. Moreover, elevated stress levels were associated with clinically significant depression and anxiety. If left untreated, psychological distress can have long-term negative consequences that adversely lead to burnout and poor patient care. Therefore, it is imperative that hospital systems

**Table 2.** Chi-square analysis comparing staff overwhelmed and not overwhelmed by the stress of COVID-19.

| Factors | Overwhelmed by the stress of COVID-19 | | *p*-value |
|---|---|---|---|
| | No | Yes | |
| Gender | | | <0.001 |
| Female | 449 (50.4%) | 442 (49.6%) | |
| Male | 175 (67.3%) | 85 (32.7%) | |
| Age | | | 0.036 |
| Millennials (20-39 years) | 253 (51.4%) | 239 (48.6%) | |
| Generation X (40-55 years) | 225 (53.6%) | 195 (46.4%) | |
| Baby boomers (56-75 years) | 126 (62.1%) | 77 (37.9%) | |
| Occupation | | | <0.001 |
| Admin + ancillary staff with indirect patient contact | 254 (52.3%) | 232 (47.7%) | |
| Ancillary staff with direct patient contact | 35 (53%) | 31 (47%) | |
| Nursing | 234 (51.2%) | 223 (48.8%) | |
| Physician + advanced practitioner | 100 (70.9%) | 41 (29.1%) | |
| Years in current position | | | 0.723 |
| 0-5 | 259 (51.5%) | 244 (48.5%) | |
| 6-9 | 78 (50%) | 78 (50%) | |
| 10+ | 197 (53.5%) | 171 (46.5%) | |
| Contact with a patient suspected or confirmed to have COVID-19? | | | 0.013 |
| Yes | 258 (50.2%) | 256 (49.8%) | |
| No | 363 (57.5%) | 268 (42.5%) | |
| PHQ-9 score | | | <0.001 |
| PHQ-9 score<10 | 547 (62.7%) | 325 (37.3%) | |
| PHQ-9 score 10+ | 46 (20.3%) | 181 (79.7%) | |
| GAD-7 score | | | <0.001 |
| GAD-7 score<8 | 518 (69.7%) | 225 (30.3%) | |
| GAD-7 score 8+ | 76 (21.3%) | 281 (78.7%) | |

*PHQ-9*, Patient Health Questionnaire; *GAD-7*, General Anxiety Disorder.

**Table 3.** Logistic regression analysis to examine predictors for a patient health questionnaire-9 ≥10.

| Predictors | Adjusted odds ratio | *p*-value |
|---|---|---|
| Occupation | | |
| Admin + ancillary staff with indirect patient contact | 5.9 (1.06,111.01) | 0.042 |
| Ancillary staff with direct patient contact | 8.9 (1.46,173.03) | 0.015 |
| Nursing | 3.85 (0.69,72.44) | 0.139 |
| Physician + advanced practitioner | Reference | |
| Age | | |
| Millennial (20-39 years) | 1.1 (0.65,1.91) | 0.723 |
| Generation X (40-55 years) | 1.03 (0.63,1.71) | 0.898 |
| Baby boomers (56-75 years) | Reference | |
| Gender | | |
| Female vs male | 1.07 (0.68,1.7) | 0.784 |
| Years in current position | | |
| 0-5 years | 1.18 (0.76,1.83) | 0.463 |
| 6-9 years | 2.08 (1.24,3.5) | 0.006 |
| 10+ years | Reference | |
| Overwhelmed by the stress of COVID-19? (Y/N) | 7.06 (4.8,10.63) | <0.0001 |
| Contact with a patient suspected or confirmed to have COVID-19? (Y/N) | 1.33 (0.92,1.93) | 0.132 |

**Table 4.** Logistic regression analysis to examine predictors for a generalized anxiety disorder-7 score ≥8.

| Predictors | Adjusted Odds Ratio | *p*-value |
|---|---|---|
| Occupation | | |
| Admin + Ancillary staff with indirect patient contact | 2.61 (0.72,12.51) | 0.153 |
| Ancillary staff with direct patient contact | 3.82 (0.94,19.74) | 0.062 |
| Nursing | 1.95 (0.54,9.33) | 0.324 |
| Physician + Advanced Practitioner | Reference | |
| Age | | |
| Millennial (20-39 years) | 1.17 (0.72,1.92) | 0.520 |
| Generation X (40-55 years) | 1.04 (0.67,1.63) | 0.848 |
| Baby boomers (56-75 years) | Reference | |
| Gender | | |
| Female vs male | 1.24 (0.82,1.88) | 0.319 |
| Years in current position | | |
| 0-5 years | 0.91 (0.62,1.35) | 0.645 |
| 6-9 years | 0.88 (0.54,1.44) | 0.620 |
| 10+ years | Reference | |
| Overwhelmed by the stress of COVID-19? (Y/N) | 9 (6.49,12.65) | <0.0001 |
| Contact with a patient suspected or confirmed to have COVID-19? (Y/N) | 1.29 (0.92,1.82) | 0.141 |

develop and implement screening resources to evaluate for stress, depression, and anxiety among staff. Early detection and assistance may potentially reduce the distress associated with COVID-19 and promote psychological well-being.

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# Emergency Medicine Journal Editorial Boards: Analysis of Gender, H-Index, Publications, Academic Rank, and Leadership Roles

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**Introduction:** Our goal in this study was to determine female representation on editorial boards of high-ranking emergency medicine (EM) journals. In addition, we examined factors associated with gender disparity, including board members' academic rank, departmental leadership position, h-index, total publications, total citations, and total publishing years.

**Methods:** In this retrospective study, we examined EM editorial boards with an impact factor of 1 or greater according to the Clarivate Journal Citations Report for a total of 16 journals. All board members with a doctor of medicine or doctor of osteopathic medicine degree, or international equivalent were included, resulting in 781 included board members. We analyzed board members' gender, academic rank, departmental leadership position, h-index, total publications, total citations, and total publishing years.

**Results:** Gender disparity was clearly notable, with men holding 87.3% (682/781) of physician editorial board positions and women holding 12.7% (99/781) of positions. Only 6.6% (1/15) of included editorial board chiefs were women. Male editorial board members possessed higher h-indices, total citations, and more publishing years than their female counterparts. Male board members held a greater number of departmental leadership positions, as well as higher academic ranks.

**Conclusion:** Significant gender disparity exists on EM editorial boards. Substantial inequalities between men and women board members exist in both the academic and departmental realms. Addressing these inequalities will likely be an integral part of achieving gender parity on editorial boards. [West J Emerg Med. 2021;22(2)353-359.]

## INTRODUCTION

### Background

Emergency medicine (EM) is a rapidly growing and highly competitive medical specialty, with over 4000 residency applicants within the United States alone in 2019.[1] Despite the fact that medical schools now graduate equal numbers of men and women, EM remains predominantly male, with men representing over 72% of emergency physicians (EP), compared to 65% of physicians across medicine as a whole.[2] This demonstrable gender gap has decreased over the past several years, with the percentage of female EPs increasing from 22% in 2007 to nearly 30%

in 2018.[2] Despite the increasing proportion of women in EM, there exists an ongoing under-representation within the field of academic EM.[3-5] Recent data from the Association of American Medical Colleges (AAMC) demonstrates that women still represent the minority of departmental and faculty leadership positions within EM; only 11.4% of EM chairs and 19.3% of full professors are women.[6,7] Participation in academia, including peer-reviewed research, is important to the advancement of the profession and would be best served with equitable representation of its constituents.

A recent study examining academic positions held by EPs found that 17% of male academic EPs held the rank of full professor, compared to only 7% of female EPs.[3] The difference was less prominent but still notable for associate professor positions, with 24% of men holding this position compared to 19% of women.[3] Men held more than twice the number of chair and vice chair positions, at 10% vs only 4% of women.[3] Furthermore, this study found significant discrepancies in income, with the mean salary of academic female EPs $19,418 less than males, even when potentially confounding factors such as experience, clinical hours, and training were accounted for.[3]

*Population Health Research Capsule*

What do we already know about this issue?
*Previous studies have found large differences in the gender distribution of academic emergency medicine and emergency medicine journal editorial boards.*

What was the research question?
*What is the proportion of men and women on EM editorial boards, and has this number changed significantly over the past decade?*

What was the major finding of the study?
*There were more men than women on all EM journal boards examined. There has been little progress in this regard over the past 10 years*

How does this improve population health?
*Although the proportion of female EM doctors has increased, women are still vastly outnumbered on EM editorial boards. This study is an important step in addressing this complex issue.*

**Importance**

Previous studies have found substantial gender imbalances within academic disciplines, professional societies,[8-10] and editorial boards of medical journals across a wide variety of medical specialties.[11-20] In 2011 only 17.5% of board members and 15.9% of editors-in-chief across 60 major medical journals were found to be women.[16] Within EM these numbers are even lower, with women comprising only 13.2% of board members and 3.6% of editors-in-chief in 2010.[21] Appointment to an editorial board is viewed as a position of influence or eminence and is often sought by both male and female candidates; accepting this premise, it is unfortunate the women have been so persistently under-represented.[16-19,22]

**Goals of This Investigation**

We set out to examine and characterize gender disparities within EM editorial boards, using board demographics to assess whether any progress has been made over the past decade. Our primary outcomes measures were the proportion of male and female board members on each journal's editorial board, as well as academic achievement of these members based on h-index, departmental/academic rank, number of publications, number of citations, and total publishing years.

## METHODS

**Study Design and Setting**

This was a retrospective, descriptive study examining all doctor of medicine, doctor of osteopathic medicine (MD/DO) or international-equivalent board members on high-ranking EM journals. Data collection took place from January–May 2019. The study did not require institutional review board approval as all data obtained were publicly available on journal websites and databases.

**Selection of Journals**

Our study included EM medical journals with an impact factor of 1 or higher based upon the 2017 InCite Journal Citation Reports by Clarivate Analytics. Using these criteria, a total of 17 journals were included (Table 1). One journal, *Emergency Medicine Clinics of North America*, was excluded because their editorial board is temporary, with different members overseeing each issue.

**Measurements**

The primary outcome of our study was the number of women and men physicians on selected journal boards. Secondary outcomes included department/academic rank, total number of publications and citations, and active publishing years, as these are metrics that are often used as a measure of academic success.[23] The h-index, a score calculated based on an author's number of publications and number of citations per publication was also included, as this is often used as a measure of research productivity.[23]

Gender was recorded as male, female, or unknown. Academic rank was coded as Dean, Assistant dean, professor,

**Table 1.** Included journals in gender survey of editorial board membership.

| Journal | Impact factor |
|---|---|
| *Resuscitation* | 5.863 |
| *Annals of Emergency Medicine* | 5.008 |
| *Emergencias* | 3.608 |
| *World Journal of Emergency Surgery* | 3.198 |
| *Academic Emergency Medicine* | 2.612 |
| *Scandinavian Journal of Trauma Resuscitation and Emergency Medicine* | 2.312 |
| *Prehospital Emergency Care* | 2.269 |
| *Injury International Journal of the care of the Injured* | 2.199 |
| *Emergency Medicine Journal* | 2.046 |
| *European Journal of Emergency Medicine* | 1.729 |
| *European Journal of Trauma and Emergency Surgery* | 1.704 |
| *Canadian Journal of Emergency Medicine* | 1.481 |
| *Emergency Medicine Australasia* | 1.353 |
| *American Journal of Emergency Medicine* | 1.29 |
| *Journal of Emergency Medicine* | 1.207 |
| *Pediatric Emergency Care* | 1.066 |

associate professor, assistant professor, instructor, or "none" if no academic rank was held. Those with emeritus or honorary standing were placed in the category of "other." Departmental leadership position was coded as chair, vice chair, director, associate director, or assistant director. Director positions included medical, residency, or clerkship directors.

**Data Extraction**

The inclusion criteria were active (non-emeritus) editorial board members holding a medical degree (MD, DO, or an international equivalent). We excluded board members for whom gender could not be determined, those that could not be found in Elsevier's SCOPUS database, or those for whom publicly available information on gender or academic/departmental rank was absent. Information on each editorial board member's gender, academic rank, and departmental leadership position were elicited through journal webpages, press releases, or from university and hospital directories. Their full names were cross-checked by a Google search to minimize inaccuracies when extracting bibliometrics from Scopus. Gender was determined by a single author via descriptors (he/him, she/her) on journal, university, or hospital webpages or press releases. If no such descriptor could be found, the board member was excluded. We collected editorial board members' h-index, active publishing years, number of publications, and total number of citations via Elsevier's SCOPUS database. If an author had multiple entries in SCOPUS, the entry with the higher h-index was used. All data were collected between January–May 2019.

**Analysis**

We performed statistical analysis using SPSS version 25.0 (IBM Corp, Armonk, NY). Gender differences were represented as mean/median and percentages. Academic ranks and editorial positions were also represented as mean/median. We performed Pearson's correlation and Kruskal-Wallis test to deduce the relationship among the bibliometric study variables.

## RESULTS

**Characteristics of Study Subjects**

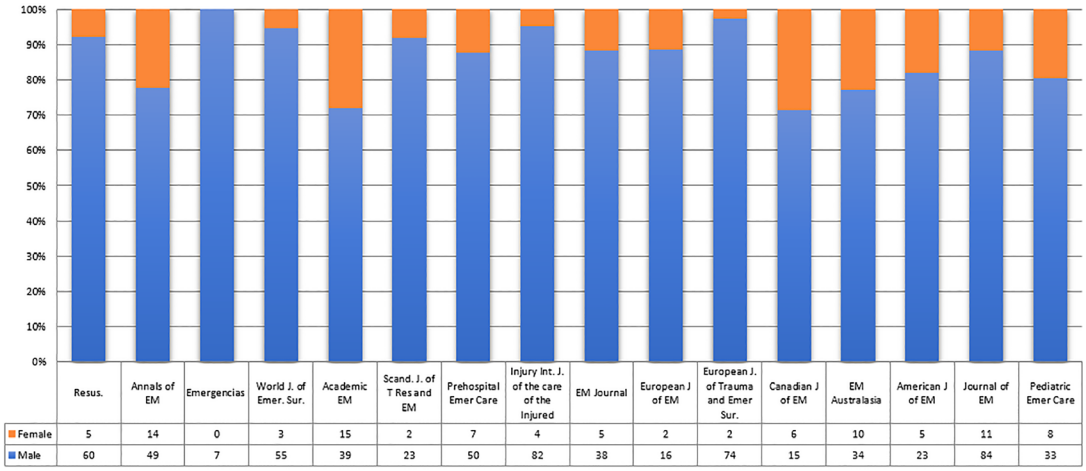
A total of 918 board members were found on the included journals' editorial board listings. We excluded 137 of these from the study based on the following: non-MD (65); inability to obtain adequate information on gender or lack of information on SCOPUS (59); the board member was deceased at the time of data collection (1); or the board member held an honorary position on the journal board only, ie, emeritus (12). Of those who were excluded, 41.6% were male, 21.9% were female, and 36.5% were of unknown gender. Overall, 781 board members were included in the study, 682 of whom were male and 99 female.

**Main Results**

There is a higher number of male editorial board members, with 87.32% (682/781) of editorial board members being male and 12.67% (99/781) female. Figure 1 shows that there is a greater proportion of male to female editorial board members across all selected journals. Senior positions (editor or editor-in-chief) on the editorial boards are more often held by men than women (13.18 %; 103/781 vs females 1.15%; 9/781) (Figure 2).

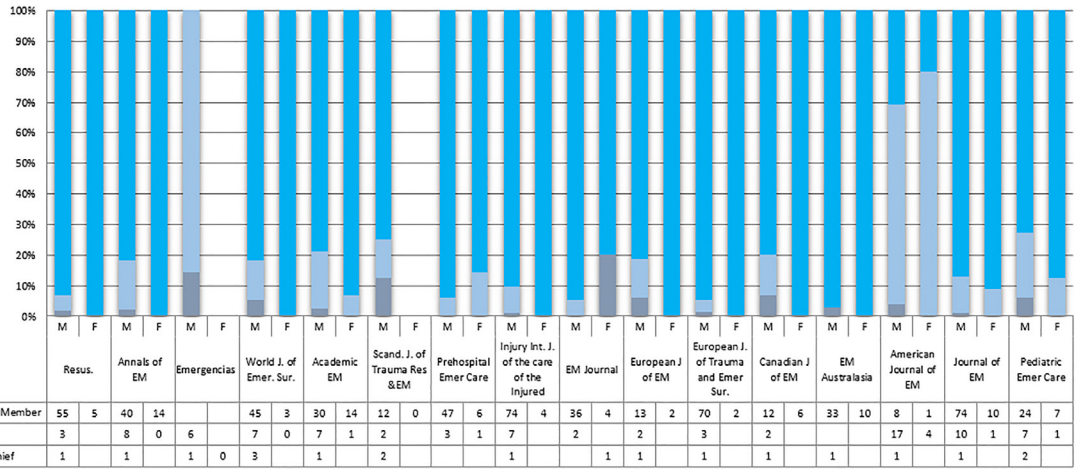
A greater proportion of men than women is seen across all academic ranks (Figure 3) and increasingly so at higher leadership positions (Figure 4). More female editorial board members are assistant or associate professors (26 of 99 [26.3%] vs 134 of 682 [19.6 %]) and more male editorial members are full professors (396 of 682 [58.1%[ vs 48 of 99 [48.5 %]), but the difference is not significant (chi square $P$ = 0.17) as seen in Figure 4. Higher departmental ranks are more often held by men. More department heads/chairs are males (216 of 682 [31.7%] vs 14 of 99 [14.1%]); however, a higher proportion of women are directors (31 of 99, 31.6% of women vs 183 of 682, 27.2% of men). This difference is statistically significant with chi-square $P$ = 0.004 (Figure 4).

Males have a higher mean h-index (23.8 vs 16.70; $P$ <0.0001) and higher mean total citations (3696.41 vs 1670.9; $P$ <0.0001). Additionally, males have significantly more publishing years compared to females (28 vs 18; $P$ = 0.00051) (Table 2). Bivariate analysis indicates that the number of publishing years are not a predictor of h-index ($P$ = 0.12).




| | Resus. | Annals of EM | Emergencias | World J. of Emer. Sur. | Academic EM | Scand. J. of T Res and EM | Prehospital Emer Care | Injury Int. J. of the care of the Injured | EM Journal | European J of EM | European J. of Trauma and Emer Sur. | Canadian J of EM | EM Australasia | American J of EM | Journal of EM | Pediatric Emer Care |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Female | 5 | 14 | 0 | 3 | 15 | 2 | 7 | 4 | 5 | 2 | 2 | 6 | 10 | 5 | 11 | 8 |
| Male | 60 | 49 | 7 | 55 | 39 | 23 | 50 | 82 | 38 | 16 | 74 | 15 | 34 | 23 | 84 | 33 |

**Figure 1.** Male and female editorial board members on individual journals.
*EM*, emergency medicine.




| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resus. | | Annals of EM | | Emergencias | | World J. of Emer. Sur. | | Academic EM | | Scand. J. of Trauma Res &EM | | Prehospital Emer Care | | Injury Int. J. of the care of the Injured | | EM Journal | | European J of EM | | European J. of Trauma and Emer Sur. | | Canadian J of EM | | EM Australasia | | American Journal of EM | | Journal of EM | | Pediatric Emer Care | |
| Editorial Member | 55 | 5 | 40 | 14 | | | 45 | 3 | 30 | 14 | 12 | 0 | 47 | 6 | 74 | 4 | 36 | 4 | 13 | 2 | 70 | 2 | 12 | 6 | 33 | 10 | 8 | 1 | 74 | 10 | 24 | 7 | | |
| Editor | 3 | | 8 | 0 | 6 | | 7 | 0 | 7 | 1 | 2 | | 3 | 1 | 7 | | 2 | | 2 | | 3 | | 2 | | | | 17 | 4 | 10 | 1 | 7 | 1 | | |
| Editor Chief | 1 | | 1 | | 1 | 0 | 3 | | 1 | | 2 | | | | 1 | | | 1 | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | | 2 | | | |

**Figure 2.** Males and females holding senior positions on editorial boards.
*EM*, emergency medicine.

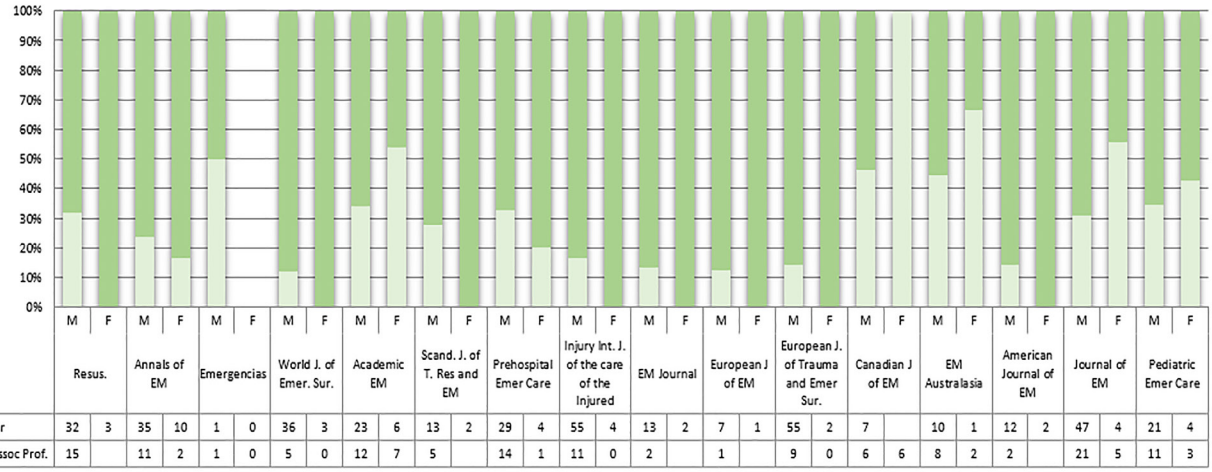
There were no significant differences between h-indexes of lower and higher academic ranks.

## DISCUSSION

Our study found that significant disparity exists within EM editorial boards. Across all journals included, women physicians on editorial boards were the vast minority, and were far less likely to hold the title of dean or full professor, or prominent departmental positions such as chair. Male editorial board members possessed higher h-indices, total citations, and more publishing years than their female counterparts. These results show that little progress has been made over the last decade: an analysis of 10 high-ranking EM journals by Miro et al in 2010 found women comprised 13.2% of editorial boards, compared to 12.7% in our study. With the percentage of female EPs increasing steadily over the past 10 years,[2] one would have expected EM editorial boards to experience similar changes in demographics, or at the very least an upward trend, but that was not the case.

Based on 2019 AAMC data, women represent 37.6% of academic EM faculty, 19.3% of professors, and 11.4% of EM chairs. Our study found lower rates of women on editorial boards (12.7%) and who were identified as professors (10.8% of professors) and as chairs (6.1% of chairs/department heads). Unfortunately, this data shows that despite the increased presence of women within academic EM,[7] there has not been an increase in the number of women represented on editorial boards.

Poor female representation on editorial boards has also been noted in numerous other specialties, including those with relatively high proportions of female physicians. In an extensive review of 60 medical journal editorial boards in 2011, women represented only 17.5% of editorial boards.[16] Even in journals dedicated to pediatrics and obstetrics, specialties in which female physicians predominate, women




| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Resus. | | Annals of EM | | Emergencias | | World J. of Emer. Sur. | | Academic EM | | Scand. J. of T. Res and EM | | Prehospital Emer Care | | Injury Int. J. of the care of the Injured | | EM Journal | | European J of EM | | European J. of Trauma and Emer Sur. | | Canadian J of EM | | EM Australasia | | American Journal of EM | | Journal of EM | | Pediatric Emer Care | |
| Professor | 32 | 3 | 35 | 10 | 1 | 0 | 36 | 3 | 23 | 6 | 13 | 2 | 29 | 4 | 55 | 4 | 13 | 2 | 7 | 1 | 55 | 2 | 7 | | 10 | 1 | 12 | 2 | 47 | 4 | 21 | 4 |
| Assist/Assoc Prof. | 15 | | 11 | 2 | 1 | 0 | 5 | 0 | 12 | 7 | 5 | | 14 | 1 | 11 | 0 | 2 | | 1 | | 9 | 0 | 6 | 6 | 8 | 2 | 2 | | 21 | 5 | 11 | 3 |

**Figure 3.** Proportion of male and female editorial board members holding full professor, associate professor, and assistant professor ranks. *EM*, emergency medicine.

were the minority on editorial boards at 30.8% and 26.9%, respectively.[16] It is clear that the proportion of women in a specialty alone is not responsible for the low numbers seen on editorial boards, and therefore measures aimed simply at increasing the number of female EPs will not be sufficient to address this issue on its own.

The explanation behind this stagnation in progress within EM editorial boards is not entirely clear, and appears not to be solely based on the numbers of women in EM and academic EM. Women in our study were less likely to be full professors or to hold departmental leadership positions, a phenomenon that has been noted by previous research and sometimes referred to as "the glass ceiling" effect.[3,4,16,24] Our research shows that there is a significant positive correlation between leadership positions and h-index; given that editorial boards often use academic productivity as a selection factor,[8-10,16,18,23] this is a systemic disadvantage for women.

It has been suggested that commitments involved with childbearing and childrearing, predilection for clinical and teaching positions over academic roles, and a lack of mentorship have all impacted the success of women in academic medicine.[16,22,25,26] Women more frequently hold education and teaching positions,[20,24] which are considered to be of lower value by many institutional promotions and tenure committees.[24] These roles are critically important but may inhibit those focused on education and teaching from advancing to higher academic ranks at the same rate as those who are focused on research. There are fewer peer-reviewed publication venues for medical educators, which may contribute to the lower number of publications among women in academic EM.

It should also be noted that, owing to a pipeline effect of fewer women entering and remaining in academic EM,[5,16,24] the pool of female academic physicians is younger than their male counterparts.[4] The women in our study had fewer publications, fewer years of publication and lower h-indices, but this may very well be reflective of an earlier career researcher, not someone who is less qualified. Overall, these factors contribute to a scenario in which women are faced with a substantial number of barriers as well as an inequitable selection process for editorial board positions. The creation of female-specific support and mentorship within academic EM is one way of potentially tackling these ongoing disparities,[16,22,23,25] and is a focus of several initiatives such as the American Academy of Emergency Medicine's Women in EM Section, the Canadian Association of Emergency Physicians Women in Emergency Medicine Committee, and the Academy for Women in Academic Emergency Medicine. All three of these groups cite support for women in leadership roles and the creation of mentorship opportunities as key goals of their organizations.[27-29]

In their 2019 paper, Agrawal et al suggest four core strategies for addressing gender disparities within academic EM: 1) commitment to education on gender bias and its mitigation; 2) ensuring equal resources and opportunities for women as compared to their male counterparts; 3) support for female leadership within EM; and 4) fostering of a workplace culture that allows balance between work and family life.[5] Importantly, the strategies outlined in their paper are aimed not only at increasing the number of women entering EM, but also at encouraging the retention and support of female EPs as they pass through the various stages, obstacles, and challenges of their careers.

In addition to these measures, we would suggest that journals themselves take on the responsibility to evaluate their editorial boards for adequate representation and set goals for improvement, such as the *Lancet* has done as part of the "#LancetWomen Project." This initiative, started in December 2017, involved a review of all editorial staff in the *Lancet* group and a subsequent commitment to reaching gender parity

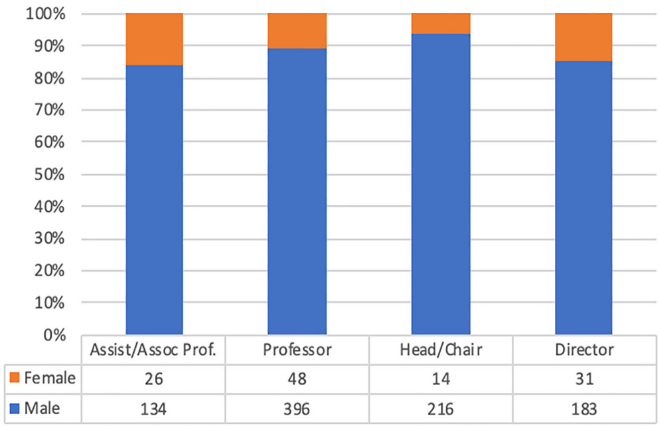



**Figure 4.** Departmental and academic rank of male vs female editorial board members.

**Table 2.** Publications, citations, and h-index of male and female editorial board members.

| | Overall Mean ± SD | Male Mean ± SD | Female Mean ± SD |
|---|---|---|---|
| Number of citations | 3467.23 ± 5752.6 | 3696.41 ± 1679.9 | 1674.52 ± 2628.5 |
| Years of publication | 27.26 ± 67.3 | 28.53 ± 72.4 | 18.35 ± 9.75 |
| Number of publications | 128.46 ± 140.2 | 136.35 ± 147.1 | 68.79 ± 61.4 |
| H-Index | 23.15 ± 17.3 | 23.8 ± 17.8 | 16.7 ± 12.1 |

*SD*, standard deviation.

on every *Lancet* group journals' editorial advisory board by 2020.[30] Although the data for 2020 has not yet been released at the time of this paper's writing, by February of 2019, 4 out of 14 *Lancet* journals had achieved this goal.[30]

## LIMITATIONS

There are several limitations to our study. Firstly, data collected on board members' gender, degree, academic rank, and leadership position were obtained through publicly available university and journal websites, or through press releases when the former were unavailable. Although this is a method that has been used and validated by other studies,[10,20,31] it is possible that data reported on these sites were either outdated or incorrect. Importantly, this study assumes that gender descriptors used in university/journal biographies or press releases are in line with the board member's gender identity. It is possible that this is not the case, and in particular may miss board members who do not identify as male or female.

Information on board members' research, including total number of publications, documents, and citations, total publishing years, and h-index was obtained through Elsevier's SCOPUS database. When there were duplicate records, the entry with the highest h-index was used. However, some authors may have publications divided between several entries and therefore were not fully credited. Further, researchers could have publications under a different last name. This may impact women more than men, as women are more likely to take their partner's surname after marriage.

To more accurately compare the proportion of male and female EPs to the proportion on editorial boards, we excluded editorial board members who did not hold an MD, DO, or international equivalent. Of these, 58% were men and 42% were women. Of note, one female editor-in-chief (the *Scandinavian Journal of Trauma*) was excluded from the study based on these criteria. Finally, there were several editorial board members who could not be identified with certainty by using the information provided on the journal's editorial board website, and others who did not have data in SCOPUS. These individuals were excluded from the study. Presumably, these would contain an equal number of men and women, but as the gender could not be elicited for many of them, the true proportion is unknown.

## CONCLUSION

Representation of women as emergency physicians has increased steadily over the past decade.[2] This move toward gender parity has not translated to editorial boards of top EM journals, with virtually no change to the proportion of female editorial board members in the past 10 years.[21] Currently, nearly 30% of EPs in the United States are women,[2] while only 12.7 % of EM editorial board members are women. Proportional representation is clearly not being achieved, and more needs to be done to address this gap.

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# First Pass Success Without Adverse Events Is Reduced Equally with Anatomically Difficult Airways and Physiologically Difficult Airways

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**Introduction:** The goal of emergency airway management is first pass success without adverse events (FPS-AE). Anatomically difficult airways are well appreciated to be an obstacle to this goal. However, little is known about the effect of the physiologically difficult airway with regard to FPS-AE. This study evaluates the effects of both anatomically and physiologically difficult airways on FPS-AE in patients undergoing rapid sequence intubation (RSI) in the emergency department (ED).

**Methods:** We analyzed prospectively recorded intubations in a continuous quality improvement database between July 1, 2014–June 30, 2018. Emergency medicine (EM) or emergency medicine/pediatric (EM-PEDS) residents recorded patient, operator, and procedural characteristics on all consecutive adult RSIs performed using a direct or video laryngoscope. The presence of specific anatomically and physiologically difficult airway characteristics were also documented by the operator. Patients were analyzed in four cohorts: 1) no anatomically or physiologically difficult airway characteristics; 2) one or more anatomically difficult airway characteristics; 3) one or more physiologically difficult airway characteristics; and 4) both anatomically and physiologically difficult airway characteristics. The primary outcome was FPS-AE. We performed a multivariable logistic regression analysis to determine the association between anatomically difficult airways or physiologically difficult airways and FPS-AE.

**Results:** A total of 1513 intubations met inclusion criteria and were analyzed. FPS-AE for patients without any difficult airway characteristics was 92.4%, but reduced to 82.1% (difference = - 10.3%, 95% confidence interval (CI), - 14.8% to - 5.6%) with the presence of one or more anatomically difficult airway characteristics, and 81.7% (difference = - 10.7%, 95% CI, - 17.3% to - 4.0%) with the presence of one or more physiologically difficult airway characteristics. FPS-AE was further reduced to 70.9% (difference = - 21.4%, 95% CI, - 27.0% to - 16.0%) with the presence of both anatomically and physiologically difficult airway characteristics. The adjusted odds ratio (aOR) of FPS-AE was 0.37 [95% CI, 0.21 - 0.66] in patients with anatomically difficult airway characteristics and 0.36 [95% CI, 0.19 - 0.67] for patients with physiologically difficult airway characteristics, compared to patients with no difficult airway characteristics. Patients who had both anatomically and physiologically difficult airway characteristics had a further decreased aOR of FPS-AE of 0.19 [95% CI, 0.11 - 0.33].

**Conclusion:** FPS-AE is reduced to a similar degree in patients with anatomically and physiologically difficult airways. Operators should assess and plan for potential physiologic difficulty as is routinely done for anatomically difficulty airways. Optimization strategies to improve FPS-AE for patients with physiologically difficult airways should be studied in randomized controlled trials. [West J Emerg Med. 2021;22(2)360-368.]

## INTRODUCTION

First pass success during tracheal intubation is associated with fewer adverse events in patients with critical illness.[1,2] Anatomic characteristics that impede glottic visualization or tube passage increase the risk of adverse events.[1,3] Consequently, emergency airway management has primarily focused on the prediction and management of patients with anatomically difficult airways to optimize the odds of achieving first pass success without adverse events (FPS-AE). Recently, there has been an increasing awareness of the importance of the physiologically difficult airway, which may increase the risk of AEs independent of any anatomic difficulty.[4-7] Critically ill patients are at high risk of hypoxemia, hypotension, and cardiac arrest because of deranged physiology that is often exacerbated during or resulting from airway management.[5,8] Hypoxemia and hypotension are particularly hazardous risks for cardiac arrest.[9-13]

Unfortunately, data are lacking regarding the effect of physiologically difficult airways on FPS-AE in the emergency department (ED). This study explores the association of physiologically and anatomically difficult airways with FPS-AE. It was hypothesized that physiologically difficult airways would also reduce FPS-AE.

*Population Health Research Capsule*

What do we already know about this issue?
*The physiologically difficult airway draws attention to non-anatomic difficulties that can increase the risks associated with emergency airway management.*

What was the research question?
*We sought to explore the relationship between physiologically and anatomically difficult airways and the desired outcome of first pass success without adverse events (FPS-AE).*

What was the major finding of the study?
*The physiologically difficult airway was associated with a similar reduction in FPS-AE compared to the anatomically difficult airway.*

How does this improve population health?
*Recognizing the physiologically difficult airway will encourage clinicians to identify and optimize physiologic derangements before intubation.*

## METHODS

### Study Design

We prospectively collected data on patient and operator characteristics for every intubation performed in our ED and stored the data in a continuous quality improvement (CQI) database, which has been described previously.[1,14] In 2014 we updated our airway data collection form to include characteristics related to the physiologically difficult airway. This is a retrospective analysis of that CQI data between July 1, 2014–June 30, 2018. This project was granted exemption from informed consent requirements by The University of Arizona Institutional Review Board.

### Study Setting and Population

This study was conducted at a 61-bed, tertiary care, urban ED with an annual volume of approximately 80,000 visits. The ED is a Level I trauma center designated by the American College of Surgeons and supports two separate three-year emergency medicine (EM) residency programs and a five-year combined EM/Pediatrics (EM-PEDS) residency program. Nearly all intubations are performed by EM or EM-PEDS residents under the direct supervision of an EM or EM-PEDS attending physician who is ultimately responsible for all aspects of emergency airway management. Inclusion criteria included all patients intubated by rapid sequence intubation (RSI). We excluded pediatric patients (age <18 years), and patients not intubated with either direct laryngoscopy (DL) or video laryngoscopy (VL). Pediatric patients were excluded because they have age-specific vital signs and compensatory mechanisms limiting the comparison to adults. Intubations performed by non-EM providers were not included because of their varying degrees of airway training. EM and EM-PEDS residents all receive annual training through similar airway didactics and rigorous simulation laboratory experience. Methods of intubation other than RSI were excluded from this analysis to create a homogenous cohort of patients.

### Data Acquisition

After each intubation, operators complete a data collection form that includes indication for, method of, and devices used for intubation, Cormack-Lehane view obtained, number and outcome of each attempt, and adverse events. An intubation attempt was defined as insertion of the laryngoscope into the mouth, regardless of whether an attempt was made to insert a tracheal tube. Adverse events include oxygen desaturation, hypotension, esophageal or mainstem intubation, aspiration, unintentional extubation, cuff damage, pneumothorax, dental/airway trauma, dysrhythmia, laryngospasm, and cardiac arrest.[1] Hypoxemia and hypotension were not considered adverse events if these physiologic derangements were present before airway management commenced. They were only considered adverse events if these physiologic derangements improved prior to the intubation attempt and subsequently deteriorated. Anatomically and physiologically difficult airway characteristics are listed in Table 1. As described previously, missing data forms are identified through a structured cross-referencing workflow to ensure 100% capture.[1]

**Table 1.** Difficult airway characteristics.

| Anatomically difficult airway characteristics | Physiologically difficult airway characteristics |
|---|---|
| Cervical immobility | Hypoxemia |
| Facial/neck trauma | Hypotension |
| Airway edema | Metabolic acidosis |
| Small mandible | Right ventricular failure |
| Obesity | |
| Large tongue | |
| Short neck | |
| Restricted mouth opening | |
| Blood in the airway | |
| Vomit in the airway | |

**Outcomes and Definitions**

The primary outcome was the proportion of patients with FPS-AE, which we defined as successful tracheal intubation on a single laryngoscope insertion without an AE. The secondary outcome was the incidence of AEs for each cohort.

**Data Analysis**

Patients were categorized into four groups: 1) patients with no difficult airway characteristics; 2) patients with one or more anatomically difficult airway characteristics; 3) patients with one or more physiologically difficult airway characteristics; and 4) patients with both anatomically and physiologically difficult airway characteristics. We reported patient demographic and clinical characteristics descriptively using means (SD) or medians (IQR), as appropriate for continuous variables. Categorical variables were reported as frequencies with percentages. The primary outcome of FPS-AE was compared between groups using a Fisher's exact test. We conducted a multivariable logistic regression analysis to determine the association between type of difficult airway characteristics and the outcome of FPS-AE. Potential confounding variables included in the model were defined a priori based on previous literature and clinical expertise of the investigators.[1] These included operator postgraduate year level, trauma status, age, and device used. The model was checked for interactions. Linearity in the log-odds was checked for continuous variables. We assessed model fit using the Hosmer-Lemeshow goodness of fit test. All statistical analyses were performed with STATA version 15 (StataCorp, College Station, TX).

**RESULTS**

A total of 2,077 intubations were performed during the study period, of which 1,513 patients met the inclusion criteria and were included in the analysis (Figure 1). Demographics are presented in Table 2. Of patients with an anatomically difficult airway, 49% (321/649) were intubated for a traumatic injury and more commonly by senior residents (44%, 284/649), while only 3% (5/186) of patients with a physiologically difficult airway were intubated for a traumatic injury and by a senior resident in 38% (70/186) of encounters. Only 5.3% of patients with anatomically difficult airways received ketamine for induction compared to 20.5% of physiologically difficult airway patients who received ketamine for induction. Of patients with an anatomically difficult airway 44% (288/649) were intubated with a hyperangulated video laryngoscope (HA VL. whereas only 12% (23/186) of patients with a physiologically difficult airway were intubated with a HA VL.

FPS-AE was reduced by similar amounts in both anatomically and physiologically difficult airway groups. This was additive when both difficult airway characteristics were present (Please see Table 3). The adjusted odds ratio (aOR) of FPS-AE are presented in Table 4. The model fit the data well (Hosmer-Lemeshow goodness of fit, $p = 0.302$), and no interactions were identified. The aOR of FPS-AE for individual difficult airway characteristics are presented in Table 5. Anatomically difficult airway characteristics that were negatively associated with FPS-AE were blood in the airway, small mandible, large tongue, and restricted mouth opening. Hypoxemia was the only physiologically difficult airway characteristic found to be negatively associated with FPS-AE.

The incidence of adverse events by cohort is depicted in Figure 2. The prevalence of AEs was similar between the anatomically and physiologically difficult airway cohorts. Oxygen desaturation was the most frequent AE in patients with anatomically difficult airways occurring in 9.2% (60/649) of tracheal intubations. In this group, hypotension occurred in only 1% (6/649) of patients. Oxygen desaturation (8.6%;

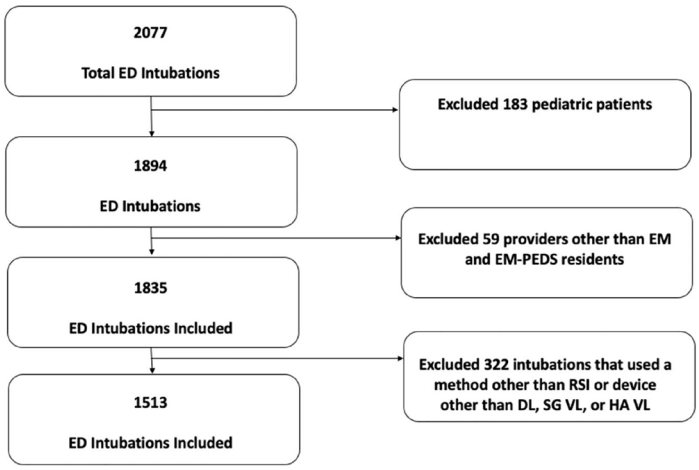


**Figure 1.** Flowchart of patients in the study during the four-year period. *ED*, emergency department; *EM*, emergency medicine residents; *EM-PEDS*, combined emergency medicine and pediatric residents; *RSI*, rapid sequence intubation; *DL*, direct laryngoscopy; *SG VL*, standard geometry video laryngoscope; *HA VL*, hyperangulated video laryngoscope.

**Table 2.** Patient, intubation, and operator characteristics.

| Groups (number of observations) | None (210) | ADA (649) | PDA (186) | Both (468) |
|---|---|---|---|---|
| Age, median (IQR), y | 51 (33 – 62) | 49 (32 – 62) | 59 (40 – 71) | 54 (38 - 66) |
| Gender | | | | |
| Male, no. (%) | 135 (64) | 441 (68) | 121 (65) | 313 (67) |
| Medical/ trauma, no. (%) | | | | |
| Medical | 189 (90) | 328 (51) | 181 (97) | 300 (64) |
| Trauma | 21 (10) | 321 (49) | 5 (3) | 168 (36) |
| Reason for Intubation, no. (%) | | | | |
| Airway protection | 156 (74) | 519 (80) | 74 (40) | 282 (60) |
| Cardiac arrest* | 3 (1) | 5 (0.8) | 5 (3) | 18 (4) |
| Patient control | 24 (12) | 65 (10) | 6 (3) | 14 (3) |
| Shock | 0 (0) | 1 (0.2) | 8 (4) | 17 (4) |
| Respiratory failure | 27 (13) | 59 (9) | 93 (50) | 134 (29) |
| Specific ADA, no. (%) | | | | |
| Cervical immobility | | 304 (47) | | |
| Facial/neck trauma | | 125 (19) | | |
| Airway edema | | 26 (4) | | |
| Small mandible | | 61 (9) | | |
| Obesity | N/A | 294 (45) | N/A | |
| Large tongue | | 100 (15) | | |
| Short neck | | 84 (13) | | |
| Restricted mouth opening | | 56 (9) | | |
| Blood in airway | | 129 (20) | | |
| Vomit in airway | | 90 (14) | | |
| Specific PDA characteristics, no. (%) | | | | |
| Hypoxemia | | | 105 (56) | 259 (55) |
| Hypotension | N/A | N/A | 90 (48) | 251 (54) |
| Metabolic acidosis | | | 59 (32) | 136 (29) |
| RV failure | | | 5 (3) | 6 (1) |
| NMBA used, no. (%) | | | | |
| Succinylcholine | 118 (56) | 451 (69) | 71 (38) | 267 (57) |
| Rocuronium | 92 (44) | 198 (31) | 115 (62) | 201 (43) |
| Induction agent used, no. (%) | | | | |
| Etomidate | 173 (82) | 603 (93) | 145 (78) | 412 (88) |
| Ketamine | 16 (8) | 35 (5.3) | 38 (20.5) | 52 (11) |
| Midazolam | 5 (2.5) | 3 (0.5) | 1 (0.5) | 3 (0.6) |
| Propofol | 15 (7) | 8 (1.2) | 2 (1) | 1 (0.2) |
| Other | 1 (0.5) | 0 (0) | 0 (0) | 0 (0) |
| Operator specialty, no. (%) | | | | |
| EM | 181 (86) | 579 (89) | 171 (92) | 412 (88) |
| EM-PEDS | 29 (14) | 70 (11) | 15 (8) | 56 (12) |
| Operator PGY EM, no. (%) | | | | |
| PGY-1 | 43 (20) | 96 (15) | 40 (21) | 63 (13) |
| PGY-2 | 82 (39) | 269 (41) | 76 (41) | 180 (39) |
| PGY-≥ 3 | 85 (41) | 284 (44) | 70 (38) | 225 (48) |

**Table 2.** continued.

| Groups (number of observations) | None (210) | ADA (649) | PDA (186) | Both (468) |
|---|---|---|---|---|
| Device Used, no. (%) | | | | |
| DL | 23 (11) | 39 (6) | 14 (8) | 15 (3) |
| SG VL | 132 (63) | 322 (50) | 149 (80) | 275 (59) |
| HA VL | 55 (26) | 288 (44) | 23 (12) | 178 (38) |

* = cardiac arrest patients who had return of spontaneous circulation.
*None*, no difficult airway characteristic; *ADA*, anatomically difficult airway; *PDA*, physiologically difficult airway; *Both*, both anatomically and physiologically difficult airway characteristic; *IQR*, interquartile range; *NMBA*, neuromuscular blocking agent; *EM*, emergency medicine residents; *EM-PEDS*, combined emergency medicine and pediatric residents; *PGY*, postgraduate year; *DL*, direct laryngoscopy; *SG VL*, standard geometry video laryngoscope; *HA VL*, hyperangulated video laryngoscope.

16/186) was also the most common AE in the physiologically difficult airway cohort. In addition, hypotension accounted for a significant number of AEs (6.4%; 12/186).

## DISCUSSION

Patients undergoing emergency airway management in the ED are at considerable risk of failed intubation attempts and AEs, which can negatively impact patient care. Thus, the objective of ED intubation is to accomplish FPS-AE to maximize patient safety. It is well appreciated that anatomically difficult airways can hinder attempts to achieve this objective. However, little is known about the impact of physiologically difficult airways on this objective. The aim of this investigation was to ascertain and compare the impact of anatomically and physiologically difficult airways on FPS-AE. We found that anatomically and physiologically difficult airways decreased FPS-AE virtually to the same extent. With the presence of one or more anatomically difficult airway characteristics, FPS-AE was reduced to 82.1%, while the presence of one or more physiologically difficult airway characteristics reduced FPS-AE to 81.7%.

Additional analysis demonstrated specific characteristics of difficult airways that were associated with reduction of FPS-AE. The logistic regression analysis revealed a reduced aOR for the following anatomically difficult airway characteristics: blood in the airway (0.52 [95% CI, 0.35 – 0.78]); small mandible (0.56 [95% CI, 0.35 – 0.89]); large tongue (0.44 [95% CI, 0.29 – 0.65]); and restricted mouth opening (0.32 [95% CI, 0.21 – 0.50]). Interestingly, the only physiologically difficult airway characteristic in the logistic regression analysis found to be associated with a reduction of FPS-AE was hypoxemia (0.35 [95% CI, 0.26 – 0.48]). A possible explanation for this is that hypoxemia is the one physiologically difficult airway characteristic that can impact both variables in the FPS-AE outcome.

For example, patients with pre-existent hypoxemia due to intrapulmonary shunt are at great risk for rapid oxygen desaturation with intubation. Thus, if the oxygen saturation decreases below 90% this would immediately result in an AE. If the oxygen saturation were above 90% but rapidly decreasing, the airway operator might choose to abort that attempt to reoxygenate, thus impacting the first pass success variable of the outcome. Also, since oxygen saturation is a continuously monitored variable throughout intubation, it more than any other physiologically difficult airway characteristic is more likely to influence the operator to abort laryngoscopy. It is possible that due to the low prevalence of the other physiologically difficult airway characteristics we were unable to demonstrate a statistically significant reduction in FPS-AE. Larger studies would likely be needed. The physiologically difficult airway, particularly hypoxemia, can negatively impact patient outcomes following emergency airway management.

While the purpose of this study was to investigate the anatomically and physiologically difficult airways impact on FPS-AE, an additional variable was found to influence the results. Both standard geometry video laryngoscopes (SG VL, aOR 1.77 [95% CI, 1.04 – 3.03]) and HA VL (aOR 1.74 [95% CI, 1.00 – 3.02]) were associated with an increase in FPS-AE. However, additional variables such as airway operator experience, the presence of traumatic injury, or age of the patient had no effect on FPS-AE. As seen in Table 2, this ED primarily uses VL to intubate patients. Our institution has been using VL in the ED for the last 20 years. The airway operators are very comfortable with the devices and are skilled with them. They are often used as the routine airway device. Numerous studies from this ED have demonstrated improved first- pass success while using VL.[1,15-18] Considering the variables assessed that may directly impact FPS-AE, VL was the only variable significant that may positively effect FPS-AE.

The data from the current study show an association between physiologically difficult airways and decreased FPS-AE. As stated above, the decrease in FPS-AE was of the same magnitude for patients with anatomically difficult airways as those with physiologically difficult airways. Focused interventions directed at attenuating these physiologically difficult airway characteristics have potential to improve the safety of emergency airway management. Implementation of an intubation bundle for the intensive care unit (ICU) was associated with a 50% reduction in the incidence of

**Table 3.** First-pass success without adverse events in all cohorts.

| Groups (n) | FPS-AE % (n) | 95% CI | % Difference (95% CI) |
|---|---|---|---|
| None (210) | 92.4 (194/210) | 87.9% to 95.6% | [Reference] |
| ADA (649) | 82.1 (533/649) | 78.9% to 85.0% | -10.3% (-14.8% to -5.6%) |
| PDA (186) | 81.7 (152/ 186) | 75.4% to 87.0% | -10.7% (-17.3% to -4.0%) |
| Both (468) | 70.9 (332/468) | 66.6% to 75.0% | -21.4% (-27.0% to -16.0%) |

*FPS-AE*, first-pass success without adverse events; *CI*, confidence interval; *None*, no difficult airway characteristic; *ADA*, anatomically difficult airway; *PDA*, physiologically difficult airway; *Both*, both anatomically and physiologically difficult airway characteristics.

**Table 4.** Multivariable regression analysis of predictors of first-pass success without adverse events.

| FPS-AE | Odds ratio | 95% CI | *p*-value |
|---|---|---|---|
| None | [Reference] | | |
| ADA | 0.37 | 0.21 – 0.66 | 0.001 |
| PDA | 0.36 | 0.19 – 0.67 | 0.001 |
| Both | 0.19 | 0.11 – 0.33 | <0.001 |
| Training year | | | |
| PGY1 | [Reference] | | |
| PGY 2 | 1.27 | 0.87 – 1.84 | 0.214 |
| PGY ≥ 3 | 1.40 | 0.96 – 2.03 | 0.078 |
| Trauma | 0.90 | 0.67 – 1.22 | 0.511 |
| Age (years) | 1.00 | 0.99 – 1.01 | 0.949 |
| Device | | | |
| DL | [Reference] | | |
| SG VL | 1.77 | 1.04 – 3.03 | 0.036 |
| HA VL | 1.74 | 1.00 – 3.02 | 0.049 |

*FPS-AE*, first-pass success without adverse events; *CI*, confidence interval; *None*, no difficult airway characteristic; *ADA*, anatomically difficult airway; *PDA*, physiologically difficult airway; *Both*, both anatomically and physiologically difficult airway characteristics; *PGY*, postgraduate year; *DL*, direct laryngoscopy; *SG VL*, standard geometry video laryngoscope; *HA VL*, hyperangulated video laryngoscope.

severe hypoxemia and cardiovascular collapse.[19] This bundle emphasized attenuating these physiological risks, including using noninvasive positive-pressure ventilation (NIPPV) for preoxygenation, which reduced the risk of hypoxemia.

Positive pressure ventilation for preoxygenation in hypoxemic patients (oxygen saturation <93%) was recently implemented in an air medical service, which resulted in reduced hypoxemia, increased intubation success, and had no effect on the incidence of witnessed aspiration.[20] Another prehospital study evaluated the impact of aggressive preoxygenation coupled with apneic oxygenation on hypoxemic events during emergency airway management. Their intubation bundle included upright positioning, positive pressure ventilation in hypoxemic patients, delayed sequence intubation, and apneic oxygenation. This combination was associated with a reduction of hypoxemic episodes from 44.2% to 3.5%.[21] Baillard demonstrated that the use of NIPPV for intubations in the ICU reduced desaturation rates (7% vs 46%) compared to standard face mask preoxygenation.[22] These studies demonstrate the importance of advanced preoxygenation techniques in these patients with physiologically difficult airways to attenuate the risks.

In addition to the use of positive pressure for preoxygenation, high-flow nasal oxygen (HFNO) has been demonstrated as a technique to further enhance preoxygenation.[23] However, in patients with severe hypoxemia, NIPPV prevented desaturation more frequently compared to HFNO in patients who underwent RSI.[24] The addition of HFNO to NIPPV further decreased the incidence of oxygen desaturation to 4% compared to 21% of patients preoxygenated with non-invasive ventilation alone during tracheal intubation of critically ill patients.[25]

Hypoxemia and hypotension are the two most frequent physiologic disturbances that contribute to serious AEs during airway management of the critically ill. Although there are several proposed approaches to prepare and proceed with intubation in the severely hypoxemic physiologically difficult airway, evidence for interventions to reduce peri-intubation hypotension is limited. Administration of norepinephrine immediately post-intubation (in hypotensive patients) and the avoidance of potent sympatholytic induction agents that depress cardiovascular function (eg, propofol and thiopental) reduced the number of cardiac arrest episodes.[19] The same patient group also received fluid loading as part of their 10-point intubation bundle. However, a recent trial with a heterogenous group of patients in eight ICUs and one ED who received a 500-mL fluid bolus before induction did not demonstrate any significant reduction in hemodynamic complications.[26] It is possible that fluid administration may have no effect on patients who have already had an initial fluid resuscitation prior to their ICU intubation. Generally, fluid resuscitation remains the recommendation as clinically indicated to the volume-responsive hypovolemic patient and, if necessary, administering inopressor agents prior to intubation for hemodynamic optimization of the physiologically difficult airway patient.

The medication used for induction may also contribute to peri-intubation hypotension. As mentioned, sympatholytic agents that contribute to depressed cardiovascular function including benzodiazepines, propofol, and thiopental should be avoided in patients with physiologically difficult airways.[5,19] Ketamine has sympathomimetic properties and etomidate is considered hemodynamically neutral, making these agents attractive choices for patients with hemodynamic compromise

**Table 5.** Adjusted odds ratios for individual difficult airway predictors.

| FPS-AE | Odds ratio | 95% CI | *p*-value |
|---|---|---|---|
| Training Year | | | |
| PGY1 | [Reference] | | |
| PGY2 | 1.27 | 0.86 – 1.87 | 0.228 |
| PGY ≥ 3 | 1.45 | 0.98 – 2.14 | 0.062 |
| Trauma | 0.86 | 0.54 – 1.38 | 0.536 |
| Age | 1.00 | 0.99 – 1.01 | 0.719 |
| Device | | | |
| DL | [Reference] | | |
| SG VL | 1.91 | 1.09 – 3.13 | 0.023 |
| HA VL | 1.77 | 1.00 – 3.12 | 0.050 |
| DAC | | | |
| None | [Reference] | | |
| Blood in the airway | 0.52 | 0.35 – 0.78 | 0.001 |
| Vomit in the airway | 0.84 | 0.55 – 1.29 | 0.436 |
| Short neck | 1.23 | 0.79 – 1.92 | 0.349 |
| Cervical immobility | 1.05 | 0.68 – 1.63 | 0.824 |
| Small mandible | 0.56 | 0.35 – 0.89 | 0.014 |
| Obesity | 0.82 | 0.59 – 1.12 | 0.238 |
| Airway edema | 0.70 | 0.35 – 1.39 | 0.308 |
| Facial/neck trauma | 0.94 | 0.58 – 1.52 | 0.812 |
| Large tongue | 0.44 | 0.29 – 0.65 | <0.001 |
| Restricted mouth opening | 0.32 | 0.21 – 0.50 | <0.001 |
| Hypoxemia | 0.35 | 0.26 – 0.48 | <0.001 |
| Hypotension | 1.26 | 0.90 – 1.78 | 0.173 |
| Metabolic acidosis | 0.96 | 0.63 – 1.44 | 0.834 |
| RV failure | 0.36 | 0.10 – 1.35 | 0.130 |

*FPS-AE*, first-pass success without adverse events; *CI*, confidence interval; *PGY*, postgraduate year; *DL*, direct laryngoscopy; *SG VL*, standard geometry video laryngoscope; *HA VL*, hyperangulated video laryngoscope; *DAC*, difficult airway characteristic; *RV*, right ventricular.

prior to intubation. Our study revealed a preference for these agents as 78% of patients with physiologically difficult airways received etomidate for induction and 20.5% received ketamine for induction. Ketamine use has demonstrated mixed results with some studies showing reduction in hemodynamic AEs, whereas other studies have found no difference in serious AEs with the use of ketamine compared to etomidate.[27,28] Furthermore, others have found a higher incidence of peri-intubation hypotension when ketamine was received compared to etomidate.[29] Based on the current data available, ketamine and etomidate are both reasonable induction agents for hemodynamically compromised patients.

It is well understood that the anatomically difficult airway places patients at risk for AEs.[1,3] Our findings suggest that the physiologically difficult airway is at least as important as the anatomically difficult airway. Furthermore, having both an anatomically and physiologically difficult airway places the patient at an additive risk for AEs and decreased FPS-AE. Physicians should approach the physiologically difficult airway with the same level of concern and preparation to mitigate risks as the anatomically difficult airway. Research is urgently needed to determine the best approach to attenuate these risks.

## LIMITATIONS

This study has several important limitations that must be considered. This was a single-center study in an academic medical center where residents performed the vast majority of intubations, limiting the ability to generalize the findings to other clinical settings. Even though 87% of forms were collected in real time, the data are subject to self-report, recall bias, and under-reporting of AEs. However, if AEs were under-reported, it is likely that they would be equally under-reported in both the anatomically and physiologically difficult airway groups. Additionally, there were potential important confounders such as level of training and indication for intubation that we attempted to account for by adjusting in the regression model. However, there could be important unknown confounders that we cannot account for, such as preintubation vital signs, vasopressor use, and fluid resuscitation.

We also did not document what modifications were made when an anatomically or physiologically difficult airway was predicted. However, in this training program, residents are instructed to perform an anatomic and physiologic difficult airway assessment prior to intubation to develop a strategy to address these issues. Device selection, particularly the use of VL, could be perceived as advantageous for the airway operator considering they were not blinded to the presence of an anatomically or physiologically difficult airway. This selection may have contributed to increased FPS-AE. However, our ED primarily uses VL as a first-line device so any advantage was likely present among all of the groups.

An additional limitation is that an independent reviewer did not determine the presence of difficult airway characteristics, potentially leading to bias that was not considered. Difficult airway assessment is subjective and this would not be feasible in our clinical environment. Furthermore, data collection forms were completed by the operator following the procedure and thus the procedure itself may have impacted what was documented on the form. Ideally, the operator would complete the airway form prior to intubation. However, given time constraints this is not feasible in our ED.

Since patients with physiologically difficult airway characteristics had similar characteristics to AEs, namely hypoxemia and hypotension, it was critical these definitions were clarified prior to the intubation attempt. Airway

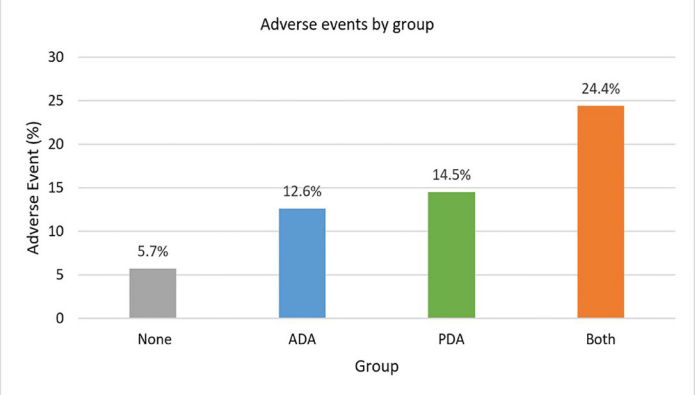


**Figure 2.** Adverse events by group.
*None*, no difficult airway characteristic; *ADA*, anatomically difficulty airway; *PDA*, physiologically difficult airway; *Both*, presence of both anatomically and physiologically difficult airway characteristics.

operators were instructed that if they had a physiologically difficult airway, hypotension or hypoxemia were not considered AEs unless there was improvement with subsequent reduction of blood pressure or oxygen saturation after the intubation event. All patients undergoing RSI in the ED were included in the study. Patients who had return of spontaneous circulation that required RSI to facilitate intubation had their anatomy and physiology assessed by the operator at the time of intubation and thus this was independent of their prehospital course.

## CONCLUSION

In this analysis of continuous quality improvement data from an academic ED, first pass success without adverse events decreased similarly for patients with either an anatomically or physiologically difficult airway. Optimization strategies to improve first pass success without adverse events for patients with physiologically difficult airways should be studied in randomized controlled trials.

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# Randomized Controlled Trial of Ultrasound-guided Fluid Resuscitation of Sepsis-Induced Hypoperfusion and Septic Shock

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**Introduction:** The ultrasound measurement of inferior vena cava (IVC) diameter change during respiratory phase to guide fluid resuscitation in shock patients is widely performed, but the benefit on reducing the mortality of sepsis patients is questionable. The study objective was to evaluate the 30-day mortality rate of patients with sepsis-induced tissue hypoperfusion (SITH) and septic shock (SS) treated with ultrasound-guided fluid management (UGFM) using ultrasonographic change of the IVC diameter during respiration compared with those treated with the usual-care strategy.

**Methods:** This was a randomized controlled trial conducted in an urban, university-affiliated tertiary-care hospital. Adult patients with SITH/SS were randomized to receive treatment with UGFM using respiratory change of the IVC (UGFM strategy) or with the usual-care strategy during the first six hours after emergency department (ED) arrival. We compared the 30-day mortality rate and other clinical outcomes between the two groups.

**Results:** A total of 202 patients were enrolled, 101 in each group (UGFM vs usual-care strategy) for intention-to-treat analysis. There was no significant difference in 30-day overall mortality between the two groups (18.8% and 19.8% in the usual-care and UGFM strategy, respectively; $p > 0.05$ by log rank test). Neither was there a difference in six-hour lactate clearance, a change in the sequential organ failure assessment score, or length of hospital stay. However, the cumulative fluid amount given in 24 hours was significantly lower in the UGFM arm.

**Conclusion:** In our ED setting, the use of respiratory change of IVC diameter determined by point-of-care ultrasound to guide initial fluid resuscitation in SITH/SS ED patients did not improve the 30-day survival probability or other clinical parameters compared to the usual-care strategy. However, the IVC ultrasound-guided resuscitation was associated with less amount of fluid used. [West J Emerg Med. 2021;22(2):369-378.]

## INTRODUCTION

Sepsis is a significant burden for emergency departments (ED) worldwide.[1-3] Moreover, it has a high mortality rate, especially in those with sepsis-induced tissue hypoperfusion (SITH) and septic shock (SS).[4-7] The initial treatment emphasizes early recognition, prompt administration of antibiotics, and the restoration of hemodynamic status with fluid resuscitation and

vasopressor therapy.[8] Treating patients with SITH/SS with a "usual-care" strategy, which includes prompt administration of isotonic crystalloid at the empirical amount of 30 milliliters per kilogram (mL/kg), has been proven to provide clinical outcomes similar to those of protocol-based therapies in large, well-designed clinical trials.[9-11] However, either excessive fluid bolus or inadequate fluid administration during the initial resuscitation is associated with increased mortality in SS patients.[12-16]

Inferior vena cava (IVC) diameter measurement during respirophasic change is widely used to help physicians predict the fluid responsiveness in shock patients and is reasonable to tailor fluid therapy during the resuscitation.[17-20] However, its benefit in reducing the mortality of sepsis patients remains unclear. The primary aim of this study was to evaluate the 30-day mortality outcome of patients with SITH/SS who were treated with ultrasound-assisted fluid management using the respirophasic change of the IVC during the first six hours compared with those who were treated with the "usual-care" strategy. Secondary outcomes were the six-hour lactate clearance, amount of intravenous (IV) fluid, rate of vasopressor and mechanical ventilator (MV) use, and change in sequential organ failure (SOFA) score at 72 hours in the two groups.

*Population Health Research Capsule*

What do we already know about this issue?
*Ultrasonographic inferior vena cava (IVC) diameter measurement is used to tailor fluid therapy in shock patients. Its benefit in reducing sepsis mortality is unclear.*

What was the research question?
*To compare the 30-day mortality of sepsis patients treated with IVC ultrasound-guided resuscitation and the usual-care strategy.*

What was the major finding of the study?
*IVC ultrasound-guided resuscitation did not improve survival of sepsis patients but was associated with less fluid volume.*

How does this improve population health?
*Assessment of ultrasonographic IVC diameter change did not affect overall survival of patients with sepsis.*

## METHODS

### Study Design and Setting

This randomized controlled trial was conducted in a 1,500-bed urban, university-affiliated tertiary-care hospital. This ED has more than 80,000 new patient visits per year. Our institutional review board approved this study, and written informed consent was required for trial participation. Patient recruitment started in January 2017 and concluded at the end of January 2020. This study was registered at ClinicalTrials.gov (identifier NCT03020407).

### Selection of participants

Adult (≥18 years old) nontraumatic SITH/SS patients (see Study definitions) who presented to the ED during the study period were enrolled in the study. Patient eligibility was assessed by emergency physicians during all work shifts. Patients were excluded if they met any of the following criteria: 1) congestive pulmonary edema or known poor systolic cardiac function (left ventricular ejection fraction ≤ 40%); 2) known right heart pathology; 3) had or were suspected of having marked ascites, significant bowel dilatation, or conditions that could cause abdominal hypertension; 4) body mass index ≥ 30 kilograms/meters squared; 5) concomitant attack of a severe airway disease (eg, asthma or chronic obstructive pulmonary disease that may have confounded the IVC interpretation; 6) IVC could not be identified, or its diameter could not be measured correctly; 7) end-stage renal disease with or without dialysis; 8) noninfectious disease as a final diagnosis; 9) pregnancy; 10) were referred from or treated at other healthcare facilities; 11) active hemorrhage; 12) duplicated or multiple case visits; 13) had a living will stating "do not resuscitate"; and 14) declined to consent.

### Study Definitions

In this study we specifically defined patients with SITH as those with infections and systolic blood pressure equal to or less than 90 millimeters of mercury (mm Hg) or initial lactate equal to or greater than 2 millimoles/liter (mmol/L) at ED presentation. However, we used the most recent definitions of septic shock and other related terms recommended in the literature.[21] In brief, patients with septic shock are defined as those who require a vasopressor to maintain a mean arterial pressure of 65 mm Hg or greater and whose serum lactate level is greater than 2 mmol/L in the absence of hypovolemia. The venous or arterial lactate level was obtained and followed up using the same method in each individual. Six-hour lactate clearance (%) is calculated as [(initial lactate – lactate at 6 hours)/initial lactate] ×100%. To follow the deterioration or improvement of organ dysfunction of a patient, the sequential organ failure assessment (SOFA) score was determined at ED presentation and at 72 hours after treatment. The SOFA scoring system is described elsewhere.[22-23]

**Study Protocol**

In our protocol we prepared the preplanned, permuted block-of-four randomization list that was blinded to the investigators before patient allocation. Randomization was set at a 1:1 ratio of the ultrasound-guided and usual-care arms. When an eligible patient was identified and informed consent was obtained, demographic data, preexisting condition, bloodwork, diagnostic investigations, microbiologic workups, and blood lactate were collected at ED arrival (hour 0). Prompt empirical antibiotics were given to every patient within one hour after ED arrival. Then, the patient was rapidly assigned in accordance with the randomization and treated with one of the two treatment strategies as follows:

*Ultrasound-guided fluid management (UGFM) strategy*

In this treatment arm, the treating emergency physician promptly assessed the IVC diameter to obtain the IVC collapsibility index (IVCCI) (or distensibility index, IVCDI; see below for the description, formulation and measurement method) of each patient while venous access was performed and initial laboratory specimens were collected. A previous study showed that IVCCI > 40% was strongly associated with fluid responsiveness.[24] Accordingly, the patient was given a 10 milliliters (mL)/kg bolus of 0.9% normal saline solution (NSS) without delay if an IVCCI > 40% was discovered, and serial measurements were immediately performed after each IV bolus was achieved an IVCCI < 40% during our protocol. Then, the rate of IV fluid administration was maintained based on the individual's condition. If the patients in this arm subsequently required endotracheal intubation and MV with sedation within six hours after initiation of therapy, the IVCDI was measured as a replacement for IVCCI. The same amount of NSS was given when IVCDI > 18%[17] until IVCDI < 18% was achieved. The IVC evaluation was serially performed and recorded every two hours until six hours after ED presentation. The same treatment protocol was repeated when the threshold of IVCCI (or IVCDI) percentage for potential fluid responsiveness was identified.

*Inferior vena cava diameter measurement and indicators of fluid responsiveness*

In our protocol, IVC was identified in longitudinal section in the subcostal area using the curvilinear or phased array transducers (cardiac) of a standard ultrasound machine. The selected area of IVC diameter measurement was set at 2 centimeters distal to the confluence of the hepatic vein by M-mode coupled with two-dimensional mode on frozen screen images using the Sonosite X-porte (Fujifilm Sonosite, Inc., Bothell, WA). All treating physicians including attending staff and residents regularly participated in hands-on training twice a year (as usual basis) by a qualified international instructor in critical care ultrasonography (the third author). The residents who were allowed to perform the study protocol required at least six months exposure in real clinical experience and had passed formal performance evaluation on ultrasonographic IVC measurement. If the patient was breathing spontaneously, the IVCCI, which reflects the decrease in IVC diameter on spontaneous inspiration, was used. IVCCI is calculated as follows:

$$[(\text{IVC diameter}_{max} - \text{IVC diameter}_{min})/\ \text{IVC diameter}_{max}]\times 100\%.$$

If the patient required MV for respiratory support, the IVCDI, which reflects the increase in IVC diameter on mechanical inspiration, was used. IVCDI is calculated as follows:

$$[(\text{IVC diameter}_{max} - \text{IVC diameter}_{min})/\ \text{IVC diameter}_{min}]\times 100\%.$$

Sample images of ultrasonographic landmark and respirophasic diameter changes of an IVC during volume expansion are shown in Figures S1A and S1B in the Supplemental material.

*Usual-care strategy*

Patients were promptly treated with 30 mL/kg loading of NSS in this treatment arm. After the NSS bolus, treatment with either the additional IV fluid or a vasopressor was given at the physicians' discretion during the six-hour study period. The threshold for the need of a vasopressor was set at mean arterial pressure below 65 mm Hg if a patient did not respond to fluid therapy during each treatment protocol, and the time of vasopressor administration was noted. However, ancillary fluid administration was allowed at treating physicians' judgment in both treatment arms. Other adjunctive therapies, such as colloid administration, central venous catheterization, or surgical removal of the infectious source, were not prohibited in our protocol and were used at the discretion of the treating physicians. The study patients were closely monitored while we recorded their clinical parameters every two hours for study purposes. Our resuscitative study protocol stopped at six hours after initiation of the treatment. After this period, patients were treated according to the physicians' judgment.

**Outcome Measurements**

At six hours after treatment, the cumulative fluid volume was recorded, and blood lactate was obtained for lactate clearance calculation. At 72 hours after ED presentation, the cumulative fluid volume from the initial presentation was again recorded, and the patients were followed for clinical condition evaluation and blood chemistry tests to calculate the SOFA score and assess its change from the hour-zero

baseline. The in-hospital requirement and time to start renal replacement therapy or MV were followed and recorded by searching the electronic data summary of a patient. The indication to initiate these life-saving procedures was at the discretion of the treating physicians. To identify the deceased patients for mortality analysis, we retrieved the electronic database of in- and outpatient clinical records or made a telephone call to the patients or their personal contact in every case at 30 days after the day of hospital presentation. The clinical data retrieval was performed and recorded by the trained non-investigators.

**Data Analysis**

*Sample-size determination*

According to the results of large trials of septic shock treatment, the 90-day mortality was 30% in the usual-care group.[9-11] Based on this information, we calculated that a sample of 254 patients would have a power of 80% to detect a relative reduction of 50% in risk (15 percentage points of absolute risk reduction) in the UGFM group, allowing for a loss to follow-up or withdrawal of 5%. The target number for primary outcome analysis would be 121 patients per group. One interim analysis was performed after the enrollment of 50% of the patients, with the use of a two-sided symmetric O'Brien–Fleming (or alpha spending method) design.[25]

*Statistical analysis*

We used Stata version 14.0 (StataCorp LLC, College Station, TX) for all statistical tests and production of graphics. The normally and non-normally distributed data were analyzed using the two independent-samples t test and Mann-Whitney U test, respectively. A $\chi^2$ test with odds ratio (OR) was performed to compare the proportions between the groups. No data were imputed for any missing information. We used the Kaplan-Meier curve and the log-rank test to compare the 30-day mortality between the treatment arms. All tests were two-sided for superiority testing and considered statistically significant at a $p < 0.05$.

**RESULTS**

In accordance with the data safety monitoring board, the investigators decided to stop the trial before the target number of participants was recruited due to the possible ineffectiveness of the intervention and safety concerns. In total, 514 patients were screened for eligibility; 106 and 105 eligible patients were randomized to the usual-care and UGFM treatment arms, respectively. In summary, there were 101 patients in each treatment group available for intention-to-treat analysis. The patient flow chart and exclusion details are shown in Figure 1 and Table S1 of the Supplemental materia**l.** There was no significant difference in the demographic data of patients between the two treatment groups as demonstrated in Table 1 and Table S2 of the Supplemental material**.**

*Study outcome analysis*

There was no significant difference in 30-day mortality between the two groups (Figure 2, 18.8% and 19.8% in the usual-care and UGFM strategies, respectively; $p > 0.05$ by log rank test). For secondary outcome analyses, we did not find a significant difference between the treatment groups in six-hour lactate clearance, SOFA score at 72 hours or the length of hospital stay. However, the rate of vasopressor use and the cumulative fluid administration in 24 hours was lower in the UGFM arm. The comparisons of the study variables are shown in Table 2. Inferior vena cava targets were achieved at least two times in 68.3% of the patients in UGFM arm. The ultrasonographic IVC parameters of the patients in this group are summarized in Table S3 of the Supplemental material.

*Subgroup analysis*

We performed prespecified analysis among different patient subgroups. However, we did not find a significant survival benefit in any specific subgroup. Whereas a positive survival trend in the UGFM treatment arm was discovered for patients with slight elevation of initial blood lactate (2 to <4 mmol/L), the analysis also revealed a potential negative effect of the intervention on those with initial lactate ≥4 mmol/L. However, neither of the subgroups reached statistical significance. A forest plot of the subgroup analysis and related information is shown in Figure 3.

**DISCUSSION**

The use of point-of-care ultrasound (POCUS) is helpful in rapidly identifying causes of shock in the ED.[26,27] Moreover, it is useful in determining fluid responsiveness during resuscitation in critically ill patients through the measurement of respiratory change in IVC diameter.[28-30] Although some investigators discourage the routine use of IVC ultrasound to guide fluid therapy in critically ill patients,[31] this study, to our knowledge, was the first to specifically investigate the effect of this intervention on patient survival. Ultimately, we did not find an improvement in the clinical outcome of septic patients treated with the UGFM strategy in our setting. Similarly, a recent study showed that the early use of POCUS protocol did not result in a survival benefit in patients with undifferentiated hypotension.[32]

The results from an impactful research on a large database of the ED patients who had been admitted to the ICUs with SS showed that the use of large fluid volume (over five liters) during the first day of SS resuscitation was associated with increased risk of hospital mortality.[33]According to our results, the median volume of fluid administered to both groups of patients was still in a low range (less than 5000

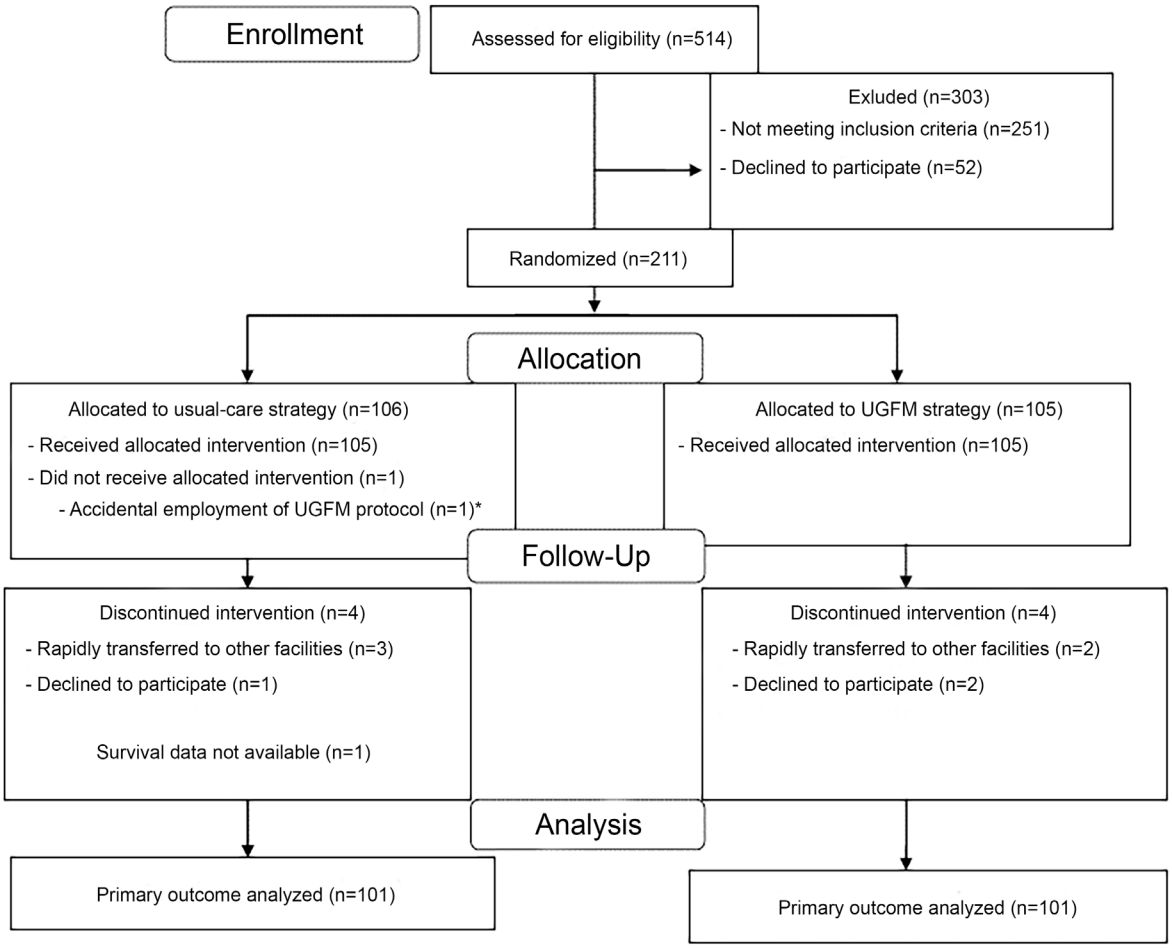


**Figure 1.** The CONSORT diagram demonstrating patient flow in both treatment groups. Reasons for patient exclusion are shown in Table S1 in the Supplemental material.
*This patient was finally analyzed in the usual-care arm according to intention-to-treat analysis.
*UGFM*, ultrasound-guided fluid management.

mL in the first 24 hours) and the difference of the 24-hour fluid amount between the study arms, although statistically significant, was not substantial (median = 4800 vs 4080 mL in the usual-care and UGFM groups, respectively). Thus, the early-phase resuscitative fluid amount used in either group did not reach the harmful threshold that may have produced an increased mortality risk. This could possibly result in the similar mortality rates no matter which treatment strategy had been performed. However, our study revealed even less fluid amount given in the UGFM group compared to that of the usual-care treatment.

Our in-depth study analysis showed that, regardless of the treatment strategies, the median amount of fluid used during the initial phase of resuscitation in non-survivors was strikingly higher than that of survivors. (Table S4 of the Supplemental material). These secondary findings imply that more volume of initial resuscitative fluid was associated with mortality probability. Thus, physicians should be aware of unnecessary or irrational fluid bolus during their resuscitation practice. The use of respiratory change of IVC diameter measured by POCUS during the initial phase of sepsis resuscitation may generate the test characteristics that prospectively direct physicians not to "overload" patients with a cautious fluid restriction. Current trends of fluid resuscitation in septic shock advocates the minimization of fluid therapy and prevention of fluid overload.[34-36] Furthermore, previous studies demonstrated that dynamic assessments to guide fluid administration can reduce the amount of fluid and potentially improve outcomes of patients with septic shock.[37-38] Our study is likely to support these concepts.

Interestingly, we found a significantly lower rate of vasopressor use in patients treated with UGFM, while a recent study revealed a higher incidence of vasopressor need in septic patients resuscitated with a restrictive fluid strategy.[39] Previous data have shown the detrimental effects of a large fluid bolus on physiologic changes and clinical outcomes of septic patients.[40-42] An animal study demonstrated that sheep with endotoxemic shock and

**Table 1.** Demographic data of the patient cohort.

| Clinical parameters and patient characteristics | Total n=202(100%) | Usual care n=101 (100%) | UGFM n=101 (100%) | *p*-value (95% CI) |
|---|---|---|---|---|
| At presentation | | | | |
| Female gender | 86(42.6) | 38(37.6) | 48(47.5) | 0.14 |
| Age, years (means±SD) | 64.5±18.5 | 63.7±16.8 | 65.3±20.1 | 0.52 |
| Body weight, kilograms (means±SD) | 55.2±12.2 | 55.6±12.8 | 54.7±11.7 | 0.55 |
| Triage-to-antibiotic time (minutes), median (IQR)[a] | 59(41-76) | 54.5(40-68.5) | 60.5(44-84.5) | 0.09 |
| SBP at presentation, mmHg (means±SD) | 102.4±28.9 | 99.2±26.9 | 105.7±30.4 | 0.11 |
| ≤ 90 | 90(44.6) | 52(51.5) | 38(37.6) | 0.06 |
| ≤ 90 without hyperlactatemia (≥ 2 mmol/L) | 23(11.4) | 11(10.9) | 12(11.9) | 0.83 |
| SOFA score (points), median (IQR)[a] | 4(3,6) | 4(3,6) | 4(3,6) | 0.82 |
| ≥ 2 | 181(89.6) | 92(91.1) | 89(88.1) | 0.49 |
| ≥ 4 | 125(61.9) | 59(58.4) | 66(65.3) | 0.31 |
| Initial lactate (mmol/L)[a] | 3.3(2.4-4.6) | 3.6(2.4-5.6) | 3.2(2.3-4.1) | 0.08 |
| ≥ 2 | 178(88.1) | 90(89.1) | 88(87.1) | 0.66 |
| ≥ 2 without SBP ≤ 90 mm Hg | 111(55.0) | 49(48.5) | 62(61.4) | 0.07 |

*UGFM*, ultrasound-guided fluid management; *CI*, confidence interval; *mmo/L*, millimoles per liter; *SD*, standard deviation; *IQR*, interquartile range; *SBP*, systolic blood pressure; *mm HG*, millimeters mercury.
*P-value < 0.05.
[a]Mann-Whitney U test.

large-volume resuscitation needed a higher vasopressor dose to maintain their mean arterial pressure.[43] Our results also revealed a possible association trend, although not statistically significant, toward the decrease in ventilator requirement in the UGFM group. However, there was conflicting data about the association between large amount of fluid volume and the requirement of MV in the resuscitation of SS patients.[44, 45] The explanation for the reduction in vasopressor need and potential decrease in ventilator requirement during the treatment of septic patients in the UGFM group in our study remains unclear and needs further investigation.

The equivocal outcomes in the specific subgroups of SITH/SS patients also require additional scientific investigation in a larger population. According to our results in this ED, the initial use of respirophasic change in IVC diameter with POCUS in resuscitating SITH/SS did not improve the overall survival probability of patients compared to those treated with the usual-care strategy. It also did not improve lactate clearance or SOFA score. However, it was associated with a reduced amount of IV fluid given during the initial resuscitation.

## LIMITATIONS

Our study had noteworthy limitations. First, this study was conducted with the specific study protocol at a single, tertiary-care hospital. The results may not be generalizable to other settings with various resuscitative techniques or protocols or if different target parameters are set. Second, since our recruited patients had median initial SOFA scores

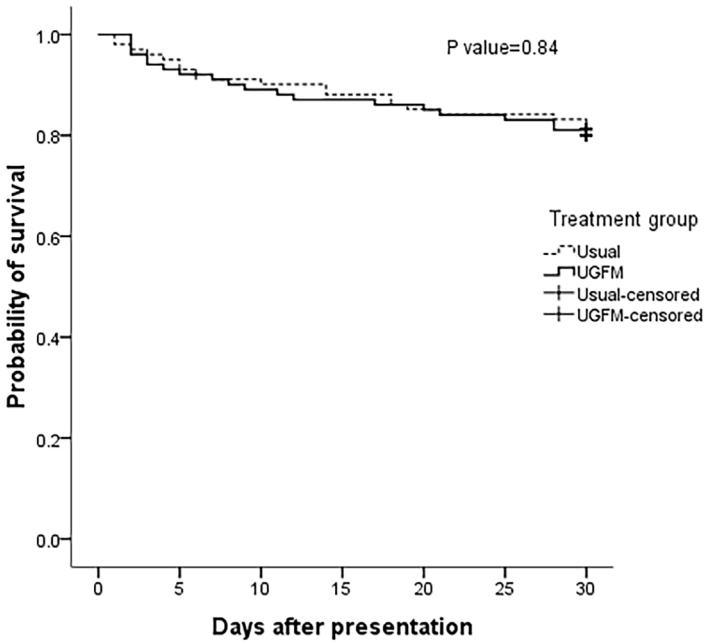


**Figure 2.** Kaplan–Meier curves showing the probability of survival among patients treated with ultrasound-guided fluid management or the usual-care strategy (intention-to-treat analysis). The hazard ratio was 0.94 (95% confidence interval [CI], 0.50 to 1.75), P>0.05 by log rank test.

**Table 2.** Results of the patient cohort and comparisons between treatment groups.

| Parameters | Total n=202 (100%) | Usual-care n=101(100%) | UGFM n=101 (100%) | *p*-value (95%CI) |
|---|---|---|---|---|
| At 6 hours | | | | |
| 6-hour lactate (mmol/L), median (IQR)[a†] | 1.9(1.1-3.2) | 2.0(1.1-3.5) | 1.8(1.1-2.8) | 0.32 |
| 6-hour lactate clearance (%), median (IQR)[a] | 37.8(10.3-60.0) | 35.9(16.3-65.5) | 39.2(7.4-60.0) | 0.86 |
| > 10% | 150(75) | 78(78) | 72(72) | 0.33 |
| > 50% | 75(75) | 34(34) | 41(41) | 0.31 |
| Normalization of 6-hour lactate | 108(54) | 51(51) | 57(57) | 0.40 |
| Vasopressor use | | | | |
| At 6 hours | 72(35.6) | 45(44.6) | 27(26.7) | 0.008* |
| Missing data | 0 | 0 | 0 | . |
| At 72 hours | 86(43.0) | 50(50.5) | 36(35.6) | 0.034* |
| Missing data | 2(1) | 2(2.0) | 0(0) | . |
| Mechanical ventilator use | | | | |
| At 6 hours | 35(17.3) | 22(21.8) | 13(12.9) | 0.094 |
| Missing data | 0 | 0 | 0 | . |
| At 72 hours | 53(26.5) | 30(30.0) | 23(23.3) | 0.26 |
| Missing data | 2(1) | 1(1.0) | 1(1.0) | . |
| Renal replacement therapy at 72 hours | 13(6.6) | 5(5.1) | 8(8.0) | 0.41 |
| sCr at 72 hours (mg/dL), median (IQR)[a] | 0.8(0.6-1.1) | 0.8(0.6-1.0) | 0.8(0.6-1.1) | 0.65 |
| Acute kidney injury[‡] (%) | 6(3.6) | 2(2.3) | 4(5.0) | 0.35 |
| Missing data | 35(17.3) | 14(13.9) | 21(20.8) | . |
| Cumulative fluid used (mL), median (IQR)[a] | | | | |
| At 6 hours | 2,400(1,839-2,950) | 2,600(2,300-3,220) | 1,900(1,500-2,570) | <0.001* |
| Amount of fluid per kilogram (mL/kg) | 44(33-57) | 48(38-63) | 36(28-49) | <0.001* |
| Missing data | 0 | 0 | 0 | . |
| At 24 hours | 4,507(3,508-5,716) | 4,800(3,810-6,410) | 4,080(2,990-5,255) | <0.001* |
| Amount of fluid per kilogram (mL/kg) | 85(61-113) | 88(67-123) | 79(51-102) | 0.005* |
| Missing data | 24(11.9) | 12(11.9) | 12(11.9) | . |
| At 72 hours | 7,530(5,500-10,266) | 7,702(5,900-11,275) | 7,300(5,040-9,200) | 0.044* |
| Amount of fluid per kilogram (mL/kg) | 149(100-199) | 156(104-204) | 142(98-193) | 0.13 |
| Missing data | 30(14.9) | 18(17.8) | 22(21.8) | . |
| SOFA score at 72 hours (points), median (IQR)[a] | 3(1-6) | 3(1-7) | 3(1.75-5) | 0.91 |
| Changes in SOFA score (points) | 1(-1 to 3) | 1(-1 to 2) | 1(-1 to 3) | 0.85 |
| < 2 points (%) | 47(28.7) | 28(32.6) | 19(24.4) | 0.25 |
| Missing data | 38(18.8) | 15(14.8) | 23(22.8) | . |
| Length of stay (days), median (IQR)a | 8(5-16) | 8(5-16.5) | 8(4-15) | 0.39 |
| 30-day mortality (%) | 39(19.3) | 19(18.8) | 20(19.8) | 0.84[§] |

Note: Changes in SOFA score, SOFA score at presentation minus SOFA score at 72 hours.
*P-value < 0.05.
[a]Mann-Whitney U tes.t
[†]Data of 6-hour lactate among 100 patients in usual-care group and 100 patients in UGFM group was available for further calculation and analyses.
[‡]Defined by an absolute increase in serum creatinine (sCr) at 72 hours after presentation at least 0.3 mg/dL (sCr at 72 hours minus sCr at presentation ≥ 0.3).
[§]Log rank test, the hazard ratio was 0.94 (95% confidence interval, 0.50 to 1.75).
*UGFM*, ultrasound-guided fluid management; *SD*, standard deviation; *IQR*, interquartile range; *mg/dL*; milligrams per deciliter; *mL/kg*, milliliters per kilogram; *SOFA*, sequential organ failure assessment.

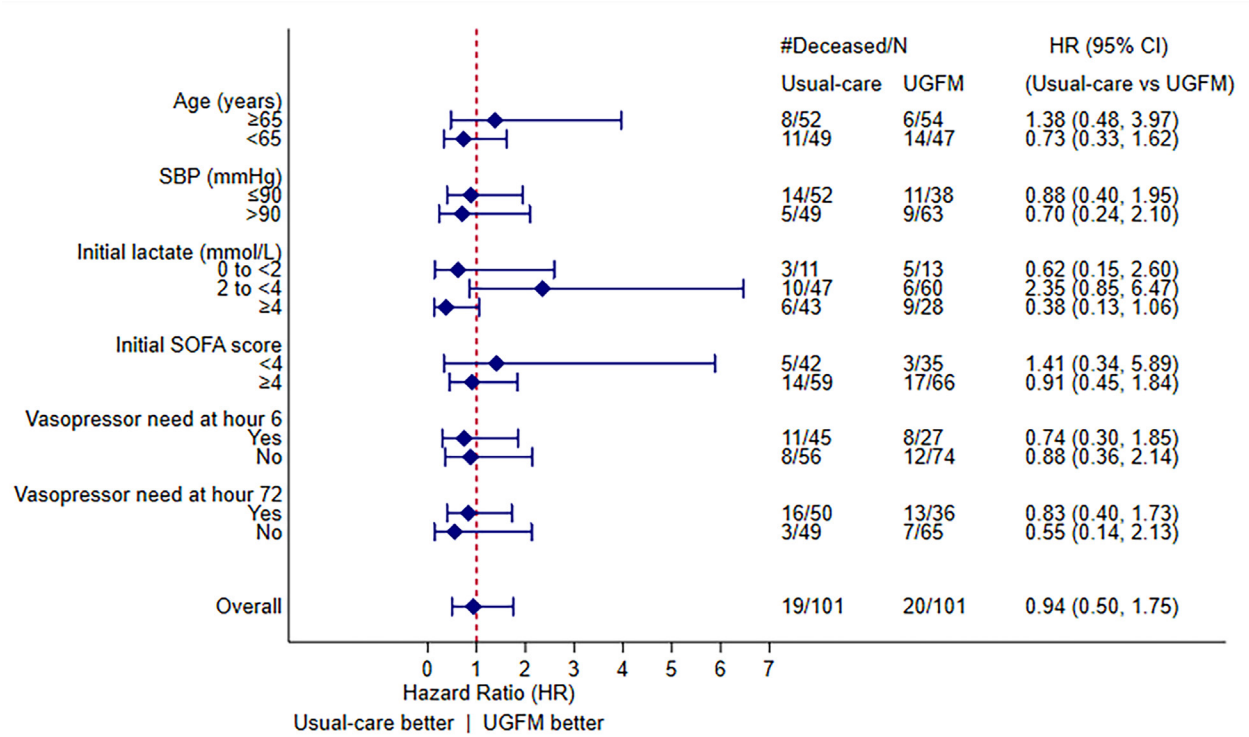


**Figure 3.** Forest plot for prespecified subgroup analyses of primary outcome adjusted for age, systolic blood pressure at presentation, initial lactate level, initial sequential organ failure assessment score, and vasopressor need at hour-6 and hour-72. All P-values for interaction are >0.05.
*SBP*, systolic blood pressure; *SOFA*, sequential organ failure assessment; *HR*, hazard ratio; *CI*, confidence interval.

of 4, and one-third of them required a vasopressor or MV during initial phase of their treatment, physicians should use cautious clinical judgment or different approaches when treating more severe septic shock patients in their practice. Third, bias may have occurred during patient allocation, data collection or outcome measurement due to the unconcealed nature of the study interventions, although this was minimized by the appropriate randomization. Moreover, the primary study outcome was the mortality rate of the patients, which is generally unaffected by blinding of the assessors.

Fourth, the higher rate of achieving the IVC collapsibility targets in patients treated in the ultrasound-guided arm may have affected the outcome. Finally, although the standard protocol and location of IVC diameter measurement was determined before the study, the interpersonal variation and sampling position may have affected the consistency of IVC diameter measurement.[46, 47] However, the fair interrater reliability of IVC measurement was demonstrated among the emergency physicians,[48, 49] and our study reflects real-life practice in dynamic EDs.

## CONCLUSION

In our ED setting, where a relatively restricted amount of IV fluid administration is generally practiced, we did not demonstrate the benefit of the use of respiratory change of IVC diameter determined by point-of-care ultrasound to guide initial fluid resuscitation in SITH/SS patients in the ED in improving the 30-day survival probability or other clinical parameters compared to the usual-care strategy. However, it was associated with less amount of fluid used. Further studies are required to identify the optimal physiologic targets and fluid resuscitation approach in the initial treatment of sepsis-induced hypoperfusion and septic shock patients in the ED.

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# Transfer of Patients with Spontaneous Intracranial Hemorrhage who Need External Ventricular Drain: Does Admission Location Matter?

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**Introduction:** Patients with spontaneous intracranial hemorrhage (sICH) are associated with high mortality and require early neurosurgical interventions. At our academic referral center, the neurocritical care unit (NCCU) receives patients directly from referring facilities. However, when no NCCU bed is immediately available, patients are initially admitted to the critical care resuscitation unit (CCRU). We hypothesized that the CCRU expedites transfer of sICH patients and facilitates timely external ventricular drain (EVD) placement comparable to the NCCU.

**Methods:** This is a pre-post study of adult patients transferred with sICH and EVD placement. Patients admitted between January 2011–July 2013 (2011 Control) were compared with patients admitted either to the CCRU or the NCCU (2013 Control) between August 2013–September 2015. The primary outcome was time interval from arrival at any intensive care units (ICU) to time of EVD placement (ARR-EVD). Secondary outcomes included time interval from emergency department transfer request to arrival, and in-hospital mortality. We assessed clinical association by multivariable logistic regressions.

**Results:** We analyzed 259 sICH patients who received EVDs: 123 (48%) CCRU; 81 (31%) 2011 Control; and 55 (21%) in the 2013 Control. The groups had similar characteristics, age, disease severity, and mortality. Median ARR-EVD time was 170 minutes [106-311] for CCRU patients; 241 minutes [152-490] ($p < 0.01$) for 2011 Control; and 210 minutes [139-574], $p = 0.28$) for 2013 Control. Median transfer request-arrival time for CCRU patients was significantly less than both control groups. Multivariable logistic regression showed each minute delay in ARR-EVD was associated with 0.03% increased likelihood of death (odds ratio 1.0003, 95% confidence interval, 1.0001-1.006, $p = 0.043$).

**Conclusion:** Patients admitted to the CCRU had shorter transfer times when compared to patients admitted directly to other ICUs. Compared to the specialty NCCU, the CCRU had similar time interval from arrival to EVD placement. A resuscitation unit like the CCRU can complement the specialty unit NCCU in caring for patients with sICH who require EVDs. [West J Emerg Med. 2020;22(2)379-368.]

## INTRODUCTION

Spontaneous intracranial hemorrhage (sICH) is associated with up to 40% mortality.[1,2] External ventricular drain (EVD) placement in these patients has been associated with improved mortality and functional outcomes.[3-5] When patients with sICH present to an emergency department (ED) that does not have neurosurgical consultation capabilities, they are typically transferred to a tertiary care center for further evaluation and management. However, the process for non-trauma patient transfer has been fragmented,[6] resulting in a significant delay for these critically ill patients.[7] As a result, delays in the transfer of patients with sICH would result in worse outcomes.[8,9]

At our urban, academic, tertiary care center, the neurocritical care unit (NCCU) is the preferable unit to receive sICH patients, especially those in need of EVD placement, from referring facilities. Historically, when there was no immediately available bed in the NCCU, patients were transferred to any adult intensive care unit (ICU) with an available bed. However, in an effort to streamline the process of transfer of patients with critical illnesses or time-sensitive disease (Type A aortic dissection, ischemic stroke, sICH, etc), our institution established the critical care resuscitation unit in July 2013. The CCRU is a six-bed ICU-based resuscitation unit that is staffed by a 24/7 team of intensivists and advanced practice providers (APP). It focuses on rapid transfer of critically ill patients or patients with time-sensitive diseases for initial resuscitation and evaluation before transferring them to a specialized ICU.[10] For patients with sICH, when there are no available beds at the NCCU, the CCRU admits, provides initial resuscitation, manages blood pressure, and supports for EVD placement as indicated. Once stabilized, patients are subsequently transferred to an available bed at the NCCU for further longitudinal care.

The CCRU represents an alternative admission location for patients with sICH, but its effectiveness in caring for these patients is not known. In this study we aimed to investigate the CCRU's efficacy in caring for patients with sICH who required EVD placement. We hypothesized that the CCRU would expedite the transfer of sICH patients and provide comparable care to the subspecialty NCCU, including timely EVD placement. We also investigated whether timely placement of EVD would be associated with outcomes of sICH patients with suspected elevated intracranial pressure (ICP).

*Population Health Research Capsule*

What do we already know about this issue?
*Spontaneous intracranial hemorrhage and intracranial hypertension are associated with high mortality and require early neurosurgical interventions.*

What was the research question?
*Does the critical care resuscitation unit (CCRU) expedite transfer and facilitate early intervention? Does time interval to external ventricular drain (EVD) placement matter?*

What was the major finding of the study?
*The CCRU decreased time to EVD placements. Delayed EVD placement was associated with higher mortality.*

How does this improve population health?
*A CCRU can complement the neurocritical care unit to improve outcomes by reducing emergency department transfer delays; facilitating similar time to EVD placements.*

## METHODS:

### Study Settings

We performed a retrospective pre-post chart review of adult patients sustaining sICH who were transferred to our academic medical center and received EVD after arrival. We included patients who were transferred from any referring EDs between January 1, 2011–September 30, 2015.

Our academic tertiary care center has a neurosurgical residency. Neurosurgery residents and senior residents provide coverage at our medical center around the clock. The residents evaluate patients with intracranial hemorrhage when they first arrive at our medical center. Once the neurosurgery team decides whether EVD placement is indicated, one of the residents will insert the EVD at the appropriate ICU. Therefore, for patients who have signs and symptoms of significant intracranial hypertension, the sooner the patients arrive at our institution, the sooner they will undergo this life-saving procedure. Furthermore, there has not been any change in the coverage of neurosurgical residents during our study period.

Clinicians from other facilities refer their patients to our medical center via our 24/7 in-hospital centralized center, Express Care. For example, the referring clinician first makes a request transfer to our transfer center. The Express Care staff then connects the referring clinician to the on-call neurosurgeon and the NCCU physician. When the patient is considered to need immediate transfer but there is no available NCCU bed, the CCRU attending physician will be contacted for bed request. This transfer process is uniform for all patient transfers from referring hospitals to any inpatient unit at our medical center.

This study was approved by our institutional review board.

### Patient Selection

We queried our academic center's electronic health records (EHR) to identify eligible patients. Patients were identified by

*International Classification of Diseases*, ninth revision (ICD-9 codes of 430.XX, 431.XX) for any sICH and procedure code 02.21 for EVD.[11,12] Patients who had sICH and were transferred directly from other hospitals' EDs were eligible.

We selected three groups of patients with sICH and EVD placement for comparison. The first group (CCRU) included patients who were admitted initially to the CCRU between August 1, 2013–September 30, 2015. The second group included a historical cohort of sICH patients (2011 Control) who were admitted to any adult ICU between January 1, 2011–July 31, 2013, before the CCRU opening. The third group (2013 Control) contained patients who were directly admitted to the NCCU during the same period when the CCRU became operational (August 1, 2013–September 30, 2015). We included this group for comparison because when the NCCU has an available bed, it can bypass the CCRU and admit a patient directly from any ED. This direct admission should be associated with shorter transfer delay.

We excluded trauma patients and patients whose hemorrhage was due to secondary pathologies, such as tumor, arteriovenous malformations, or ischemic stroke, because the common neurosurgical severity scores were neither designed for nor validated in these patients.[13,14] We excluded patients who did not have sufficient records or patients who did not have documentation of EVD after arrival at our academic center. Patients who presented first to our academic center's ED were also excluded. These patients did not have to undergo the transfer process between hospitals, which had been associated with delays of care. Moreover, they usually had early access to interventions by neurosurgical teams at our institutions. As a result, these patients would have different outcomes from patients who were transferred from other hospitals. Furthermore, the sample size for this group was small and would not provide meaningful statistical analysis.

**Outcomes**

The primary outcome was the time intervals from arrival at the CCRU or our ICUs to the time of EVD placement. Secondary outcomes included a) time intervals from transfer request to arrival at one of our medical center's ICUs; and b) in-hospital all-cause mortality.

**Data Collection**

The principal investigator (PI) of the study trained the other investigators who were not blinded to our hypothesis to extract data from patients' records into a standardized Microsoft Access database (Microsoft Corp., Redmond, WA). Investigators input data in sections and independently of each other to reduce bias. For example, investigators who collected data for disease severity did not have access to data regarding patients' EVD placement or outcomes. The disease severity scores for subarachnoid hemorrhage (SAH) were the Hunt and Hess Scale [H&HS], and the World Federation of Neurological Surgeons Scale [WFNSS]. The severity scores for patients with spontaneous intraparenchymal hemorrhage were the Intracerebral Hemorrhage Score [ICHS], and the Functional Outcome in Patients with Primary Intracerebral Hemorrhage scale [FUNC score]. Up to 20% of the data (time interval to EVD placement, ICP measurements) was independently validated by another investigator to maintain at least 90% inter-rater agreement. Discrepancies were adjudicated by the PI during the group's quality meetings every three months, until data extraction was completed.

Patient data were obtained from multiple sources including patients' ED records, the accepting ICUs' flow sheets and our institution's EHR. Time of EVD placements and ICP measurements were obtained from procedural notes and nursing notes. Time of arrival at the NCCU or CCRU, and patient mortality were obtained from our EHR.

**Data Analysis**

We used descriptive analyses (mean ± standard deviation [SD], median (interquartile ranges [IQR]), and number [n] [%]) for demographic and clinical factors to compare groups. Continuous data between two groups were analyzed via Student's t-test or the Mann-Whitney tests, as appropriate. We analyzed continuous data between three groups via analysis of variance with Holm-Sidak post-hoc test or Kruskal-Wallis with Dunn's post-hoc tests. We compared categorical data by chi-square test. We used the Kaplan-Meier graph to present the time interval between ICU arrival and EVD placement, and time interval between transfer request and arrival at the CCRU or other ICUs. Any event that occurred after six hours was reported and analyzed as occurring after six hours from the index time.

We performed multivariable logistic regression to assess associations between clinical variables and in-hospital all-cause mortality. Prior to analysis, we visually inspected the histograms of the time intervals between arrival-EVD placement and transfer request to ICU arrival for their patterns of distribution. Based on their patterns of distribution, no transformation was necessary. To identify relevant independent variables for the multivariable logistic regressions, we first performed univariable logistic regression using single independent variable and mortality. We included a priori-determined clinically significant factors (admitting to the CCRU; Arr-EVD, transfer request to arrival), and any independent variable with $p$-value $\leq 0.10$[15,16] in the multivariable logistic regression. Goodness-of-fit of our regression was assessed using the Hosmer-Lemeshow test, for which a $p$-value $> 0.05$ was considered a good fit.

Since patients with SaH or intraparenchymal hemorrhage have different physiopathology and severity scores, we a priori decided during our planning sessions to perform subgroup analyses involving patients with SAH only and patients with intraparenchymal hemorrhage only to investigate the effect of time to EVD placement and outcomes in these particular groups. We performed separate logistic models, adjusting for

appropriate disease severity, in subgroups of patients with SAH or intraparenchymal hemorrhage only, using *a priori-determined factors* as stated above. For example, in the multivariable logistic regression model for patients with SAH, we included only the H&HS and the WFNSS.

All two-tailed *p*-values of < 0.05 were considered statistically significant. We performed statistical analyses using Sigma Plot version 14 (Systat Software Inc., San Jose, CA).

## RESULTS

### Patient Characteristics

We identified 343 patients who were transferred from other hospitals to our institution and received EVD placement between January 2011–September 2015. Of these, 259 patients who were transferred from various EDs met inclusion criteria and were included in the final analysis (Figure 1).

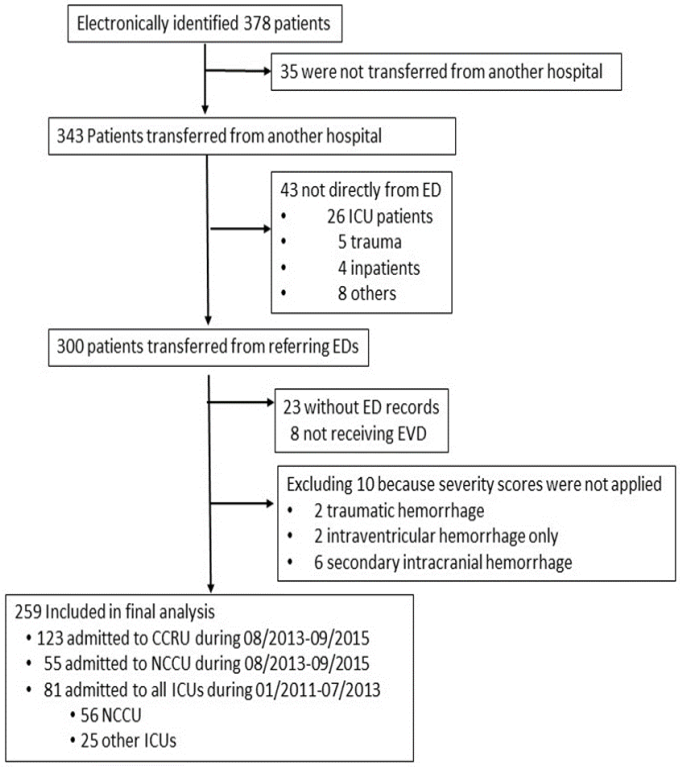



**Figure 1.** Patient selection diagram.
*ED,* emergency department; *CCRU,* critical care resuscitation unit; *EVD,* external ventricular drain; *ICU,* intensive care unit; *NCCU,* neurocritical care unit.

A total of 123 patients were admitted initially to the CCRU with an average of 4.9 patients per month from August 2013–September 2015. A total of 81 patients were transferred to various adult ICUs at our institution from January 2011–July 2013, with an average of 2.7 patients per month (Table 1A). Subsequently, 55 patients were admitted directly to the NCCU between August 2013–September 2015 with an average of 2.2 patients per month.

For patients with SAH, the median H&HS of patients admitted to the CCRU was 3 (IQR 2-4]. The median H&HS was 3 [2-4] and 2 [2-3] for 2011 Control patients and 2013 Control patients, respectively. The median WFNSS of patients admitted to the CCRU was 4 [2-4]. The median (IQR) WFNSS for 2011 Control patients (01/2011-07/2013) and 2013 Control (08/2013-09/2015) was 4 [2-5] and 2 [2-4], respectively. Other demographic characteristics between groups were similar (Table 1A).

Table 1B shows the demographic characteristics between patients with only SAH or only intraparenchymal hemorrhage. Invasive mechanical ventilation in EDs among patients who had intraparenchymal hemorrhage was more frequent (75%), compared to 47% (p = 0.001) among patients with SAH only. The opening ICP for patients with intraparenchymal hemorrhage was similar to those with SAH only (21 [8] centimeters water [cm $H_20$] vs 22 (7), p = 0.36) (Table 1B).

### Outcomes

Overall, the CCRU facilitated significantly earlier EVD placement for transferred patients with sICH when compared with the historical 2011 Control patients who were transferred between January 2011–July 2013 (Figure 2), but not the 2013 Control patients. The median time interval from arrival to EVD placement was 170 minutes [106-311] for patients admitted initially to the CCRU, compared to 241 minutes [152-490] (p < 0.01) for 2011 Control and 210 minutes [139-574], p = 0.28) for 2013 Control (Table 2A).

We performed a post-hoc analysis between the CCRU and the 2013 group to investigate whether the difference in time interval between arrival and EVD placement between the CCRU and the 2011 group was due to change in practice. We found that up to 54% of CCRU patients received EVD placement within three hours from CCRU arrival (Figure 2), while only 40% of the 2013 control group received EVD placement. This difference was statistically different by chi-square test (95% CI, 1.005-3.09, p = 0.047). This difference suggested that change of neurosurgery practice alone would not explain our findings, as this data was collected between two groups during the same period of time.

There were no significant different in time-to-event intervals between subgroup of patients with SAH only or patients with intraparenchymal hemorrhage only (Table 2B).

Time interval from transfer request to arrivals for patients initially admitted to the CCRU was 84 minutes [61-111], compared to 135 minutes [89-225] (p < 0.001) for 2011 Control and 132 minutes [99-177] (p < 0.001) for 2013 Control (Figure 3) and (Table 1B). Hospital outcomes (mortality, length of stay or rates of discharge home) in bivariate analyses were similar between patients who were transferred directly to the CCRU or other ICUs during different time periods (Table 2A). The percentage of discharge home for patients who had only intraparenchymal hemorrhage were significantly less than those with SAH only (9% v. 28%, p = 0.01) (Table 2B).

**Table 1A.** Characteristics of patients with spontaneous intracranial hemorrhage who were transferred from emergency departments to the critical care resuscitation unit or other intensive care units at a tertiary academic medical center.

| | CCRU | Other ICUs | | P-value | |
|---|---|---|---|---|---|
| | 08/2013-09/2015) Group A | 01/2011-07/2013 Group B | 08/2013-09/2015 Group C | A versus B | A versus C |
| Total Patient n, (n per month) | 123 (4.9) | 81 (2.7) | 55 (2.2) | | |
| Age (years), mean (SD) | 59 (14) | 57 (14) | 58 (14) | 0.69 | 0.69 |
| Gender | | | | | |
| Female, n (%) | 70 (57) | 48 (59) | 32 (58) | 0.84 | 0.99 |
| Male, n (%) | 53 (43) | 33 (41) | 23 (42) | | |
| Ground distance (km), mean (SD) | 28 (40) | 33 (45) | 26 (26) | 0.47 | 0.47 |
| Transport type, n (%) | | | | | |
| Ground | 76 (62) | 60 (74) | 39 (71) | 0.09 | 0.31 |
| Air | 47 (38) | 21 (26) | 16 (29) | | |
| Intracranial hemorrhage type, n (%) | | | | | |
| IPH | 34 (28) | 28 (35) | 38 (69) | 0.37 | <0.001 |
| SAH | 89 (72) | 53 (65) | 17 (31) | | |
| Seizure, n (%) | | | | | |
| No | 113 (91) | 72 (89) | 46 (84) | 0.64 | 0.17 |
| Yes | 10 (9) | 9 (11) | 9 (16) | | |
| Mechanical ventilation in ED, n (%) | | | | | |
| No | 54 (44) | 38 (47) | 24 (44) | 0.77 | 0.88 |
| Yes | 69 (56) | 43 (53) | 31 (56) | | |
| Severity | | | | | |
| ESI**, median [IQR] | 2 [1-3] | 2 [2-3] | 2 [1-3] | 0.042 | 0.076 |
| Hunt and Hess* | 3 [2-4] | 3 [2-4] | 2 [2-3] | 0.08 | 0.08 |
| WFNSS* | 4 [2-4] | 4 [2-5] | 2 [2-4] | 0.29 | 0.29 |
| ICH, mean (SD)* | 3 (1) | 2 (1) | 3 (1) | 0.10 | 0.10 |
| FUNC** | 3 (1) | 8 (2) | 6 (2) | 0.07 | 0.07 |
| Anticoagulation, n (%) | 27 (22) | 19 (23) | 16 (29) | 0.92 | 0.40 |
| Anticoagulation, n(%) | 11 (9) | 6 (7) | 4 (7) | 0.88 | 0.78 |
| Anti-Platelet, n (%) | 16 (13) | 13 (16) | 12 (21) | 0.69 | 0.20 |
| Triage GCS, median [IQR] | 13 [7-15] | 14 [9-15] | 14 [7-15] | 0.43 | 0.43 |
| Triage SBP (mm Hg), mean (SD) | 179 (40) | 178 (40) | 173 (36) | 0.61 | 0.61 |
| ED Maximum SBP (mm Hg), mean (SD) | 196 (36) | 198 (38) | 190 (40) | 0.47 | 0.47 |
| ED Minimum SBP (mm Hg), mean (SD) | 136 (26) | 137 (27) | 135 (25) | 0.89 | 0.89 |
| ED LOS (min), median [IQR] | 173 [121-236] | 189 [147-314] | 195 [137-257] | 0.06 | 0.32 |
| EDMV length (min), median [IQR] | 85 [56-129] | 126 [66-168] | 92 [70-151] | 0.07 | 0.07 |
| ICU first GCS, median [IQR] | 9 [6-14] | 8 [5-14] | 9 [7-14] | 0.65 | 0.65 |
| ICU SBP (mm Hg), mean (SD) | 140 (21) | 155 (29) | 147 (22) | <0.001 | 0.17 |
| Intracranial opening pressure (cm $H_20$), mean (SD) | 21 (8) | 22 (8) | 23 (7) | 0.28 | 0.28 |

*CCRU,* critical care resuscitation; *ICU,* intensive care unit; *km,* kilometer; *IPH,* intraparenchymal hemorrhage; *SAH,* subarachnoid hemorrhage; *ESI,* Emergency Severity Index; *WFNSS,* World Federation of Neurosurgeons Scale Score; *ICH,* Intracerebral Hemorrhage Score; *FUNC,* Functional Outcomes in Patients with Primary Intracerebral Hemorrhage score; *ED,* emergency department; *LOS,* length of stay; *EDMV,* mechanical ventilation in the emergency department; *GCS,* Glasgow Coma Scale; *SBP,* systolic blood pressure *IQR,* interquartile range; *cm $H_20$,* centimeters of water; *SD,* standard deviation; *mm Hg,* millimeters mercury.

In our multivariable logistic regression for all patients, each minute longer from time interval between ICU arrival and EVD placement was associated with 0.03% of increased likelihood of death (odds ratio [OR] 1.0003, 95% CI, 1.0001-1.006, p = 0.043) (Table 3). In other words, each 30 minutes in delay of EVD placement was associated with 1% increased likelihood of death in our patient population. In the subgroup analysis of patients with SAH, the multivariable logistic regression, adjusting for disease severity for SAH was associated with higher likelihood of death (OR 1.0001,

**Table 1B.** Demographic characteristics of subgroups of patients with subarachnoid hemorrhage and intraparenchymal hemorrhage who were transferred from emergency departments to a tertiary care academic medical center during the study period.

| | All patients | Only SAH | Only IPH | P-value (SAH versus IPH) |
|---|---|---|---|---|
| Total Patient (n) | 259 | 180 | 79 | |
| Age (years), mean (SD) | 58 (14) | 58 (13) | 60 (14) | 0.15 |
| Gender | | | | |
| Female, n (%) | 150 (58) | 117 (65) | 33 (32) | 0.001 |
| Male, n (%) | 109 (42) | 63 (35) | 46 (58) | |
| Ground distance (km), mean (SD) | 29 (40) | 28 (32) | 33 (53) | 0.42 |
| Transport type, n (%) | | | | |
| Ground | 175 (68) | 120 (67) | 55 (70) | 0.64 |
| Air | 84 (32) | 60 (33) | 24 (30) | |
| Seizure, n (%) | 27 (10) | 16 (9) | 11 (14) | 0.22 |
| Mechanical ventilation in ED, n (%) | 143 (55) | 84 (47) | 59 (75) | 0.001 |
| Disease severity | | | | |
| ESI**, median [IQR] | 2 [1-3] | 2 [1-3] | 2 [1-3] | 0.21 |
| Hunt and Hess*, median [IQR] | 3 [2-4] | 3 [2-4] | NA | NA |
| WFNSS*, median [IQR] | 4 [2-4] | 4 [2-4] | NA | NA |
| ICH, mean (SD)* | 2.5 (1) | NA | 2.5 (1) | NA |
| FUNC** | 7 (2) | NA | 7 (2) | NA |
| Anticoagulation, n (%) | 21 (12) | 10 (6) | 11 (14) | 0.02 |
| Anti-platelet, n (%) | 41 (23) | 20 (11) | 21 (26) | 0.002 |
| Triage GCS, median [IQR] | 14 [7-15] | 14 [10-15] | 9 [6-14 | 0.001 |
| Triage SBP (mm Hg), | | | | |
| Mean (SD) | 178 (39) | 174 (35) | 186 (44) | 0.03 |
| ED max SBP (mm Hg), mean (SD) | 195 (37) | 190 (36) | 207 (39) | 0.001 |
| ED Min SBP (mm Hg), mean (SD) | 136 (26) | 135 (25) | 138 (28) | 0.36 |
| ED LOS (min), median [IQR] | 181 [134-262] | 184 [130-267] | 173 [142-253] | 0.78 |
| EDMV length (min), median [IQR] | 100 [60-148] | 87 [54-153] | 105 [66-142] | 0.34 |
| ICU First GCS, median [IQR] | 9 [6-14] | 9 [6-14] | 7 [6-12] | 0.051 |
| ICU SBP (mm Hg), mean (SD) | 146 (25) | 145 (23) | 151 (27) | 0.06 |
| Intracranial Opening pressure (cm $H_20$), mean (SD) | 21 (7) | 22 (7) | 21 (8) | 0.36 |

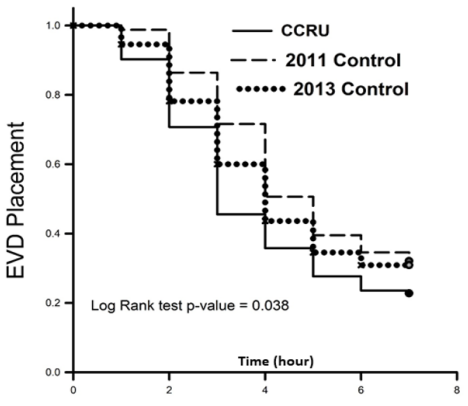
*Higher score, higher severity
**Lower score, higher severity
*SAH,* subarachnoid hemorrhage; *IPH,* intraparenchymal hemorrhage; *km,* kilometer; *cm $H_2O$,* centimeters of water; *ED,* emergency department; *EDMV,* mechanical ventilation in the emergency department; *ESI,* Emergency Severity Index; *EVD,* external ventricular drain; *FUNC,* Functional Outcome in Patients with Primary Intracerebral Hemorrhage score; *GCS,* Glasgow Coma Scale; *ICH,* Intracranial Hemorrhage score; *WFNSS,* World Federation of Neurological Surgeons scale; IQR, interquartile range; *LOS,* length of stay; min; minute; *SBP,* systolic blood pressure; *SD*, standard deviation; *mm Hg,* millimeters mercury.

95% CI, 1.0001-1.001, p = 0.016). However, time interval between ICU arrival and EVD placement was not significantly associated with mortality in the subgroup of patients with intraparenchymal hemorrhage (Table 2).

## DISCUSSION

Our study demonstrated that the CCRU contributed to more than a 200% increase in transfers of patients with sICH requiring EVD placement to our institution. However, this increase did not account for the number of patients who presented directly to our institution's ED or those who were not transferred from a referring ED. Compared to the historical cohort, patients admitted to the CCRU experienced a shorter time interval from transfer request to arrival, and shorter time interval from arrival to EVD placement. Our study also suggested that longer time interval from arrival to EVD placement was associated with higher likelihood of mortality; however, more studies are needed to confirm our observation.

The CCRU at our academic medical center is a six-bed unit that was created to expedite a high volume of transfers and to provide timely resuscitation for critically ill patients, as




Number of EVD Placement, N (%)*

| Hours from ICU Arrival | 0 | 1 | 2 | 3 | 4 | 5 | >6 |
|---|---|---|---|---|---|---|---|
| CCRU (N=123) | 0 | 12 (10) | 24 (20) | 31 (25) | 12 (10) | 10 (8) | 34 (28) |
| 2011 control (N=81) | 0 | 1 (1) | 10 (12) | 12 (15) | 17 (21) | 9 (11) | 32 (40) |
| 2013 Control (N=55) | 0 | 3 (6) | 9 (16) | 10 (18) | 9 (16) | 5 (9) | 19 (35) |

**Figure 2.** Comparisons of time intervals from arrival at intensive care unit to placement of external ventricular drain between critical care resuscitation unit, 2011 Control, 2013 Control groups. *percentage of EVD placement at a particular hour.
*CCRU,* critical care resuscitation unit; *ICU,* intensive care unit; *EVD,* external ventricular drain.

described previously.[10,17] It serves as a multidisciplinary unit to provide resuscitative efforts to all adult critically ill patients who need immediate resuscitation, whether the patients come from other facilities or from our own medical center. To achieve this purpose, the CCRU was specially designed to expedite transfer of patients who need immediate resuscitation.

To reduce unnecessary miscommunications and delays, a transfer request for patient to the CCRU involves the referring clinician, the specialty consultant attending, and the CCRU attending physician. During this phone conversation for transfer request, the CCRU attending physician initiates the transfer process immediately without having to wait for the request to officially appear on our institution's bed tracking system, unlike other traditional ICUs at our medical center. Additionally, a plan of care for the patient before transfer, during transfer and upon arrival at the CCRU is proposed between the attending physicians once the patient is accepted for transfer to the CCRU. This anticipatory plan of care enables the CCRU team to prepare for necessary interventions prior to the patient's arrival, including uncross-matched blood products, infusion medications at patient's bedside, alerting operating rooms, mobilizing surgical teams, etc. Using this anticipatory plan allowed the CCRU to bring surgical patients to the operating rooms sooner than those who were historically admitted to other traditional ICUs.[17]

There are other potential reasons for the difference in time interval from arrival to EVD placement between the CCRU and other ICUs. The first reason could be a result from different volumes, as higher volume could be associated with higher efficiency. Furthermore, the CCRU's nursing staff was designed to provide immediate resuscitation. The CCRU employs a flexible nursing model, so one to two nurses can be reassigned to assist with the resuscitative efforts for a critically ill patient, or a patient who would need an immediate life-saving procedure, without compromising care for other patients. This flexible nursing model, which allows the CCRU to maximize the efforts on patients' resuscitations, is possible partly because CCRU nurses are not tied up with other chronic, longitudinal care as are nurses in traditional ICUs. Additionally, the CCRU attending physician is available 24 hours in the unit to provide immediate support for procedures, such as providing moderate sedation and airway management during EVD placement, while the APP provides care for other patients. Therefore, the CCRU team could provide fast and efficient support for our specialists to initiate life-saving procedures.

The design of the CCRU allows the unit to receive transfer of a wide variety of critically ill patients.[10] Additionally, the staffing model and high volumes of transfer enable the CCRU to becomes more efficient in the immediate resuscitation of these patients. As a result of this efficiency, the resuscitation provided for these patients can be comparable to other specialty

**Table 2A.** Comparisons of time-to-event and hospital outcomes between patients who were transferred from emergency departments to the critical care resuscitation unit or other intensive care units.

| | CCRU | Other ICUs | | P-value | |
|---|---|---|---|---|---|
| | (08/2013-09/2015) (Group A) (N=123) | 01/2011-07/2013 (Group B) (N=81) | 08/2013-09/2015 (Group C) (N=55) | A vs B | A vs C |
| Arrival-EVD Placement (min), Median [IQR] | 170 [106-311] | 241 [152-491] | 210 [139-574] | <0.01 | 0.28 |
| Transfer Request-Arrival (min), median [IQR] | 84 [61-111] | 135 [89-255] | 132 [99-177] | <0.001 | <0.001 |
| Hospital LOS (day), median [IQR] | 20 [12-28] | 22 [15-32] | 21 [14-31] | 0.47 | 0.47 |
| Mortality, n (%) | 31 (25) | 14 (17) | 14 (25) | 0.23 | 0.88 |
| Discharge Home, n (%) | 24 (19) | 20 (24) | 13 (24) | 0.48 | 0.67 |

*CCRU,* critical care intensive care unit; *ICU,* intensive care unit; *EVD,* external ventricular drain; *min,* minutes; *IQR,* interquartile ratio; *LOS,* length of stay.

**Table 2B.** Comparisons of time-to-event and hospital outcomes between patients who were transferred from emergency departments to a tertiary care center for management of either subarachnoid hemorrhage only or intraparenchymal hemorrhage only.

| | All Patients (N= 259) | Only SAH (N=180) | Only IPH (N=79) | P-value (SAH vs IPH) |
|---|---|---|---|---|
| Arrival-EVD Placement (min), median [IQR] | 203 [130-426] | 202 [132-377] | 224 [112-507] | 0.63 |
| Transfer Request - Arrival (min), median [IQR] | 103 [76-155] | 102 [70-152] | 111 [86-162] | 0.10 |
| Hospital LOS (day), median [IQR] | 20 [13-30] | 20 [14-29] | 22 [13-32] | 0.33 |
| Mortality, n (%) | 59 (23) | 37 (21) | 22 (28) | 0.20 |
| Discharge Home, n (%) | 57 (22) | 50 (28) | 7 (9) | 0.001 |

*SAH,* subarachnoid hemorrhage; *IPH*, intraparenchymal hemorrhage; *EVD,* external ventricular drain; *min,* minutes; *IQR*, interquartile range; *LOS,* length of stay.

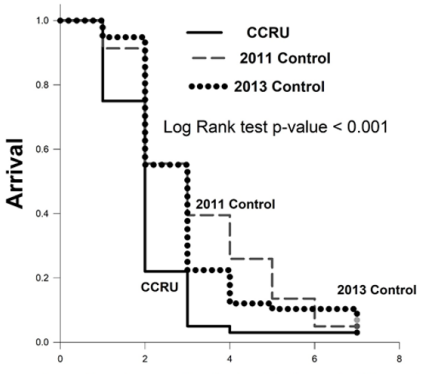
ICUs, as shown in this study with sICH patients. Once patients receive adequate resuscitation, they are transferred to the specialty ICUs where staff is well trained for longitudinal care. If there is no available bed once the patient is stabilized, the CCRU will continue to care for the patient until an available bed at an appropriate unit becomes available. To improve CCRU bed flow, patients from the CCRU would have the second highest priority after our own medical center's ED patients, for the first available and appropriate bed. As a result, within a few hours of a patient's arrival, another bed in the CCRU becomes available to receive the next critically ill patient(s). Therefore, the CCRU can complement the neurocritical care unit (NCCU) or other specialty ICUs to care for critically ill patients in the acute and hyperacute phase, while being able to reduce delays of transfer from referring EDs or from within our medical center.

Having the six-bed CCRU, or a similar resuscitation unit, is considered more efficient use of beds than opening up more beds in each of the six adult specialty ICUs at our medical center: cardiac surgical ICU, coronary care unit, medical ICU, NCCU, surgical ICU, and trauma ICU. Since the CCRU admits patients from all medical, surgical specialties and trauma,[10,17] each adult specialty ICU would hypothetically need to create one extra ICU bed to accommodate these transfers, or the equivalent of the CCRU's six beds. Furthermore, transfer requests for any single disease state are not uniformly distributed across time. Consequently, the NCCU, for example, would have to keep an open ICU bed while there is no patient requiring immediate EVD placement. On the other hand, the CCRU can use its available bed to admit patients with other disease states or with other neurological emergencies.

Our findings were consistent with previous studies demonstrating that EVD placement for patients with sICH and signs or symptoms of elevated ICP is an important and timely intervention. In patients with sICH, EVD placement was associated with lower mortality[3-5] and good functional independence.[4] However, while further study is needed to confirm our observations, our study also suggests that shorter time interval to EVD placement in these critically ill patients was also associated with lower odds of death. In addition, reducing delay of transfer from the EDs was also associated with improved patient outcomes. A previous study showed that sICH patients who waited for more than five hours in the ED were associated with higher mortality.[8] Further study is needed to investigate whether the CCRU, which was able to reduce delay of transfer when compared with transferring to traditional ICUs, would be associated with improved outcomes in patients with sICH.

## LIMITATIONS

Our study had several limitations. In this pre-post analysis, we were not able to account for possible changes of neurosurgeons' practice regarding EVD placement. Its




Number of patients Arriving at ICUs, N (%)*

| Time from Transfer Request to ICU arrival (hour) | 0 | 1 | 2 | 3 | 4 | 5 | >6 |
|---|---|---|---|---|---|---|---|
| CCRU (N=123) | 0 | 30 (24) | 69 (56) | 19 (15) | 2 (2) | 3 (3) | 0 |
| 2011 Control (N=81) | 0 | 7 (9) | 29 (36) | 13 (16) | 11 (14) | 10 (12) | 11 (13) |
| 2013 Control (N=55) | 0 | 3 (5) | 21 (38) | 18 (33) | 6 (11) | 1 (2) | 6 (11) |

**Figure 3.** Comparisons of time interval from transfer request to arrival at intensive care units for critical care resuscitation unit patients, 2011 Control, 2013 Control groups.
*percentage of patients arriving at the ICU at a particular hour.
*CCRU,* critical are resuscitation unit; *ICU,* intensive care unit.

**Table 3.** Multivariable logistic regressions assessing association between clinical factors and mortality.

| | All patients | | | SAH only | | | IPH only | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables | OR | 95% CI | P-value | OR | 95% CI | P-value | OR | 95% CI | P-value |
| ARR-EVD# | **1.0003** | **1.0001-1.006** | **0.043** | **1.0001** | **1.0001-1.001** | **0.016** | 1.0 | 1.00-1.001 | 0.29 |
| Age | **1.04** | **1.008-1.066** | **0.012** | **1.04** | **1.005-1.08** | **0.024** | 1.07 | 0.9-1.2 | 0.06 |
| 12-Hour GCS | **0.79** | **0.67-0.91** | **0.001** | **0.8** | **0.7-0.99** | **0.047** | **0.6** | **0.4-0.94** | **0.02** |
| CNSLT-ARR# | 0.99 | 0.99-1.002 | 0.21 | 1.0 | 0.9-1.003 | 0.096 | 0.99 | 0.9-1.004 | 0.25 |
| Admit-CCRU | 0.8 | 0.4-2.3 | 0.92 | 0.86 | 0.3-2.2 | 0.77 | 0.9 | 0.9-1.004 | 0.91 |
| EDMV | 1.48 | 0.39-5.6 | 0.56 | 1.6 | 0.3-9.6 | 0.64 | 0.3 | 0.01-4.9 | 0.38 |
| ESI** | 1.02 | 0.6-1.7 | 0.93 | 1.2 | 0.6-2.5 | 0.52 | 1.3 | 0.5-3.3 | 0.65 |
| Triage GCS | 0.90 | 0.80-1.04 | 0.28 | 0.96 | 0.83-1.1 | 0.54 | 0.86 | 0.7-1.07 | 0.18 |
| ED Lowest SBP | 0.98 | 0.98-1.003 | 0.15 | 0.99 | 0.9-1.009 | 0.30 | 0.9 | 0.9-1.002 | 0.07 |
| EDMV LOS | 0.99 | 0.99-1.004 | 0.42 | 0.99 | 0.9-1.004 | 0.32 | 1.0 | 0.9-1.01 | 0.97 |
| ICU GCS | 0.93 | 0.82-1.06 | 0.29 | 0.94 | 0.8-1.01 | 0.43 | 0.9 | 0.6-1.2 | 0.56 |
| Type of Hemorrhage ICH | 0.86 | 0.39-1.9 | 0.72 | NA | NA | NA | NA | NA | NA |
| Hunt and Hess* | NA | NA | NA | **2.8** | **1.3-6.2** | **0.008** | NA | NA | NA |
| WFNSS* | NA | NA | NA | 0.6 | 0.2-1.4 | 0.23 | NA | NA | NA |
| ICH* | NA | NA | NA | NA | NA | NA | 1.9 | 0.7-5.0 | 0.19 |
| FUNC** | NA | NA | NA | NA | NA | NA | 1.5 | 0.8-2.6 | 0.20 |

#clinically significant factor
*Higher score, higher disease severity.
**Lower score, higher disease severity
NA Variable was not included in multivariable logistic regression.
Bolded variables were associated with statistical significance.
*SAH,* subsrachnoid hemorrhage; *IPC,* interparenchymal hemorrhage; *ARR-EVD,* time intervals in minutes between arrival at ICU and placement of external ventricular drain; *CNSLT-ARR,* time intervals in minutes between transfer request and arrival at ICU; *Admit-CCRU,* admission to the critical care resuscitation unit; *CI,* confidence interval; *ED,* emergency department; *EDMVLOS,* duration of invasive mechanical ventilation in minutes while in ED; *ESI,* Emergency Severity Index; *FUNC,* Functional Outcome in Patients with Primary Intracerebral Hemorrhage score; *GCS,* Glasgow Coma Scale; *ICH,* Intracerebral Hemorrhage score; *ICU,* intensive care unit; *WFNSS,* World Federation of Neurological Surgeon Scale.

retrospective nature also prevented us from elucidating the medical decision-making processes regarding when to place EVD in these critically ill patients. Furthermore, mortality may not represent an effective outcome marker as most patients died from withdrawal of life support. We did not have 90-day functional outcome, and we did not collect the data retrospectively as it was shown to be unreliable.[18] We did not account for patients who presented initially and who were transferred from another ED to the ED at our home institution. These patients may have had early neurosurgical interventions but still received care in the ED setting; thus, their outcomes may not be comparable to those who were transferred to an ICU as the CCRU or the NCCU. Furthermore, the small sample size of 35 patients who were admitted from our ED (Figure 1) may not provide a statistically meaningful comparison at this time. Our study did not examine the effect of the CCRU on outcome of patients with sICH but did not require EVD placement. Finally, the results from our study may not be generalizable due to factors such as intensivist shortage, costs, and different institutional needs. For example, the University of Michigan Emergency Critical Care Center was established to improve access to critical care for patients in its EDs,[19] while the CCRU serves as a regional ICU.

## CONCLUSION

We demonstrated that the Critical Care Resuscitation Unit can complement the specialty Neurocritical Care Unit in the care of patients with sICH and who required EVD placement in the hyperacute and acute phase. The CCRU increased the overall numbers of patients with sICH requiring EVD placement who were transferred to our medical center from outlying EDs. Patients transferred to the CCRU had shorter transfer time than those admitted directly to the NCCU, although both the CCRU and the NCCU had similar time to EVD placement once the patients arrived at our medical center. Thus, a resuscitation unit can improve overall care for patients with spontaneous intracranial hemorrhage by reducing ED length of stay while facilitating urgent, time-saving procedures. Finally, delays in EVD placement in patients with spontaneous intracranial hemorrhage was associated with increased mortality.

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# Impact of Providing a Tape Measure on the Provision of Lung-protective Ventilation

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**Introduction:** Emergency department (ED) patients are frequently ventilated with excessively large tidal volumes for predicted body weight based on height, which has been linked to poorer patient outcomes. We hypothesized that supplying tape measures to respiratory therapists (RT) would improve measurement of actual patient height and adherence to a lung-protective ventilation strategy in an ED-intensive care unit (ICU) environment.

**Methods:** On January 14, 2019, as part of a ventilator-associated pneumonia prevention bundle in our ED-based ICU, we began providing RTs with tape measures and created a best practice advisory reminding them to record patient height. We then retrospectively collected data on patient height and tidal volumes before and after the intervention.

**Results:** We evaluated 51,404 tidal volume measurements in 1,826 patients over the 4 year study period; of these patients, 1,579 (86.5%) were pre-intervention and 247 (13.5%) were post-intervention. The intervention was associated with a odds of the patient's height being measured were 10 times higher post-intervention (25.1% vs 3.2%, P <0.05). After the bundle was initiated, we observed a significantly higher percentage of patients ventilated with mean tidal volumes less than 8 cubic centimeters per kilogram (93.9% vs 84.5% P < 0.05).

**Conclusion:** Patients in an ED-ICU environment were ventilated with a lung-protective strategy more frequently after an intervention reminding RTs to measure actual patient height and providing a tape measure to do so. A significantly higher percentage of patients had height measured rather than estimated after the intervention, allowing for more accurate determination of ideal body weight and calculation of lung-protective ventilation volumes. Measuring all mechanically ventilated patients' height with a tape measure is an example of a simple, low-cost, scalable intervention in line with guidelines developed to improve the quality of care delivered to critically ill ED patients. [West J Emerg Med. 2021;22(2)389-393.]

## BACKGROUND

Approximately 240,000 patients receive mechanical ventilation in US emergency departments (ED) every year.[1] However, these patients frequently do not receive ventilation with a lung-protective strategy as outlined by recommendations from American and European critical

care societies.[2,3] An important element of a lung-protective ventilation strategy is low tidal volume ventilation.[4] Since appropriate tidal volumes are based on predicted body weight by height, accurate assessment of patient height is crucial. In clinical practice, patient height is often estimated, although visual estimation of patient height by clinicians is imprecise and may lead to larger tidal volumes than would otherwise be indicated.[5]

Lung-protective ventilation strategies applied to patients at risk for acute respiratory distress syndrome (ARDS) may reduce the incidence of ventilator associated lung injury and ARDS.[6-8] Previous investigations of ventilator strategies in the ED have demonstrated that a substantial percentage of patients are ventilated with a non-lung-protective ventilation strategy and have few adjustments made to the ventilator.[9,10] Inappropriate ventilator settings with excessively large tidal volumes and increased airway pressures are injurious, even when administered for a relatively short period of time.[6,11] This time becomes more and more important as critically ill patients board in the ED for longer periods. A recent multicenter, retrospective study showed that patients who receive lung-protective ventilation in the ED have decreased incidence of ARDS and decreased risk of death compared to patients who do not.[12] However, in this study only 58.4% of patients actually received lung-protective ventilation in the ED. In addition, therapeutic interventions started in the ED are often carried forward during the patient's stay in the intensive care unit (ICU),[13] further highlighting the importance of starting lung-protective ventilation early.

ED-based intervention bundles to improve adherence to lung-protective strategies can improve patient outcomes.[14,15] The Society of Critical Care Medicine/American College of Emergency Physician joint ED-Critical Care Medicine Boarding Task Force identified obtaining an accurate height to provide appropriately protective tidal volumes as a key component of mechanical ventilation practice in the ED, which is a simple but vital intervention to improve patient care.[16] The objective of our study was to assess whether providing a tape measure to respiratory therapists, along with a best practice advisory (BPA) to measure patient height, is associated with improved compliance with patient height measurement and lung-protective ventilation. We hypothesized that encouraging measurement of patient height in the ED and provision of a tape measure would improve compliance with a lung-protective ventilation strategy.

*Population Health Research Capsule*

What do we already know about this issue?
*Lung-protective ventilation is often not achieved in the emergency department (ED). Assessing patient height is crucial, and clinicians are often inaccurate in visually estimating patient height.*

What was the research question?
*Does provision of a tape measure impact lung-protective ventilation in the ED?*

What was the major finding of the study?
*Patients were more likely to receive lung-protective ventilation in the ED when a tape measure was provided.*

How does this improve population health?
*Providing a tape measure in the ED is a simple, low-cost intervention to improve lung-protective ventilation.*

## METHODS

### Design

This was a single-center, retrospective cohort study, designed to evaluate the results of a quality improvement initiative. The institutional review board at the University of Michigan reviewed and approved this study. This study is presented in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[16]

### Setting

The Michigan Medicine adult ED is part of a large academic medical center with approximately 75,000 ED visits per year. The ED-based ICU – the Emergency Critical Care Center (EC3) – is a hybrid ED-ICU setting.[18]

### Patients

This study included all adult patients with ventilator management performed in EC3 from February 16, 2015–November 3, 2019, which determined the sample size.

### Interventions

On January 14, 2019, a ventilator-associated pneumonia (VAP) prevention bundle was instituted in EC3 for mechanically ventilated patients. As part of this bundle, respiratory therapists (RT) were provided with tape measures to accurately measure patient height. At the same time, a BPA was built into the electronic health record (EHR) reminding RTs to obtain patient height and to record whether the patient's height was measured, estimated, or stated (Figure 1).

RTs performing clinical care were not aware of the ongoing study. We collected data on patient height and tidal volumes before and after the intervention. The pre-intervention period was from February 16, 2015, (EC3 opening date) through January 14, 2019 (the VAP prevention

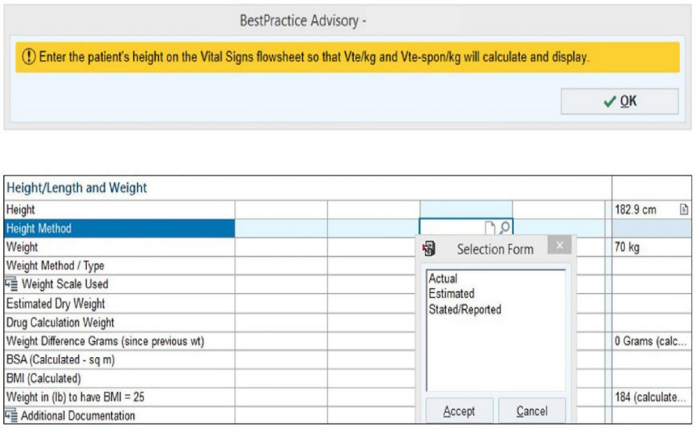


**Figure 1.** Best practice advisory requesting respiratory therapists to enter patient height and indicate how it was obtained. *wt,* weight; *sq m,* squared meter; *lb,* pound; *BMI,* body mass index.

bundle initiation date). The post-intervention period was January 15, 2019–November 3, 2019.

### Statistical Analysis

The study sample was characterized with descriptive statistics and frequency distributions. We compared categorical variables from pre- to post- intervention using chi-squared tests. Continuous variables were compared from pre- to post-intervention using independent sample t-tests. We compared categorical variables from pre- to post-intervention using chi-squared tests and bivariate logistic regression analysis. We used multivariable logistic regression analysis to test for intervention as a predictor of measured height, statistically controlling for potential confounders (age, gender, and EC3 length of stay). Data were analyzed using IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 26 (IBM Corp., Armonk, NY).

## RESULTS

We identified 54,188 tidal volume measurements in 2023 patients. We excluded from analysis the records of 197 patients with incomplete or missing data regarding tidal volumes or patient height. Our final analysis included 51,404 tidal volume measurements in 1826 patients over the study period, with a median of 21 measurements per patient (range 1 to 64 measurements per patient). The average variance in tidal volumes per patient was 12 milliliters (mL). Tidal volumes for each patient were averaged over the course of their ED-ICU stay and this average was used to determine whether lung-protective ventilation was achieved. In the pre-intervention period 1,579 (86.5%) patients were seen and 247 (13.5%) were seen in the post-intervention period. The sample was 43% female with no significant gender difference pre- and post-intervention (see Table 1).

Similarly, results from a bivariate logistic regression analysis showed that the odds of patient height being measured were 10 times higher post-intervention compared to pre-intervention (odds ratio [OR] 10.0, 95% confidence interval [CI], 6.7, 15.0). To rule out potential confounders, we conducted a multivariable logistic regression analysis of intervention as a predictor of measured height. Results showed that even when age, gender, and EC3 LOS were statistically controlled, the effects of the intervention on the odds of patient height being measured remained strong and significant (adjusted OR 9.9, 95% CI, 6.6, 15.0).

**Table 1**. Pre- and post-intervention group characteristics.

| | Pre-intervention n = 1579 | Post-intervention n = 247 | *P* |
|---|---|---|---|
| Female (%) | 676 (42.8%) | 107 (43.3%) | 0.891 |
| Mean age (years) | 57.9 ± 17.6 | 60.4 ± 18.2 | < 0.05 |
| Mean height (inches) | 67.3 ± 4.4 | 67.3 ± 4.2 | 0.939 |
| Mean tidal volume (mL) | 451.8 ± 86.4 | 425.3 ± 72.6 | < 0.05 |
| EC3 LOS (hours) | 11.0 ±7.9 | 10.0 ± 6.7 | < 0.05 |

*mL,* milliliters; *EC3 LOS,* emergency critical care center length of stay.

Although baseline compliance with a low tidal volume strategy was high, we found that more patients in the post-intervention group were ventilated with mean tidal volumes less than 8 cubic centimeters per kilogram (cc/kg) (84.5% vs 93.9%, $P < 0.05$). The difference in mean tidal volumes < 6 cc/kg was not significant (14.8% vs 17.0% $P = 0.39$). After the intervention, patients were ventilated with tidal volumes closer to 6 cc/kg ideal body weight compared to prior. The difference between delivered tidal volumes and 6 cc/kg of predicted body weight was less post-intervention (63±43 cc vs 36±76 cc, $P < 0.05$).

To address the potential confounding factor of increased awareness of lung-protective ventilation over time, we re-analyzed the data including only patients in the year prior to our intervention. We observed a similar increase in patients ventilated with tidal volumes less than 8 cc/kg after the intervention (89.2% vs 94.0%, $P = 0.05$) (Table 2).

## DISCUSSION

Providing RTs with a tape measure to measure actual patient height and creating a BPA in the EHR was associated with more frequent use of a lung-protective tidal volume strategy in an ED-ICU environment. Our study highlights the potential of a simple, inexpensive intervention to improve patient care.

Previous studies have found that clinicians are inaccurate when visually estimating patient height. Height measurements are biased toward the mean, which can result in significant overestimation of height in shorter stature patients.[5] After our intervention, a significantly higher percentage of patients had height measured rather than reported or estimated, allowing for more accurate determination of ideal body weight and calculation of lung-protective ventilation volumes.

**Table 2.** Pre- and post-intervention measurement and tidal volume outcomes.

| | Pre-Intervention (n = 1579) | Post-Intervention (n = 247) | *P* |
|---|---|---|---|
| Height used by clinicians to generate tidal volume | | | |
| Measured | 51 (3.2%) | 62 (25.1%) | < 0.05 |
| Estimated | 455 (28.8%) | 57 (23.0%) | 0.37 |
| Stated | 787 (49.8%) | 94 (38.1%) | < 0.05 |
| Not recorded | 286 (18.2%) | 34 (13.8%) | 0.53 |
| Mean tidal volume < 6 cc/kg | 234 (14.8%) | 42 (17.0%) | 0.39 |
| Mean tidal volume < 8 cc/kg | 1332 (84.5%) | 232 (93.9%) | < 0.05 |

*cc,* cubic centimeter; *kg,* kilogram.

Measuring all mechanically ventilated patients' height with a tape measure is an example of a simple, low-cost, scalable intervention in line with guidelines developed to improve the quality of care delivered to critically ill ED patients.

We observed tidal volumes closer to the ideal 6 cc/kg predicted body weight after the intervention, even though no portion of our intervention required respiratory therapists to alter tidal volumes. It thus appears that a simple reminder to measure height also improved compliance with lung-protective ventilation. We did note that, although our baseline compliance with < 8cc/kg was high (84.5%), significantly more patients were ventilated with volumes < 8 cc/kg ideal body weight after the intervention (93.9%). This represents a substantial improvement in adherence to lung-protective ventilation in the ED.

The simplicity of the intervention allows it to be generalizable to any ED setting. Providing tape measures is a low-cost intervention that can help patients even in limited resource settings. In our ED-ICU environment, we observed a large and clinically meaningful increase in the measurement of patient height. Future studies could focus on the difference between estimated and measured height, the magnitude of the resulting difference in tidal volumes, and whether this impacts patient outcomes. Other important parts of a lung-protective ventilation strategy, including maintaining plateau pressure < 30 centimeters water and using optimal positive end-expiratory pressure, should also be evaluated.

## LIMITATIONS

We did not collect data regarding clinical indications for intubation, which may have impacted the tidal volumes used. We did not make additional height measurements to determine whether measurements by RTs were done accurately. In this study, we were unable to comment on other aspects of lung-protective ventilation such as prevention of barotrauma or atelectrauma. We also could not comment on the impact of improved compliance with lung-protective ventilation on clinical outcomes in this study; however, this was demonstrated in prior studies.

This was a single-center study in a hybrid ED-ICU environment, which may limit generalizability. We did not correlate compliance with lung-protective ventilation to specific physicians or respiratory therapists; it is unclear what impact individual practice patterns may have had on these results, including whether completing a critical care fellowship impacted this practice.

## CONCLUSION

Patients in an ED-ICU environment were ventilated with a lung-protective strategy more frequently after a simple quality improvement intervention reminding respiratory therapists to measure actual patient height and providing a tape measure to do so. Measuring all mechanically ventilated patients' height with a tape measure is an example of a simple, low-cost, scalable intervention in line with guidelines developed by thoracic and critical care professional societies to improve the quality of care delivered to critically ill ED patients.

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# Comment on "The Incidence of QT Prolongation and Torsades des Pointes in Patients Receiving Droperidol in an Urban Emergency Department"

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Dear Editors:

We read with interest the recent article discussing QT prolongation and torsade des pointes (TdP) and droperidol.[1] The paucity of readily available antipsychotics and antiemetics that are not associated with QT prolongation makes selection of an appropriate pharmaceutical challenging in ideal situations and decidedly complex when confronted with an agitated, delirious, or intoxicated patient.

Our issue lies with the determination of incidence of TdP. The authors identify one case of TdP among the 16,546 patients who received droperidol. They found this case by examining electrocardiograms (ECG) and computerized ECG reports for 396 and 2431 patients, respectively, and by reviewing an electronic health record for documented diagnoses of TdP, ventricular fibrillation, and ventricular tachycardia. We are concerned that this analysis might have missed two groups of patients.

First, we suspect most patients receiving droperidol are not subject to continuous cardiac monitoring. TdP frequently terminates spontaneously and would likely not be captured on a single post-administration ECG, even in the limited subset for whom one was done.[2] In an (intentionally) sedated patient, the episode may go unnoticed and unrecorded. Nor would a transient episode in an alert patient likely be recorded as one of the diagnoses the authors queried, but instead as lightheadedness, syncope, palpitations, chest pain, seizure, or any number of subjective complaints. While these episodes may be less clinically relevant than an episode of TdP that degenerates into ventricular fibrillation, they nonetheless reflect real and important contributions to the incidence.

Secondly, we are told little of the disposition of the patients under study. How many of these patients were discharged from the emergency department (ED) after receipt of droperidol? How long were they observed before discharge? While the risk of QT prolongation may be highest in the initial period after administration, the absolute duration of risk is not known, particularly with the wide range of doses that are described in clinical practice. The authors describe a patient population with high rates of alcohol and/or substance use disorders – a population that is at persistent risk of exposure to another QT prolonging xenobiotic after discharge, either in the form of a drug of abuse or iatrogenically upon presentation to a different ED.

A rigorous calculation of incidence typically requires a prospective study. In this case, one might be more reassured by a study in which the cohort of interest undergoes ECG to confirm normal QT before exposure, receives a standardized dose of droperidol, and then undergoes serial ECGs and continuous cardiac monitoring for the expected duration of effect. We acknowledge that recruitment of a sufficiently large population to measure a rare adverse event would be challenging, but we see no alternative to calculating an accurate incidence.

We appreciate the efforts of Dr. Cole et al. and largely agree with their thoughtful discussion of the limited evidence upon which droperidol's black box warning was issued. Droperidol may in reality have a low risk of TdP in comparison to other antiemetics or antipsychotics, but we would like to caution readers from relying on this methodology to make determinations of the incidence of rare adverse events, or to find assurances of safety.

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# Respone to: "Limitations of Retrospective Chart Reviews to Determine Rare Events, and the Unknown Relative Risk of Droperidol"

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*In reply:*

We thank the authors for their interest in our article, and for highlighting some important limitations of our work.[1] We are grateful for the opportunity to address these concerns further.

Regarding the authors' first concern, indeed we already acknowledge in our limitations section that many of our patients did not receive continuous cardiac monitoring, and asymptomatic events could have been missed. While the clinical importance of asymptomatic self-terminating dysrhythmias is debatable, this question has fortunately been addressed by the DORM II investigators, who prospectively studied patients receiving droperidol for acute behavioral disturbance in multiple Australian emergency departments (ED). All patients in that study were initially treated in a critical care bed and attached to a cardiac monitor. When available, continuous ECG recordings were later analyzed, no patients had dysrhythmias, and while QT prolongation was observed the investigators found it was frequently due to causes other than droperidol.[2] We believe the incidence of such transient asymptomatic dysrhythmias in our study is likely miniscule.

Second, regarding disposition of the patients in our study, while these data were not collected (and are no longer available, as the electronic health record (EHR) from that time has been retired), here we can provide additional clarity. From previously published data we know our mean ED visit length for patients receiving droperidol was approximately seven hours,[3] with the outlier groups being headache (range, 1.5 - 4 hours)[4] and acute agitation (median, 8 hours).[5] It is highly likely patients in the present study had similar visit lengths. This is clinically important, as the recommended observation period in the FDA boxed warning is 2-3 hours. Furthermore, due to droperidol's short half-life, its clinical effect on the QT interval is likely equally short. In a study of 3,113 patients receiving a mean dose of 4.4 milligrams of droperidol to facilitate endoscopic retrograde cholangiopancreatography in which ECGs were obtained before droperidol and 1-3 hours post-procedure, the authors found that while QT intervals did increase no cardiovascular events attributable to droperidol occurred, and that QT intervals had normalized by the 1-3 hour ECG measurement.[6] Assuming the same is true for ED patients, it is likely that if droperidol-induced torsades des pointes (TdP) occurs, it will do so early in the ED visit. Thus, the risk of missed events in our study is likely low.

We agree with the authors that our study, due to the limitations noted, likely does not determine an exact incidence of droperidol-induced TdP in ED patients. Nevertheless, all studies have an endpoint (ours was the course of usual care for a single ED visit), and our conclusions remain valid within the parameters of our study. We believe, regardless of the precision of our measurement, our data reflect truth in the universe: that droperidol-induced TdP is exceedingly rare, as has been confirmed in other studies both outside[6] and within the ED.[7,8]

While the exact incidence of droperidol-induced TdP can be debated, we believe one of the more important findings of our study is that we did find such a case. Drug-induced TdP, in general, is quite rare. When it occurs, it frequently does so in patients with multiple risk factors,[9] which was true with the single case we found. This suggests that it is not the individual medication (ie, droperidol) that requires close monitoring and scrutiny, but rather high-risk patients receiving any QT-prolonging medication. Take, for example, antiemetics, one of the most commonly administered medication classes in the ED. Despite droperidol's boxed warning, data are clear that the risk of droperidol-induced TdP is quite rare. Ondansetron, a commonly

**Table.** Common antiemetics used in emergency medicine.

| Antiemetic | CredibleMeds.org* rating for torsades des pointes | Usual adult dose (IV) | Half-life |
|---|---|---|---|
| Droperidol | Known risk of TdP | 0.625 - 2.5 mg | 2 hours |
| Haloperidol | Known risk of TdP | 0.5 - 2 mg | 14 - 26 hours (IV) |
| Ondansetron | Known risk of TdP | 4 - 8 mg | 3 - 6 hours; up to 20 hours with severe hepatic impairment |
| Promethazine | Possible risk of TdP | 12.5 - 25 mg | 10 hours (IM)<br>9 - 16 hours (IV) |
| Metoclopramide | Conditional risk of TdP | 10 - 20 mg | 5 - 6 hours |
| Olanzapine | Conditional risk of TdP | 1.25 - 2.5 mg | 30 hours (IM; IV half-life unknown) |
| Prochlorperazine | Not classified | 5 - 10 mg | 6-10 hours (IV) |

*CredibleMeds.org is a non-profit, federally funded, online database of independent information regarding safe medication use. It rates the risk of drug-induced torsades des pointes (TdP) from highest (known risk) to lowest (conditional risk). Definitions for each category of risk are available at www.crediblemeds.org.
*mg,* milligram; *IM,* intramuscular; *IV,* intravenous.

used antiemetic in the ED, has a similarly strongly worded boxed warning for QT prolongation. We are unaware of a study similar to ours that attempts to determine the rate of ondansetron-induced TdP in the ED, despite the fact that in controlled studies, ondansetron causes QT prolongation at similar rates and to a similar degree as droperidol.[10] Most commonly administered antiemetics in the ED are associated with QT prolongation (Table); it remains unclear which of these is safest. Taken in this context, we believe our findings suggest that vigilance and monitoring be focused on high-risk patients for drug-induced TdP, rather than on a specific medication. A vomiting, hypokalemic patient on multiple QT prolonging medications with poor nutritional status should be on a cardiac monitor, regardless of which antiemetic they receive.

We thank the authors for giving us the opportunity to further address our study's limitations. We join them in calling for rigorous future studies to determine the true incidence of droperidol-induced TdP, and additionally call for similar scrutiny of other commonly administered medications in the ED known to prolong the QT interval.

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# POCUS to Confirm Intubation in a Trauma Setting

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To the Editor:

In the recent edition of the *Western Journal of Emergency Medicine*, Gottlieb and colleagues discuss point of care ultrasound (POCUS) confirmation of intubation.[1] Up to 25% of intubations using the classic formula of endotracheal tube (ETT) depth equal to three times the ETT diameter are inappropriately positioned,[2] and 35-60% of mainstem intubations are missed by auscultation.[1] Therefore, chest radiograph (CXR) has traditionally been used for confirmation of appropriate ETT placement.

In a prior review, Gottlieb reviews the utility of POCUS of the airway to demonstrate proper positioning of the ETT in real time.[3] After publication of that review, Uya and colleagues identified the saline-filled ETT cuff on POCUS to demonstrate correct ETT depth in children undergoing cardiac catheterization.[4] This technique builds on prior work suggesting that bilateral lung sliding can confirm appropriate placement of the ETT.[5,6] However, bilateral lung sliding in adult studies is only 92-100% sensitive and 56-100% specific for confirmation of ETT position.[3]

To date, no authors have discussed the use of POCUS for confirmation of an appropriately placed ETT in a trauma setting in which the neck is obscured by a cervical spine collar. We wish to present a case which highlights the limitation in using bilateral lung sliding to confirm ETT placement.

A 12-year-old male was brought to our pediatric emergency department by emergency medical services. The child was intubated with a 6-0 uncuffed tube and his neck protected by cervical collar. The tube was secured with cloth tape. The tape and his cervical collar made it difficult to determine the ETT depth by inspection and difficult to perform POCUS of the trachea. POCUS using a modified Rapid Ultrasound for Shock and Hypotension (RUSH) protocol showed a bilateral "sand on the beach" pattern, indicative of pleural sliding in both hemithoraces, and the treating physician falsely assumed that the ETT was positioned correctly. The child's initial CXR showed the tip of the ETT at the level of the carina. The ETT was unsecured and found to be at a depth of 21 centimeters at the lip. Repositioning to 18 centimeters at the lip resulted in appropriate positioning at the level of the sternoclavicular joints, as shown on repeat CXR.

Reliance on bilateral lung sliding to confirm appropriate ETT position is problematic. While absence of bilateral sliding may indicate a one-lung intubation, it cannot confirm a secured airway. In our experience, a low position of the ETT cuff is preferred to a high position, particularly in the prehospital setting where after intubation we are dealing with the transport of critically ill patients: a cuff position high in the trachea renders the ETT susceptible to dislodgement and risks loss of a definitive airway. In a child with bilateral lung sliding on POCUS, air in the ETT cuff, and a cervical collar, we wonder what information a transtracheal ultrasound adds. We question the safety of replacing air with saline in an established intubation in order to facilitate POCUS identification of a saline-filled cuff for confirmation of appropriate ETT placement.

We thank Gottlieb and colleagues for their important work. Further study is required to build a POCUS protocol to confirm an established intubation in a child with a cervical collar.

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# Response to: "POCUS to Confirm Intubation in a Trauma Setting"

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To the Editor:

We thank the authors for their insights and for sharing this case. The authors describe a patient who was intubated with the endotracheal tube (ETT) located at the tip of the carina, thereby allowing for bilateral lung sliding, while placing the ETT at risk of converting to a mainstem intubation.

This case highlights the importance of considering ETT depth and the potential for suboptimal, deep ETT placement to be present even when bilateral lung sliding is present. This can be particularly dangerous among younger patients (who have shorter tracheal lengths) and when there is a high probability of ETT movement, such as in the prehospital setting or when transferring between beds.

We agree with the authors that, while bilateral lung sliding can confirm that mainstem intubation is not present, it is not sufficient to confirm the optimal ETT depth. In these cases, additional assessment strategies, such as numeric depth assessment and direct ETT cuff visualization, offer additional information to supplement lung sliding. Moreover, we believe it is important to consider point-of-care ultrasound (POCUS) as a serial test used to assess initial position and reassess the position when the clinical condition changes or there is concern for ETT movement. This would allow rapid identification of mainstem intubation and reduce the time to intervention compared with radiographs.[1]

We appreciate the authors concern regarding inflating the ETT cuff with saline. However, it can be more challenging to visualize an air-filled ETT cuff, and several studies have assessed the use of a saline-filled ETT cuff to confirm ETT depth without identified complications.[2,3] With regard to transtracheal ultrasound, many cervical collars have a central opening in the anterior aspect which could be used to assess for ETT placement with POCUS using the transtracheal approach. We propose that transtracheal ultrasound is an important aspect of the ETT confirmation technique and can assess for ETT location, as well as hypopharyngeal placement.[1,4,5] As the body of literature regarding POCUS for ETT confirmation continues to grow, we believe future research should prospectively assess combined POCUS protocols and identify which approach is best for determining the ideal ETT depth.

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# Prospective Observational Multisite Study of Handover in the Emergency Department: Theory versus Practice

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**Introduction:** The handover process in the emergency department (ED) is relevant for patient outcomes and lays the foundation for adequate patient care. The aim of this study was to examine the current prehospital to ED handover practice with regard to content, structure, and scope.

**Methods:** We carried out a prospective, multicenter observational study using a specifically developed checklist. The steps of the handover process in the ED were documented in relation to qualification of the emergency medical services (EMS) staff, disease severity, injury patterns, and treatment priority.

**Results:** We documented and evaluated 721 handovers based on the checklist. According to ISBAR (Identification, Situation, Background, Assessment, Recommendation), MIST (Mechanism, Injuries, Signs/Symptoms, Treatment), and BAUM (Situation [German: *Bestand*], Anamnesis, Examination [German: *Untersuchung*], Measures), almost all handovers showed a deficit in structure and scope (99.4%). The age of the patient was reported 339 times (47.0%) at the time of handover. The time of the emergency onset was reported in 272 cases (37.7%). The following vital signs were transferred more frequently for resuscitation room patients than for treatment room patients: blood pressure (BP)/(all comparisons $p < 0.05$), heart rate (HR), oxygen saturation ($SpO_2$) and Glasgow Coma Scale (GCS). Physicians transmitted these vital signs more frequently than paramedics BP, HR, $SpO_2$, and GCS. A handover with a complete ABCDE algorithm (Airway, Breathing, Circulation, Disability, Environment/Exposure) took place only 31 times (4.3%). There was a significant difference between the occupational groups ($p < 0.05$).

**Conclusion:** Despite many studies on handover standardization, there is a remarkable inconsistency in the transfer of information. A "hand-off bundle" must be created to standardize the handover process, consisting of a uniform mnemonic accompanied by education of staff, training, and an audit process. [West J Emerg Med. 2021;22(2)401–409.]

## INTRODUCTION

Medical handover from prehospital care to the emergency department (ED) is defined as the transfer of responsibility of the care of one or more patients to another person or team.[1,2] Handovers, especially in the ED, are of enormous significance for the subsequent emergency treatment because that treatment requires precise timing, rapid decision-making, and specific expertise.[2,3] Furthermore, the handover is critical for the relaying of information, such as interventions that have occurred and details from the emergency scene. The transfer from prehospital care to the ED is always an interprofessional process involving at least two professional groups. This can

lead to misunderstandings and dissatisfaction due to different expectations and approaches.[2,4-6]

**Importance**

Studies by the Australian Commission on Safety and Quality in Health Care have shown that the quality of handover decreases based on an increasing rate of adverse events due to a lack of structure and communication, particularly in the presence of complex patient problems.[7] Inadequate, incorrect, or misleading information puts patients at risk.[8] Inadequate communication was one of the most frequent causes of malpractice claims reported to the Joint Commission between 1995–2006.[9] A study published in 2016 showed that communication errors caused 1744 deaths and resulted in costs of 1.7 billion US dollars over a period of five years in American hospitals.[10,11] The transmission of information in a stressful, highly dynamic work environment such as the ED represents a high-risk source of treatment errors and avoidable adverse events and is therefore relevant to patient outcomes influencing mortality.[12-14]

**Aim**

As early as 2007, the Joint Commission called for the process of handover to be standardized with the aim of increasing patient safety.[15] In 2008, the World Health Organization (WHO) formulated the development of "standard operating procedures" in communication as one of the five priorities in the area of patient safety for industrialized countries.[9,16] To date, a large number of protocols for the standardization of oral handovers have been published.[17,18] In addition to checklists, computer-assisted handover programs and algorithms as well as specific mnemonics have been established to serve as reminders intended to provide guidance when following a process.[19]

The goal of this study was to examine the handover procedures in an ED, focused on content, scope and structure and the application of existing handover mnemonics. Our project was a prospective observational study of the handover process, focusing on the interface between the prehospital care and the ED.

*Population Health Research Capsule*

What do we already know about this issue?
*The handover process is relevant for adequate treatment of patients and therefore affects patient outcomes. Consequently, it plays a major role in patient safety.*

What was the research question?
*We sought to provide a current status of handover practice in EDs with regard to content and structure.*

What was the major finding of the study?
*To date no handover standard has been established and current practice reveals deficits in structure.*

How does this improve population health?
*This study raises awareness of the need to include handover in national health policy programs, thereby accelerating the process of standardization.*

## METHODS

**Emergency Medical Services System Organization**

Emergency care in Germany is provided by rescue vehicles that are manned by one of two types of clinicians – paramedics or emergency physicians (EP). The responsible emergency call center decides when an EP is called to the scene according to pre-specified criteria. In many cases, following initial emergency medical care under the supervision of the EP, further transport of the patient is then carried out by the paramedics. In Germany, paramedic training consists of a three-year course with theoretical and practical content as well as a final examination. Physicians can acquire an additional qualification with focus on emergency medicine (EM). This includes 24 months of clinical specialist training, an additional six months of anesthesia, intensive care and EM expertise, an 80-hour theory course, 50 life-saving emergency medical services (EMS) missions, and a final examination. The EMS staff or the responsible control center, respectively, is in charge of the pre-registration of emergency patients at the ED. The above-mentioned training courses historically have had no specific focus on training with regard to the EMS handover process.

**Design**

We carried out a prospective, multicenter observational study. To minimize bias and to allow comprehensive assessment of EMS handovers, we used a checklist. The checklist was derived by including elements from the following established mnemonics, which are benchmarks in the handover literature: ISBAR (Identification, Situation, Background, Assessment, Recommendation), MIST (Mechanism, Injuries, Signs/Symptoms, Treatment) and BAUM (Situation [German: *Bestand*], Anamnesis, Examination [German: *Untersuchung*], Measures).[20-23] The checklist was developed by a selected expert committee of five EPs and paramedics with experience in both prehospital and clinical EM. The final checklist contains all relevant core contents for memory (SAMPLER algorithm – Symptoms, Allergies, Medication, Past medical history, Last oral intake, Events prior to incident, Risk factors) and assessment of the patient's condition (ABCDE algorithm - Airway, Breathing, Circulation, Disability, Environment/Exposure) as well as vital signs. The ABCDE and SAMPLER algorithms are recommended

by WHO for patient treatment according to priority but not specifically for handover process. Both algorithms are core elements of baseline paramedic training and advanced training courses such as International Trauma Life Support (ITLS) and Prehospital Trauma Life Support (PHTLS).[24,25] Detailed descriptions of all mnemonics and algorithms are provided in the electronic attachment.

To gather more nuanced data, handovers were assessed by profession (paramedic vs physician), and severity of the disease/treatment priority (resuscitation vs treatment room), as well as trauma vs non-trauma patients.

**Setting**

The study was carried out at three hospitals with different emergency care levels. The University Hospital Bonn (UKB) is a comprehensive care hospital with about 45,000 ED visits per year. The Florence Nightingale Hospital in Düsseldorf sees approximately 37,000 emergency patients per year and is a teaching hospital of the University Hospital Düsseldorf. The Protestant Hospital in Cologne Kalk is a non-tertiary teaching hospital of the University Hospital Cologne that cares for approximately 20,000 ED patients per year. In these three EDs, EMS are not specifically required or trained to use any particular handover structure. In this study, we examined only handovers by EMS paramedics or physicians.

**Data Collection**

During the test period from March 11, 2019–October 31,2019, under supervision of the Institute for Medical Biometry, Informatics and Epidemiology of the University Hospital Bonn, study personnel documented the handovers in EDs between 6:30 AM - 9:30 PM. To minimize loss of information, details on prehospital care were obtained from the emergency services documentation record. To ensure standardized application of the checklist and to minimize errors in the documentation, only persons directly involved in the development of the checklist carried out the application. Due to limited personnel, not all handovers within the observation period were recorded.

**Statistical Analysis**

We used Microsoft Excel 2017 (Microsoft Corporation, Redmond, WA) to manage and tabulate the comprehensive data set. The duration of patient transfer was evaluated descriptively as a continuous variable by specifying the mean value and standard deviation. All other collected data were categorical and were represented by the specification of absolute and relative frequencies, the odds ratio (OR), and the specification of 95% confidence intervals (CI). A statistical comparison of subgroups was carried out using the Chi-square test, or for smaller group sizes, Fisher's exact test to a significance level of 0.05 (5%). We evaluated all data using SPSS version 26 (SPSS Inc. Chicago, IL).

**Ethics Statement**

The study received approval (No. 002/19) from the chairman of the local ethics committee (K. Racké, MD, PhD, Professor, University Bonn). Data obtained from the clinical information system may be used in accordance with the code of medical ethics (article 15/1) (https://www.aekno.de/aerzte/berufsordnung#_15http://www.aekno.de/page.asp?pageID=57#_15) of the General Medical Council. Furthermore, as stipulated by German data protection regulations, the physician may use existing patient data for analyses without explicitly asking for the consent of patient. All collected clinical data evaluated in this study were fully anonymized prior to analysis. Furthermore, the data collected do not contain any patient information. The study design is consistent with the Declaration of Helsinki.[26]

## RESULTS

**Baseline Characteristics**

During the observation period, a total of 721 handovers were examined in the three EDs. Of these handovers, 44.5% (n = 321) were carried out by EPs and 55.5% (n = 400) by paramedics. 79.1% (n = 570) of the transfers invovled non-trauma emergency patients, and 20.9% (n = 151) patients after trauma. Of the transfers, 30.5% (n = 220) took place in the resuscitation room, the remaining 69.5% (n = 501) in normal treatment rooms or in the triage room. The mean value of the transfer time was one minute 11 seconds. (standard time deviation STD ± 0:34 minutes). In 74.5% (n = 537), the ED personnel raised further questions for better understanding.

**Identification, Mechanism and Medical Situation**

The sex of the emergency patient was mentioned with a frequency of 95.6% (n = 689) at the time of delivery; the name of the patient was mentioned with a frequency of 83.8% (n = 604) and the age of the patient was mentioned in 47.0% (n = 339) of the cases. The suspected diagnosis was reported in 95.7% (n = 690) and the emergency event in 90.4% (n = 652). Comparatively less frequently, information regarding the place where the emergency occurred was reported in 66.4% (n = 479) and the time it occurred in 37.7% (n = 272) of cases (Table 1).

**Leading Priority and Vital Signs**

The frequency of the handovers in which the ABCDE algorithm recommended by WHO was completely applied (chronological mention of all elements) was 4.3 % (n = 31). The subgroup analysis shows that physician staff performed a complete ABCDE handover 7.2% of the time, compared to paramedics who used it 2.0% of the time (OR: 3.8, $p < 0.05$). Also, the complete ABCDE algorithm was applied to resuscitation room patients more frequently (OR: 7.2, $p < 0.05$), compared to transfers in the conventional treatment rooms or the triage room. The same trend was observed in the transfer of trauma patients compared to non-trauma emergency patients (OR: 18.7, $p < 0.05$). In 86.1% (n = 621) of the handovers, the ABCDE algorithm was not applied, while in 3.2% (n = 23), a handover with at least three points of the ABCDE algorithm took

**Table 1.** Absolute frequency, 95% confidence interval, and evaluated numbers related to treatment location and professional qualification in terms of identification (name, sex, age) and details of emergency event.

| | Absolute frequency (n = 721) | Percentage | Resuscitation room (n = 220) | 95% CI | Treatment room (n = 501) | 95% CI | Physician staff (n = 321) | 95% CI | Paramedical staff (n =400) | 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | 604 | 83.8% | 204 (92.7%) | 89.3 – 96.2 | 400 (79.8%) | 76.3 – 83.4 | 287 (89.4%) | 86.0 – 92.8 | 317 (79.3%) | 75.3 – 83.2 |
| Sex | 689 | 95.6% | 217 (98.6%) | 97.1 – 100.0 | 472 (94.2%) | 92.2 – 96.3 | 314 (97.8%) | 96.2 – 99.4 | 375 (93.8%) | 91.4 – 96.1 |
| Age | 339 | 47.0% | 175 (79.5%) | 74.2 – 84.9 | 164 (32.8%) | 29,0 – 37.3 | 229 (71.3%) | 66.4 – 76.3 | 110 (27.5%) | 23.5 – 32.5 |
| Suspected Diagnosis | 690 | 95.7% | 213 (96.8%) | 94.5 – 99.2 | 477 (95.2%) | 93.3 – 97.1 | 311 (96.9%) | 95.0 – 98.8 | 379 (94.8%) | 92.6 – 96.9 |
| Description of Emergency Event | 652 | 90.4% | 217 (98.6%) | 97.1 – 100.0 | 435 (86.8%) | 83.9 – 89.8 | 318 (99.1%) | 98.0- 100.0 | 334 (83.5%) | 79.8 – 87.1 |
| Location of Emergency Event | 479 | 66.4% | 177 (80.5%) | 75.2 – 85.7 | 302 (60.3%) | 56.0 – 64.6 | 261 (81.3%) | 77.0- 85.6 | 218 (54.5%) | 49.6 – 59.4 |
| Time of Emergency Event | 272 | 37.7% | 109 (49.5%) | 42.9 – 56.2 | 163 (32.5%) | 28.4 – 36.7 | 155 (48.3%) | 42.8- 53.8 | 117 (29.3%) | 24.8 – 33.7 |

*CI,* confidence interval.

place (Table 2).

Looking at the prehospital vital signs and their communication during handover, the following pattern becomes apparent: In only 44.7% (n = 289) of cases was the blood pressure (BP) mentioned in the handover. In 30.6% (n = 199) of handovers the heart rate (HR) was verbalized, while the oxygen saturation ($SpO_2$) was only communicated in 25.6% (n = 165) of cases. The respiratory rate was only communicated in 12.8% of handovers. The testing of circulation, sensation and mobility (CSM) was communicated much more often, in 76.9% of cases.

**Table 2.** Application of ABCDE algorithm during the handover process dependent on trauma/non-trauma patients, physician/paramedical staff and resuscitation room/treatment room. Additionally, OR, 95% CI and p-value are displayed to allow comparison.

| Application of ABCDE algorithm | Handover of trauma patients (n = 151) | Handover of non-trauma patients (n = 570) | OR | 95% CI | P-value |
|---|---|---|---|---|---|
| No application of ABCDE algorithm | 89 (58.9%) | 532 (93.3%) | 0.1 | 0.07 – 0.2 | <0.05 |
| Partial application of ABCDE algorithm † | 37 (24.5) | 32 (5.6%) | 5.4 | 3.3 – 9.1 | <0.05 |
| Full application of ABCDE algorithm | 25 (16.6%) | 6 (1.1%) | 18.7 | 7.5 – 46.4 | <0.05 |
| Application of ABCDE algorithm | Handover by physician staff (n = 321) | Handover by paramedical staff (n = 400) | OR | 95% CI | p-value |
| No application of ABCDE algorithm | 249 (77.6%) | 372 (93.0%) | 0.3 | 0.2 – 0.4 | <0.05 |
| Partial application of ABCDE algorithm † | 49 (15.2%) | 20 (5.0%) | 3.4 | 2.0 – 5.9 | <0.05 |
| Full application of ABCDE algorithm | 23 (7.2%) | 8 (2.0%) | 3.8 | 1.7 – 8.6 | <0.05 |
| Application of ABCDE algorithm | Handover resuscitation room (n = 220) | Handover treatment room (n = 501) | OR | 95% CI | p-value |
| No application of ABCDE algorithm | 149 (67.7%) | 472 (94.2%) | 0.1 | 0.08 – 0.2 | <0.05 |
| Partial application of ABCDE algorithm † | 48 (21.8%) | 21 (4.2%) | 6.4 | 3.7 – 11.0 | <0.05 |
| Full application of ABCDE algorithm | 23 (10.5%) | 8 (1.6%) | 7.2 | 3.2 – 16.4 | <0.05 |

† Using at least one and up to four letters of ABCDE algorithm.
*ABCDE,* Airway, Breathing, Circulation, Disability, Environment/Exposure; *OR,* odds ratio; *CI,* confidence interval

Other important elements, such as Glasgow Coma Scale (GCS), blood sugar (BS) and temperature are listed in Table 3.

The subgroup analysis of the different occupation groups shows that trained EPs more often refer to the transmitted vital parameters BP (OR: 1.9), HR (OR: 2.2), $SpO_2$ (OR: 2.7) and GCS (OR: 5.1) at the time of handover (Table 4). The subgroup analysis of transfers in resuscitation room patients shows that the above-mentioned vital signs were also more frequently reported compared to handovers in normal treatment rooms (Table 5). Differentiation between trauma patients and non-trauma emergency patients revealed that GCS was mentioned more frequently in trauma patients ($p < 0.05$).

**Medical History and Risk Factors**

Previous illnesses of the emergency patient were reported at the handover with a frequency of 49.7% (95% CI, 46.0-53.3 / n = 358) and the risk factors of the patient in 54.4% (95% CI, 50.7-58.0 / n = 392). The patient's home medication was mentioned in 41.2% (95% CI, 37.6-44.8 / n = 297) of the cases. Information on existing allergies was significantly less often reported in 17.0% (95% CI, 14.3-19.8 / n = 123) and on the last meal in 3.9% (95% CI, 2.6-5.3 / n = 28) of cases.

In just 1.1% of the cases (n = 8) was the SAMPLER algorithm, recommended by WHO, fully applied (chronological mention of all letters or their contents). In 27.2% (n = 200) of the handovers, at least three contents of the SAMPLER algorithm were mentioned at the handover. The subgroup analysis shows that in comparison to the paramedics, physicians more frequently mentioned at least three SAMPLER components ($p < 0.05$). The same is true for resuscitation room handovers when compared to the treatment room patients ($p < 0.05$), and for the trauma vs the non-trauma emergency patients ($p < 0.05$). In 20.0% (n = 144) of the handovers, no information of the SAMPLER algorithm was transmitted.

**3.5 Emergency Treatment**

Analysis of prehospital therapeutic activities shows the following results: Intravenous (IV) access was mentioned in only 37.2% (n = 132) of the cases at handover and had the lowest ratio between performance and handover of all preclinically performed measures. The preclinically derived 12-lead electrocardiogram was discussed in 75.7% (n = 109) of the cases at handover. In 58.9% (n = 63) of cases, information on prehospital oxygen therapy was provided at the handover. Drug administration and airway management were the most frequently mentioned rescue measures at handover. Defibrillation as a life-saving measure was mentioned in 85.7% of the cases, if performed as a prehospital treatment (Table 6).

The subgroup analysis of resuscitation room patients shows that, in comparison to handover of patients in normal treatment rooms, all prehospital therapeutic measures were mentioned with the same frequency. The only significant difference was found in the establishing of an IV access ($p < 0.05$).

## DISCUSSION

This is the first prospective study to examine the EMS handover process in German EDs in terms of content, scope, and structure in relation to existing handover mnemonics. The work is intended to present the current handover practice and demonstrates that the handover does not follow a clear protocol and that a pronounced inconsistency exists in information transfer. In addition, differences in the extent and completeness of the handovers are apparent depending on staff and the priority of treatment (resuscitation room vs treatment room) and the injury pattern (trauma vs non-trauma patients). The data collected from the three EDs refer to a large supply area of the rescue service in the German federal state of North Rhine-Westphalia (NRW). Since NRW is the federal state with the highest population in Germany (approximately 18 million) and the structure of emergency services does not differ significantly from that of the other regions of Germany, we believe that the data presented have a high scientific validity for Germany and may have important implications for other countries as well.

The data of the present study are supported by another

**Table 3.** Frequency of preclinically evaluated vital signs with total occurrence and percentage as well as 95% confidence interval during handover.

| Vital signs | Total prehospital evaluation (n = 721) | Handover frequency | Percentage | 95% CI |
|---|---|---|---|---|
| Blood pressure | 646 | 289 | 44.7% | 41.0 – 48.6 |
| Heart rate | 650 | 199 | 30.6% | 27.1 – 34.2 |
| Oxygen saturation | 645 | 165 | 25.6% | 22.2 – 29.0 |
| Respiratory rate | 382 | 49 | 12.8% | 9.2 – 15.9 |
| Glasgow Coma Scale | 566 | 126 | 22.2% | 18.8 – 25.5 |
| Blood sugar | 400 | 98 | 24.5% | 20.3 – 28.7 |
| Temperature | 262 | 62 | 23.7% | 18.5 – 28.8 |
| CSM | 255 | 196 | 76.9% | 71.7 – 82.1 |

*CI,* confidence interval; *CSM,* circulation, sensation and movement.

**Table 4.** Vital signs in terms of prehospital evaluation and handover frequency depending on professional qualification. Odds ratio (OR), 95% confidence interval (CI), and P-value were used to show statistical correlation. The physician provider was used as reference for the development of the OR.

| Vital signs | Prehospital evaluation physician staff (n = 321) | Handover frequency | Prehospital evaluation paramedical staff (n = 400) | Handover frequency | OR | 95% CI | P-value |
|---|---|---|---|---|---|---|---|
| Blood pressure | 318 (99.1%) | 167 (52.5%) | 328 (82.0%) | 122 (37.2%) | 1.9 | 1.4 – 2.6 | <0.05 |
| Heart rate | 319 (99.4%) | 125 (39.2%) | 331 (82.8%) | 74 (22.4%) | 2.2 | 1.6 – 3.2 | <0.05 |
| Oxygen saturation | 317 (98.8%) | 111 (35.0%) | 328 (82.0%) | 54 (16.5%) | 2.7 | 1.9 – 4.0 | <0.05 |
| Respiratory rate | 238 (74.1%) | 36 (15.1%) | 144 (36.0%) | 13 (9.0%) | 2.0 | 1.0 – 3.9 | 0.052 |
| Glasgow Coma Scale | 294 (91.6%) | 100 (34.0%) | 272 (68.0%) | 26 (9.6%) | 5.1 | 3.2 – 8.2 | <0.05 |
| Blood sugar | 234 (72.9%) | 50 (21.4%) | 166 (41.5%) | 48 (28.9%) | 0.7 | 0.4 – 1.1 | 0.084 |
| Temperature | 157 (48.9%) | 33 (21.0%) | 105 (26.3%) | 29 (27.6%) | 0.7 | 0.4 – 1.2 | 0.22 |
| CSM | 154 (48.0%) | 121 (78.6%) | 101 (25.3%) | 75 (74.3%) | 1.3 | 0.7 – 2.3 | 0.42 |

*CSM,* circulation, sensation and movement.

European study conducted by Delupis et al in Italy. They found comparable results in their work: the absence of standardization of the handover process; a high variability in information transfer; and deficiencies in the transfer of responsibility of patient care.[27]

It is notable that the presence of a higher disease severity with pathological vital signs appears to be a trigger for more verbalization at the handover. Conversely, in less critical patients, information regarding the leading medical problem, vital signs, and other information from the patient's medical history may not be considered relevant for the handover. To date, numerous studies have shown that vital signs, especially respiratory rate, BP, and GCS, have a predictive value for the outcome of critical emergency patients.[28,29] In this context, vital signs play an important role in order to evaluate critical conditions of patients by using scores such as CRB 65 and qSOFA.[30,31] Here, a transfer of vital signs is categorically called for, independent of the severity of the illness and the qualification of the person transmitting the data. Information on the time component of the emergency event is essential regarding time-critical therapeutic measures including thrombolytics for stroke or time-sensitive sepsis bundles.[32]

The main findings show that with regard to MIST, ISBAR and BAUM, no mnemonics were applied during handover, resulting in a lack of structure and information transfer. This is supported by the high demand for additional information from the receiving team. One explanation lies in the individual design of the handover process, resulting in incongruence between expected and actually transferred information. In our opinion, this is not due to a lack of handover mnemonics, but rather to the fact that to date, no handover practice exists that fully meets the high requirements of a transfer in the ED. According to Nasarwanji et al, not all information necessary for the transfer can be accommodated in a generally valid mnemonic.[33] Hence, the handover process needs a specifically adapted mnemonic, with elements from the ABCDE or SAMPLER algorithms. Since the handover is strongly influenced by human factors, consideration should be given to integrating crew resource management aspects into the handover process to improve patient safety.[34] Other handover practices to promote effective transfer of information include the following: no actions performed on patients during the handover; face-to-face communication; presence of all team members; a repeat back of essential handover content; and an opportunity for questions.

This thesis is supported by the work of Keebler et al, who with the help of a systematic literature review and a series of meta-analyses, examined many publications on handover standardization. Keebler et al took on the standardization of the handover in 2017, as called for by the Joint Commission in 2007, and found that all studies follow different standards, enabling only limited comparability.[19] In their conclusion, the authors recommended that protocols should standardize the handover and provide users with orientation as to what information should be transmitted.

It becomes clear that despite the available mnemonics and the numerous studies on standardization of the handover, we still have a gap between the theoretical handover approach and its practical implementation. The target must be the creation of a shared mental model between emergency services and hospital

**Table 5.** Vital signs in terms of prehospital evaluation and handover frequency depending on treatment localization. The resuscitation room was used as reference for the development of the odds ratio (OR), 95% confidence interval (CI), and p-value were used to show statistical correlation.

| Vital signs | Prehospital evaluation resuscitation room (n = 220) | Handover frequency | Prehospital evaluation treatment room (n = 501) | Handover frequency | OR | 95% CI | P-value |
|---|---|---|---|---|---|---|---|
| Blood pressure | 218 (99.1%) | 121 (55.5%) | 428 (85.4%) | 168 (39.3%) | 1.9 | 1.4 – 2.7 | <0.05 |
| Heart rate | 219 (99.5%) | 81 (37.0%) | 431 (86.0%) | 118 (27.4%) | 1.6 | 1.1 – 2.2 | <0.05 |
| Oxygen saturation | 218 (99.1%) | 76 (34.9%) | 427 (85.2%) | 89 (20.8%) | 2.0 | 1.4 – 2.9 | <0.05 |
| Respiratory rate | 156 (70.9%) | 22 (14.1%) | 226 (45.1%) | 27 (11.9%) | 1.1 | 0.6 – 2.1 | 0.66 |
| Glasgow Coma Scale | 204 (92.7%) | 83 (40.7%) | 362 (72.3%) | 43 (11.9%) | 5.0 | 3.3 – 7.6 | <0.05 |
| Blood sugar | 170 (77.3%) | 40 (23.5%) | 230 (45.9%) | 58 (25.2%) | 0.9 | 0.6 – 1.4 | 0.70 |
| Temperature | 108 (49.1%) | 22 (20.4%) | 154 (30.7%) | 40 (26.0%) | 0.7 | 0.4 – 1.3 | 0.29 |
| CSM | 131 (59.5%) | 106 (80.9%) | 124 (24.8%) | 90 (72.6%) | 1.6 | 0.9 – 2.9 | 0.12 |

*CSM,* circulation, sensation and movement.

staff. This would enable handovers in an interprofessional, team-based manner.[35,36] Therefore, future research should concentrate on combining elements of clinical effectiveness and implementation using hybrid study designs to enhance the practical application of specifically adapted mnemonics.[37] In concrete terms this means developing a mnemonic with the requirements described above, which then is validated using the Delphi method. Subsequently, the effectiveness of the mnemonic and its implementation (ie. its acceptance by paramedics) has to be examined by prospective studys.

Furthermore, national initiatives for the general implementation of handover approaches in the clinical setting are necessary for Germany and other countries, in line with the initiatives already taken in Australia, Great Britain, and the USA. The provision of appropriate financial and human resources for the implementation of this health policy objective is an indispensable prerequisite. In the near future, external audits must review the introduction and application of structured handover processes in relation to triage in the ED. It also seems necessary to include the topic of handover as training content in the curricula of the proven prehospital and hospital course concepts such as Advanced Life Support, ITLS, PHTLS, Advanced Trauma Care for Nurses, and Advanced Trauma Life Support. The handover should be incorporated into

**Table 6.** Frequency of prehospital applied treatment with total occurrence and percentage as well as 95% confidence interval during handover.

| Prehospital treatment | Prehospital treatment (n = 721) | Handover frequency | Percentage | 95% CI |
|---|---|---|---|---|
| 12-channel electrocardiogram | 144 | 109 | 75.7% | 68.6 – 82.8 |
| Oxygen application | 107 | 63 | 58.9% | 49.4 – 68.4 |
| Intravenous access | 355 | 132 | 37.2% | 32.1 – 42.2 |
| Drug administration | 295 | 259 | 87.8% | 34.0 – 91.6 |
| Wound care | 29 | 15 | 51.7% | 32.4 – 71.1 |
| Airway management | 41 | 37 | 90.2% | 80.8 – 99.7 |
| Immobilization | 85 | 42 | 49.4% | 38.6 – 60.3 |
| Defibrillation | 7 | 6 | 85.7% | 50.7 – 100.0 |

*CI,* confidence interval.

the training of paramedics, as well as into the further training programs for EPs and nurses.

## LIMITATIONS

It is possible that this study includes repetitive handovers by the same EMS staff during the observation period. Thus, some of our results may have been limited by our sample population. However, given the large catchment area of the three EDs, this is unlikely to affect the overall significance and results of the study. Additionally, the selected period from March 2019–October 2019 did not allow any conclusions to be drawn for an entire year, as possible seasonal fluctuations were not considered. Furthermore, patient transfers during night shifts were not documented. It cannot be ruled out that the content and scope of the handover may vary regarding the time of day.

It is possible that while applying the checklist, information may not have been recorded or missed. However, we consider the percentage as negligible, since the person documenting never participated in direct patient care and was as an external observer. Finally, since it could not be avoided that several handovers took place at the same time, the external observers were not able to record the data of all handovers in the given observation period. Therefore, it must be assumed that in comparison to the results, both better structured as well as worse structured handovers were not recorded. Nevertheless, due to the high number of cases and the observation at three EDs, the present results create a representative picture of the current handover process.

## CONCLUSION

The present study shows that despite many existing handover protocols, there is no widespread implementation or acceptance of these protocols. Not even the measures recommended by the World Health Organization to increase patient safety are reliably transmitted during handover. Future research should aim at establishing appropriate user-friendly handover protocols for the ED. Improving and standardizing the EMS-to-ED handover process has a high potential to improve patient safety and emergency care.

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# Rising Trends in Wrestling-associated Injuries in Females Presenting to US Emergency Departments

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**Introduction:** Wrestling is one of the fastest-growing sports among females in the United States (US). However, female wrestling injuries remain poorly characterized. In this study we describe historical and projected national estimates of female wrestling injuries, and compare injury characteristics with those of male wrestlers.

**Methods:** We queried the National Electronic Injury Surveillance System (NEISS) database (2005-2019) to compare national weighted estimates and injury characteristics of male vs female wrestlers presenting to US emergency departments (ED) and projected annual female wrestling injuries expected by 2030.

**Results:** Our analyses demonstrated a significant (P < 0.001) increase in female wrestling injuries between 2005 (N = 1500; confidence interval [CI], 923 – 2,078) and 2019 (N = 3,404; CI 2,296 – 4,513). Linear regression (R2 = 0.69; P < 0.001) projected 4,558 (CI, 3104 – 6033) such injuries in 2030. Of female wrestling injuries 50.1% (CI, 44.1 – 56.2) occurred in patients 14-18 years of age. Compared with age-matched males, female wrestlers were significantly less likely to present with fractures (Female [F]: 10.6%; CI 7.5% – 13.7%; Male [M]: 15.7%; CI 14.7% – 16.7%; P = 0.003) or head/neck injuries (F: 18.5%; CI 13.2% – 23.9%; M: 24.6%; CI 23.2% – 26.0%; P = 0.018), and significantly more likely to present with strains/sprains (F: 48.8%; CI, 41.2% – 56.3%; M: 34.4%; CI 31.6% – 37.1%; P < 0.001).

**Conclusion:** Males and females possess distinctly unique physiology and anatomy, such as variances in ligamentous and muscular strength, which may help to explain differences in wrestling injury characteristics. Prompt management of injuries and specific training strategies aimed at prevention may help to reduce the projected increase of female wrestling-associated injuries as the popularity of the sport continues to rise. [West J Emerg Med. 2021;22(2)410–416.]

## INTRODUCTION

Wrestling has long been regarded as one of the most physically taxing sports in the world, with an injury rate of nearly 70 per 1,000 athletic exposures, which is second only to football.[1] In the United States (US), wrestling has historically been a male-dominated sport, and injuries among male wrestlers have been well described.[2] Among females, wrestling is one of the fastest-growing sports: participation has increased for 30 consecutive years with a parallel rise in female-only competitive tournaments.[3] Uniquely, female and male wrestlers often practice and compete together at the high school level, yet national regulations vary between the genders. For example, requirements for body composition state that male and female wrestlers must maintain body fat percentages greater than 7% and 12%, respectively.[4] Fat-free body mass has been associated with strength, power, and

elite performance among both male and female wrestlers, and different body fat requirements may therefore contribute to variations in performance and injuries among wrestlers.[5-7]

Despite increased participation, female wrestling injuries remain poorly characterized. For instance, female wrestlers at the elite and Olympic levels have lower observed injury rates than males, with no significant differences in injury sites or severities. However, sample sizes in such studies are low and do not include youth wrestlers.[8] Even broader epidemiological investigations on wrestling-associated injuries have historically excluded female wrestlers from their analyses altogether due to underpowered sample sizes.[9] With the recent surge in popularity of wrestling among female participants, data from larger cohorts of female athletes is now available to better inform injury prevention strategies, and training and rehabilitation programs for all wrestlers.

In this study we describe historical and projected national estimates of female wrestling-associated injuries and compare injury characteristics among females and males during the study period. We hypothesized that an increase in wrestling-associated injuries among females would be observed over the study period, and that female wrestlers would sustain lower proportions of severe injuries such as fractures and concussions compared with males.

*Population Health Research Capsule*

What do we already know about this issue?
*Wrestling is one of the fastest-growing sports among females in the United States (US). However, female wrestling injuries remain poorly characterized.*

What was the research question?
*What is the projected increase of female wrestling injuries and how do they compare to male injury characteristics?*

What was the major finding of the study?
*Female wrestling injuries are projected to increase, and they suffer different injury characteristics than males.*

How does this improve population health?
*An understanding of the projected trend and injury characteristics will allow implementation of appropriate injury prevention and emergency care to female wrestlers.*

## METHODS

We retrospectively identified cases of wrestling-associated injuries in the National Electronic Injury Surveillance System (NEISS), which is maintained by the US Consumer Product Safety Commission (CPSC). The NEISS database functions to oversee and document product- or activity-related injuries presenting to US EDs; it is publicly available, deidentified, and published annually on a freely accessible governmental website. Importantly, it is a nationally representative probability sample of designated hospital EDs stratified by hospital size and geographic location, from which weighted national estimates and sampling errors for queried injuries may be derived. Various reliable, reproducible epidemiologic studies on injury-related ED visits have been published using this database.[10,11] Specific information pertaining to collection methodologies and quality control precautions are available on the CPSC webpage.[12]

In this study we queried each yearly sample in the NEISS database between 2005–2019, both inclusive, for injuries classified as associated with the sport of wrestling (Product Code: 1,270 – "Wrestling (activity/apparel/equipment)"). A total of 16,404 unique cases were identified in the NEISS database during this period, which amounted to 590,803 weighted national estimates of wrestling-associated injuries presenting to US EDs. Of note, we excluded the years prior to 2005 due to an overall low case number of female wrestling-associated injuries, which made annual statistics unstable. Next, free-text case narratives were searched to identify and exclude cases unrelated to the sport of wrestling. These included the following activities: *sumo wrestling, mud wrestling, World Wrestling Entertainment, Inc. wrestling,* and any description of a patient wrestling with a sibling, friend, or parent in a non-sports setting (eg, *on the couch*, *horsing around at home*, etc.). We identified 472 cases unrelated to the sport of wrestling, leaving 15,932 unique cases amounting to 569,813 weighted national estimates of wrestling-associated injuries presenting to US EDs for our final analyses.

We calculated all weighted national estimates, standard errors (SE), and 95% confidence intervals (CI) by using the *svyset* function in Stata/IC 15.1 statistical software (StataCorp LLC, College Station, TX).[13] Significance of trends in the total national survey estimates was determined using adjusted Wald tests, given the use of weighted survey data. $P$ values < 0.05 (2-sided) were considered significant.

## RESULTS

Annual national estimates of wrestling-associated injuries among female participants between 2005 and 2019 are shown in Table 1**.** The national number of female patients per year presenting to US EDs increased significantly ($P < 0.001$) from 2005 (N = 1,500; CI, 923-2,078) to 2019 (N = 3,404; CI, 2,296-4,513). In Figure 1, linear regression ($R^2 = 0.69$; $P < 0.001$) projected female wrestling injuries to reach 4,556 (CI, 3,104-6,033) by 2030.

The demographic characteristics of female patients presenting to US EDs with wrestling-associated injuries

**Table 1.** Weighted national estimates of female patients presenting to United States emergency departments with wrestling-related Injuries, 2005-2019.

| Year | National case estimates | Standard error | 95% Confidence interval |
|---|---|---|---|
| 2019 | 3,404 | 558 | 2,296 - 4,513 |
| 2018 | 3,350 | 524 | 2,309 - 4,392 |
| 2017 | 3,014 | 419 | 2,182 - 3,846 |
| 2016 | 2,601 | 548 | 1,514 - 3,689 |
| 2015 | 2,178 | 453 | 1,279 - 3,078 |
| 2014 | 2,141 | 376 | 1,394 - 2,888 |
| 2013 | 1,291 | 293 | 710 - 1,873 |
| 2012 | 1,724 | 306 | 1,115 - 2,332 |
| 2011 | 1,279 | 315 | 655 - 1,904 |
| 2010 | 2,301 | 450 | 1,408 - 3,195 |
| 2009 | 1,428 | 259 | 914 - 1,942 |
| 2008 | 1,301 | 262 | 781 - 1,822 |
| 2007 | 1,473 | 243 | 991 - 1,955 |
| 2006 | 1,474 | 302 | 874 - 2,075 |
| 2005 | 1,500 | 291 | 923 - 2,078 |

between 2005–2019 are shown in Table 2. More than half of females sustaining wrestling-associated injuries were 14-18 years of age (50.1%; CI, 44.1-56.2%). The majority of female patients identified as White (51.4%; CI, 43.3-59.6%). Race was not specified for 25.4% (CI, 16.4-34.5%) of patients, and 98.7% (CI, 97.9-99.5%) of patients were treated and released from the ED.

Injury characteristics, including body parts affected and final diagnoses for patients 14-18 years of age, are stratified by patient gender and reported in Table 3. Males sustained significantly ($P = 0.018$) greater proportions of head and neck injuries (24.6%; CI, 23.2–26.0%) compared with females (18.5%; CI, 13.2- 23.9%). No other significant differences in affected body parts were demonstrated ($P > 0.05$). When comparing diagnoses, females sustained significantly ($P < 0.001$) greater proportions of sprains and strains (48.8%; CI, 41.2-56.3%) compared with males (34.4%; CI, 31.6-37.1%). In addition, males sustained significantly ($P = 0.003$) greater proportions of fractures (15.7%; CI, 14.7-16.7%) as compared with females (10.6%; CI, 7.5-13.7%).

Table 4 ranks the top five most common body parts affected in sprain or strain injuries among patients 14-18 years of age presenting to US EDs with wrestling-associated injuries during the study time period, stratified by patient gender. No significant differences ($P > 0.05$) were found in body parts sprained or strained between male and female wrestlers. The most commonly sprained or strained body part in both female (17.1%; CI, 12.8-21.5%) and male (20.3%; CI, 19.0-21.7%) wrestlers was the shoulder.

## DISCUSSION

Our findings demonstrate that female wrestling-associated injuries presenting to US EDs increased significantly over time. Recently, national estimates have more than doubled, rising from 1,500 in 2005 to 3,404 in 2019. Furthermore, the incidence of annual female wrestling-associated injuries is projected to be greater than 4,550 by 2030. To our knowledge, this is the first study on the prevalence and characteristics of female wrestling-associated injuries in the US. As the popularity of the sport continues to grow, an in-depth understanding of injury characteristics in female wrestlers will be integral to the development and implementation of risk minimization strategies in practice and competitions.

The most likely explanation for the significant and increasing trend of wrestling-associated injuries among female athletes in our study is rising participation, particularly at the high school level. According to the National Federation of State High School Associations (NFHS), 4,334 high school females in the US participated in wrestling during the 2004-

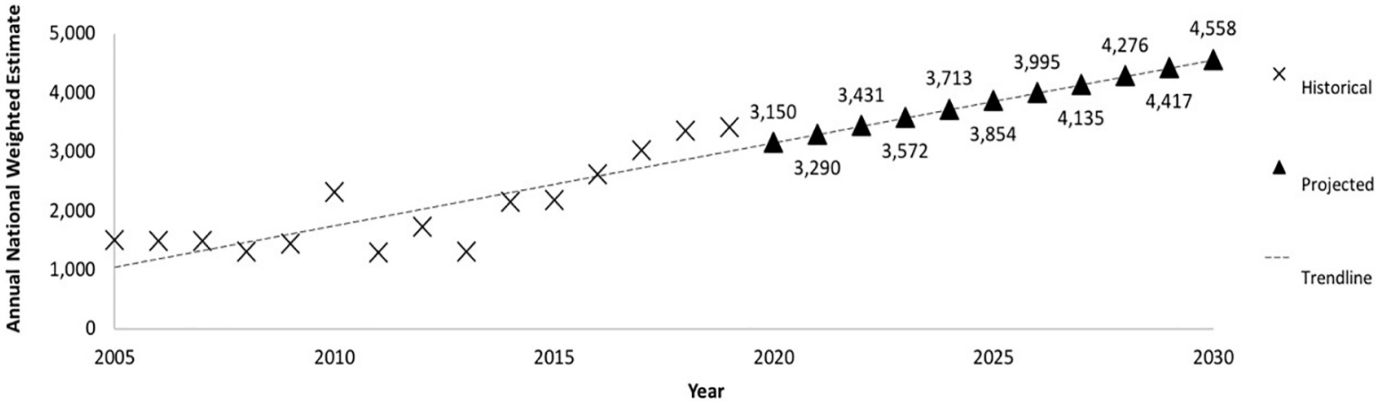


**Figure 1.** Historical and projected weighted national estimates of female patients presenting to US emergency departments with wrestling-associated injuries, 2005-2030.

**Table 2.** Demographic characteristics of female patients presenting to US emergency departments with wrestling-related injuries, 2005-2019.

| Demographic variable | Percentage | Standard error | 95% Confidence interval |
|---|---|---|---|
| Age (in years) | | | |
| ≤4[a] | 0.6% | | |
| 5 to 10 | 8.9% | 1.7% | 5.6% - 12.2% |
| 11 to 13 | 16.4% | 2.0% | 12.3% - 20.4% |
| 14 to 18 | 50.1% | 3.0% | 44.1% - 56.2% |
| 19 to 25 | 11.3% | 1.4% | 8.5% - 14.1% |
| ≥26 | 12.8% | 1.9% | 9.0% - 16.6% |
| Race | | | |
| White | 51.4% | 4.1% | 43.3% - 59.6% |
| Black | 10.9% | 1.9% | 7.2% - 14.7% |
| Hispanic | 7.0% | 1.4% | 4.2% - 9.8% |
| Other[a] | 5.2% | | |
| Race not specified | 25.4% | 4.6% | 16.4% - 34.5% |
| Disposition | | | |
| Treated and released | 98.7% | 0.4% | 97.9% - 99.5% |
| Treated and admitted[a] | 0.4% | | |

[a]The estimate is considered to be potentially unstable due to the number of unweighted cases from the sample frame totaling <20, the weighted national estimate totaling <1200, or coefficient of variation >33%. Therefore, no standard errors or confidence intervals are provided; the unstable percentage estimate is provided for reference purposes only. Variable results with sample frame totals <20 cases or percentages <0.1% were omitted from this table, resulting in percentage totals not necessarily summing to 100%.

2005 academic year.[14] The most recent NFHS participation survey estimated 21,134 females participated in high school wrestling during the 2018-2019 academic year.[3] This rise in participation is likely multifactorial, reflecting increased societal acceptance of female participation in a male-dominated sport and more opportunities for competition. Given that injury rates in wrestling are highest during competition as opposed to practice,[15] the overall risk of wrestling-associated injuries in female participants may be rising as they are afforded more opportunities to compete at higher levels.[3]

Wrestling-associated injuries have been well characterized in male participants. For instance, the study by Myers and colleagues used the NEISS database to characterize wrestling-associated injuries in all participants aged 7-17 years old between 2000–2006.[9] However, their analyses excluded female wresters because they only constituted 3.5% (5,998/173,604) of wrestling-related ED visits during the study period. Therefore, they were unable to report on any characteristics of wrestling-associated injuries in females. Nearly 15 years later, our analyses benefit from improved statistical power in order to compare and contrast wrestling-related injuries between male and female participants.

The vast majority (50.1%) of wrestling-related injuries in females occurred in high school-age athletes. Our comparisons reveal that female wrestlers in this age group were significantly less likely to sustain fractures than male wrestlers. Our supplemental analysis of all ages (Supplemental Table 1) found similar injury differences between males and females as the high school-age cohort, albeit a significantly higher rate of wrestling-related concussions by male athletes. Similar injury characteristics have been found in other sports, such as basketball and soccer: male participants generally suffer more fractures rather than strains/sprains compared with females.[16] In wrestlers, this may be due to males using more high-risk takedown techniques, which inherently increase the risk of sustaining more severe injuries.[3] In addition, female wrestlers were significantly more likely to sustain strains and sprains compared with male counterparts, which may be partly explained by differences in ligamentous strength and laxity. In general, females have more lax ligaments compared with males, allowing for greater flexibility.[17] However, this makes the ligaments more prone to sustaining more strain and thus becoming injured. The incidence of female high school athletes suffering ligamentous knee injuries that require surgery is nearly double their male counterparts, illustrating this effect.[18] Specifically in high school soccer, female athletes have been found to be up to 13.3 times more likely to suffer ligamentous knee injuries during competition that require surgery.[19] Females have also been found to have decreased hamstring to quadriceps ratios, predisposing them to ligamentous knee injuries.[20]

The higher propensity for both male and female wrestlers to sustain strains and sprains relative to other injury types

**Table 3.** Injury characteristics for patients 14-18 years of age presenting to US emergency departments with wrestling-related injuries between 2005 and 2019, stratified by the reported gender of the patient.

| | Female | | Male | | |
|---|---|---|---|---|---|
| Injury variable | % | 95% CI | % | 95% CI | P Value |
| Body Part | | | | | |
| Head & neck (Incl. face) | 18.5% | 13.2% - 23.9% | 24.6% | 23.2% - 26.0% | 0.018 |
| Shoulder | 16.7% | 12.4% - 20.9% | 14.9% | 13.9% - 15.9% | 0.430 |
| Knee | 10.4% | 6.8% - 14.0% | 10.3% | 9.6% - 11.1% | 0.975 |
| Elbow | 10.9% | 6.5% - 15.4% | 7.0% | 6.0% - 7.9% | 0.089 |
| Upper trunk | 9.8% | 5.9% - 13.7% | 8.1% | 7.2% - 9.1% | 0.396 |
| Lower arm[a] | 1.3% | | 2.6% | | |
| Lower trunk[a] | 4.2% | | 3.0% | | |
| Hand and wrist (Incl. fingers) | 12.0% | 7.9% - 16.2% | 12.2% | 11.0% - 13.5% | 0.931 |
| Foot and ankle (Incl. toes) | 11.5% | 7.4% - 15.7% | 9.0% | 8.3% - 9.8% | 0.218 |
| All other body parts[a] | 4.6% | | 8.4% | | |
| Diagnosis | | | | | |
| Strain sprain | 48.8% | 41.2% - 56.3% | 34.4% | 31.6% - 37.1% | <0.001 |
| Fracture | 10.6% | 7.5% - 13.7% | 15.7% | 14.7% - 16.7% | 0.003 |
| Pain | 13.2% | 8.5% - 17.8% | 9.7% | 5.6% - 13.8% | 0.154 |
| Contusions/abrasions | 11.5% | 7.3% - 15.7% | 12.3% | 11.3% - 13.3% | 0.712 |
| Concussion or CHI | 8.8% | 4.9% - 12.7% | 11.5% | 10.5% - 12.5% | 0.150 |
| Dislocation[a] | 4.6% | | 6.2% | | |
| Laceration[a] | 0.3% | | 5.6% | | |
| All Other Diagnoses[a] | 2.8% | | 5.0% | | |

[a]The estimate is considered to be potentially unstable due to the number of unweighted cases from the sample frame totaling <20, the weighted national estimate totaling <1200, or coefficient of variation >33%. Therefore, no standard errors or confidence intervals are provided; the unstable percentage estimate is provided for reference purposes only. Variable results with sample frame totals <20 cases or percentages <0.1% were omitted from this table, resulting in percentage totals not necessarily summing to 100%.
*CI,* confidence interval; *Incl,* including; *CHI,* closed head injuries including traumatic brain injuries.

underscores the need for more targeted training measures that help ensure muscles remain both strong and flexible. For instance, training programs that include strength, balance, plyometric, and agility exercises have been found to significantly reduce ankle sprains and anterior cruciate ligament tears among female athletes.[21,22] In addition, all injuries should be promptly reported to coaches, trainers, or team physicians so that proper care may be initiated expeditiously. Typically, it is recommended that first-degree strains be managed with rest, ice, compression, and elevation therapy, while second- and third-degree strains require evaluation by a physician. Inappropriate triaging or delays in management can aggravate injuries and predispose athletes to more severe diagnoses. Therefore, implementing these

**Table 4.** Top five most commonly sprained body parts in patients 14-18 years of age presenting to United States emergency departments with wrestling-related injuries between 2005-2019, stratified by the reported gender of the patient.

| | Female | | Male | | |
|---|---|---|---|---|---|
| Body part sprained or strained | % | 95% CI | % | 95% CI | P Value |
| Shoulder | 17.1% | 12.8% - 21.5% | 20.3% | 19.0% - 21.7% | 0.164 |
| Foot and ankle (Incl. toes) | 17.0% | 11.0% - 23.0% | 16.2% | 14.6% - 17.7% | 0.785 |
| Hand and wrist (Incl. fingers) | 16.6% | 12.0% - 21.2% | 15.1% | 13.4% - 16.8% | 0.564 |
| Knee | 15.5% | 10.4% - 20.6% | 16.1% | 14.8% - 17.5% | 0.803 |
| Head and neck (Incl. face) | 11.8% | 6.9% - 16.6% | 12.3% | 10.6% - 13.9% | 0.838 |

*CI,* confidence interval; *Incl,* including.

targeted interventions may help minimize the burden of strain- and sprain-related wrestling injuries while maximizing success on the mat.

Differences in injury characteristics between male and female wrestlers may also be explained by the number of athletic exposures. More skilled athletes typically stay on the mat longer in practice and competition, increasing their overall exposure to injury.[15,23] Furthermore, a study by Kordi and colleagues found that the risk for fractures and dislocations was positively correlated with years of wresting experience and age of sport initiation.[24] Thus, as more female athletes are exposed to wrestling at earlier ages, the overall injury characteristics may begin to more closely resemble those of males given the inevitable increase in practice, skill, and injury exposure that has been previously demonstrated in the literature.[2,15,23]

## LIMITATIONS

There are several limitations to this study that are associated with use of the NEISS database. First, the data only include injuries that presented to US EDs. Patients with less acute injuries may have first presented to urgent care or primary care offices. Therefore, our wrestling-associated injury estimates most likely underreport the true national burden of said injuries, instead emphasizing the most severe cases. Second, the database does not code for multiple injuries in a single ED encounter. In such situations, the NEISS survey only codes for the single most severe injury. Thus, multiple injuries suffered by a single participant would not be captured. Third, there may be differences in rules, regulations, and wrestling styles that vary on a state-by-state or national level that were not accounted for. At the scholastic level nationally, both males and females wrestle *folkstyle*, while collegiately males wrestle *folkstyle* and females switch to *freestyle*. We did not have the statistical power to analyze injuries in this specific demographic and thus did not make conclusions on any differences in injury characteristics due to wrestling styles.

Although the number of female wrestling-associated injuries in all participants and the 14-18 age group was large enough to undertake this epidemiologic study, statistical power was limited when evaluating more granular comparisons of injuries between males and females by body part, diagnosis, or age group. It is possible that true differences between the types of strains and sprains were not identified due to inadequate statistical power. Thus, our ability to make more specific training and injury prevention recommendations based on certain body parts or diagnosis was limited.

## CONCLUSION

We predict that the incidence of wrestling-associated injuries in female participants will increase significantly over the next decade as the popularity of the sport continues to rise. Wrestling is unique compared with many other sports at the scholastic level in that males and females practice and compete together. This is the first study that reports on the youth female wrestling injury profile, and demonstrates that females sustain more strains and sprains than males. Although wrestling carries an inherent risk of injury, prompt management of these injuries combined with specific training strategies aimed at preventing them may help to reduce the inevitable increase of wrestling-associated injuries among female and male athletes alike.

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# "I wanted to participate in my own care": Evaluation of a Patient Navigation Program

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**Introduction:** Patient navigation programs can help people overcome barriers to outpatient care. Patient experiences with these programs are not well understood. The goal of this study was to understand patient experiences and satisfaction with an emergency department (ED)-initiated patient navigation (ED-PN) intervention for US Medicaid-enrolled frequent ED users.

**Methods:** We conducted a mixed-methods evaluation of patient experiences and satisfaction with an ED-PN program for patients who visited the ED more than four times in the prior year. Participants were Medicaid-enrolled, English- or Spanish-speaking, New Haven-CT residents over the age of 18. Pre-post ED-PN intervention surveys and post-ED-PN individual interviews were conducted. We analyzed baseline and follow-up survey responses as proportions of total responses. Interviews were coded by multiple readers, and interview themes were identified by consensus.

**Results:** A total of 49 participants received ED-PN. Of those, 80% (39/49) completed the post-intervention survey. After receiving ED-PN, participants reported high satisfaction, fewer barriers to medical care, and increased confidence in their ability to coordinate and manage their medical care. Interviews were conducted until thematic saturation was reached. Four main themes emerged from 11 interviews: 1) PNs were perceived as effective navigators and advocates; 2) health-related social needs were frequent drivers of and barriers to healthcare; 3) primary care utilization depended on clinic accessibility and quality of relationships with providers and staff; and 4) the ED was viewed as providing convenient, comprehensive care for urgent needs.

**Conclusions:** Medicaid-enrolled frequent ED users receiving ED-PN had high satisfaction and reported improved ability to manage their health conditions. [West J Emerg Med. 2021;22(2):417-426.]

## INTRODUCTION

United States emergency department (ED) utilization has increased over the last three decades at a rate faster than the US population has grown.[1,2] Frequent ED users, defined as individuals with four or more ED visits in a one-year period, comprise 4.5-8% of all ED patients, yet account for 21-28% of all annual ED visits.[3] Frequent ED users are more likely to be older, have chronic illnesses, be Medicaid-insured, and have complex medical, behavioral health, and psychosocial needs.[3-7] Approximately 85% of ED visits among Medicaid-enrolled frequent ED users result in discharge home. Many of these visits could occur in a primary care setting, which

is more cost-effective and better for long-term patient outcomes.[8-10] However, Medicaid patients have greater difficulty scheduling outpatient appointments compared to privately insured patients[11] and encounter many barriers to accessing primary care, including lack of transportation and appointment availability.[6,8,12-14]

Patient navigation programs have been implemented across the US to help patients overcome barriers to accessing outpatient care.[15-17] These programs provide services navigation, education, and care coordination.[8] Many patient navigation programs have demonstrated success in reducing ED utilization and healthcare spending,[15,16,19-24] but few have examined patient acceptability, experiences, and satisfaction. Evaluating patient experiences is critical for understanding which aspects of these programs successfully engage and meet patients' needs. In this mixed-methods study, we evaluated patient perspectives, experiences, and satisfaction with an ED-initiated patient navigation (ED-PN) intervention for Medicaid-enrolled frequent ED users.[24]

*Population Health Research Capsule*

What do we already know about this issue?
*Patient navigation (PN) programs provide services navigation, education, and care coordination, resulting in reduced ED use, hospitalizations, and healthcare costs.*

What was the research question?
*What are patient perspectives, experiences, and satisfaction with an ED-initiated PN program?*

What was the major finding of the study?
*Participants were highly satisfied with ED-initiated PN and reported increased self-confidence managing their health.*

How does this improve population health?
*EDs can use patient navigation programs to support and improve the health of marginalized and medically complex patients.*

## METHODS

### Study Setting and Population

We recruited participants from the Yale New Haven Hospital (YNHH) ED, a large, urban, academic hospital in New Haven, CT, treating over 100,000 adult patients annually. New Haven has over 130,000 residents (33% Black, 32% White, and 27% Hispanic). Of this population, 48% live at or below 200% of the federal poverty level.[25] Twelve percent of Medicaid-enrolled YNHH ED patients are frequent ED users, accounting for 38% of all ED visits.[26]

### Participant Recruitment and Enrollment

Individuals were eligible for inclusion if they had the following characteristics: 18-62 years old; Medicaid-enrolled; English or Spanish speaking; residents of one of the twelve towns in the greater New Haven area; had 4-18 visits to a YNHH ED in the prior year; less than 50% of their prior year ED visits were for a psychiatric or substance use concern; and they were not being primarily treated for a psychiatric or substance use concern at the time of enrollment. We excluded from enrollment patients with frequent ED utilization for substance use disorders and behavioral health problems because they have additional and often complex clinical, behavioral, and social needs that the intervention was not designed or equipped to support.[24]

Participants were enrolled from March 2013–February 2014. After providing informed consent, they were randomized to either ED-PN or standard care using a previously generated, stratified randomization algorithm with a concealed sequence. Of the 100 individuals enrolled, 49 received the ED-PN intervention and 51 received standard care. The PNs were employed by Project Access-New Haven (PA-NH), a community-based non-profit that provides patient navigation to medical specialty services for people who are uninsured and Medicaid-enrolled.[27] Details about study enrollment and randomization can be found in previously published manuscripts.[6,24]

### Patient Navigation Intervention

Participants in the intervention arm received ED-PN for 12 months through PA-NH, a community-based nonprofit organization providing PN services for underserved Greater New Haven area residents.[27] The navigation team included a bilingual (English/Spanish) patient nagivator and a nurse navigator. Both completed a two-day intensive training at the Harold Freeman Institute for Patient Navigation on how to provide PN and address barriers to care.[28] Study navigators had supervision from a multidisciplinary team comprised of an emergency physician, a primary care physician, the PA-NH executive director, and a program coordinator. The study team met weekly, developed tailored plans for each participant, and provided direction on coordination of medical and social services.

The navigators scheduled post-ED primary care visits for each participant and offered accompaniment to up to three office visits. They met the participants prior to outpatient appointments to review their concerns and outline questions for the provider. Navigators encouraged participants to ask questions during the visit and helped create a post-visit task list based on the provider's recommendations. The patient navigators also scheduled visits for provider-recommended specialty care and ancillary services.

Navigators contacted participants by phone every two weeks during weeks 0-4 and every four weeks during weeks 13-52 to review participants' health and social needs. They also scheduled and reminded patients of medical appointments, addressed barriers to care, and provided referrals for social needs. Finally, navigators were available to answer participant questions and provide assistance as needed.

### Study Design

Participants completed a baseline questionnaire (via staff interview) at enrollment that included questions about demographics, health status/needs, healthcare utilization, and access/barriers to care. One-year post-enrollment and following completion of the ED-PN intervention, a research assistant not directly involved in PN conducted follow-up phone surveys to assess participant-reported healthcare utilization, access/barriers to care, and program satisfaction. Follow-up survey completion had no bearing on receipt of ED-PN. Survey questions included novel and validated questions to measure health literacy,[29,30] healthcare utilization,[31] health status,[32] and self-efficacy for managing chronic diseases[33] (Appendix A). Surveys were piloted with patient navigators for comprehension and lasted approximately 15-30 minutes. Responses were collected using a web-based platform (Qualtrics XM, Provo, UT). Respondents received a $25 gift card for participation.

Upon completion of the follow-up survey, English-speaking ED-PN participants were invited to participate in a qualitative interview about the PN program. The study team developed the interview guide, which was reviewed by patient navigators for understandability and iteratively revised (Appendix B). The interviewer had not previously interacted with any of the participants. Audiorecorded interviews were approximately 45-60 minutes in length and transcribed verbatim. Interviews were conducted until thematic saturation was reached. Participants received a $50 gift card for completing the interview. Interview and follow-up survey completion occurred following completion of ED-PN intervention. Participants were informed that participation in these assessments had no bearing on current or future services received. This study was approved by the Yale University Institutional Review Board.

## ANALYSIS

### Patient Surveys

We analyzed baseline and follow-up survey responses as proportions of total responses. The datasets analysed are available from the corresponding author on reasonable request.

### Patient Interview.

The coding structure and categories followed the topical framework of the interview guide and were iteratively refined through group discussion. The coding classification scheme was finalized by consensus and applied to each transcript by at least two independent reviewers. Any coding discrepancies or ambiguities were resolved through discussion. Codes were applied to each transcript using ATLAS.ti version 5.2 (ATLAS.ti, Berlin, Germany). The study team reached consensus on a final thematic framework and identified illustrative quotes that represented the responses relevant to each theme.

## RESULTS

### Survey Results

Forty-nine participants received ED-PN. Over half were female (67%), nearly half (47%) were Black, most spoke English (86%), and over half (57%) worked at least part time (Table 1). Over half (65%) reported fair to poor health at baseline and most (86%) had at least one chronic health condition. At baseline, 48% reported not being able to get outpatient appointments as soon as needed and 70% reported receiving most of their healthcare in the ED (Table 2). Of the ED-PN participants, 80% (39/49) completed the post ED-PN survey (Table 3). After receiving ED-PN, participants were more likely to report "usually" or "always" getting medical appointments as soon as needed (94% vs 53%) and having their medical questions answered the same day (96% vs 50%). Participants also reported decreased use of the ED as their primary site of care (30% vs.70%), fewer barriers to care, and increased confidence in their ability to coordinate their own care and self-manage their medical conditions (Table 3).

Participants reported high overall satisfaction and identified assistance with scheduling appointments, appointment reminders, follow-up calls, and having someone to talk to about their health as the most helpful navigation services (Figure, Panels A and B). Participant reported satisfaction with ED-PN services was high. All participants reported being overall satisfied with ED-PN, and 89.7% (35/39) reported being very satisfied. The majority (87.2%, 34/39) also reported being very satisfied with how long they had to wait for a medical appointment. Most (87.2%, 34/39) reported that it was easy to follow treatment advice after getting ED-PN and easy to get care (76.9%, 30/39). After receiving ED-PN, most thought their ability to get care had improved (84.6%, 33/39).

### Interview Results

We conducted 11 interviews. Compared to the ED-PN group, most interviewed participants (n = 11) were female (82% vs 67%) and Black (55% vs 47%) and fewer had full-time employment (9% vs 18%). Interviewees were otherwise similar to the overall ED-PN group in their sociodemographic characteristics and reported health (Tables 1 and 2). Four main themes emerged: 1) Patient nagivators were perceived as effective healthcare coordinators and advocates who provided continuity and individualized support (Theme 1); 2) health-related social needs were frequent drivers of and barriers to healthcare utilization that required PN assistance (Theme 2); 3) primary care utilization

**Table 1.** Demographics of all participants receiving emergency department patient navigation and individuals interviewed.

| | All navigation recipients (n=49) N(%) | Interviewees (n=11) N(%) |
|---|---|---|
| Gender | | |
| Female | 33 (67) | 9 (82) |
| Age (mean years) | 40.2 | 37.1 |
| Race/ethnicity | | |
| Hispanic/Latino | 19 (39) | 3 (27) |
| Non-Hispanic, Black | 23 (47) | 6 (55) |
| Non-Hispanic, White | 5 (10) | 1 (9) |
| Non-Hispanic, American Indian/Alaska Native | 1 (2) | 1 (9) |
| Non-Hispanic, Other | 1 (2) | 0 (0) |
| Primary language | | |
| English | 42 (86) | 10 (91) |
| Spanish | 7 (14) | 1 (9) |
| Marital status | | |
| Never married | 21 (43) | 5 (45) |
| Married/civil union/living with partner | 12 (24) | 2 (18) |
| Separated/divorced/widowed | 16 (33) | 4 (36) |
| Education | | |
| Elementary/grade school | 5 (10) | 0 (0) |
| Some high school | 6 (12) | 1 (9) |
| High school/GED | 18 (37) | 5 (45) |
| Some college (no degree) | 14 (29) | 4 (36) |
| Associate's/Bachelor's Degree | 6 (12) | 1 (9) |

*GED,* General Educational Development exam.

depended on clinic accessibility and quality of interpersonal relationships with providers and staff (Theme 3); and 4) participants characterized the ED as providing convenient, comprehensive care for urgent needs and filling gaps in primary care access (Theme 4)(see Supplemental Table).

*Theme 1: Patient navigators perceived as effective healthcare coordinators and patient advocates who provided continuity and individualized support.*

Participants provided unanimously positive feedback about PN support. Many described feeling relieved about finally receiving the assistance they felt they needed. One participant observed, "You feel like nobody elsewhere is helping you and they're there to help… I was at my wit's end when [the PN] came to me. I was so fed up." (Participant 5)

Strong PN-patient relationships were consistently cited as a key program component. One participant described their relationship with the patient navigator as, "Wonderful… I felt that they cared, they really cared, not just about me, but actually me." (Participant 10) Participants linked this directly to the development of self-worth and trust. PN services were viewed as non-judgmental, unconditional, and made participants feel comfortable. "They made me feel like, 'This is my hand extended out to you, whether you want it or you don't.' They didn't make me feel bad, they made me feel comfortable." (Participant 8)

Patient navigators also educated participants about healthcare utilization and what to expect from healthcare visits. Some participants said this allowed them to "[Know] my rights a little bit more." (Participant 6) Drawing from PN education and support, participants described developing improved self-efficacy navigating the healthcare system. One participant reported feeling, "More comfortable to go back to my primary care doctor and say 'Hey, you're my primary care doctor, you're supposed to be the one to see me and give me care'… I felt stronger… I felt empowered to make an appointment." (Participant 6) The participant continued: "Within a year, I was able to… go to the primary care doctor, go to the dentist. I was able to get going, I became familiar. I was driven, I … wanted to participate in my own care." (Participant 6)

Participants described developing very strong bonds and trust with their patient navigators and indicated that they made a noticeable difference in their lives. One participant described, "If it wasn't for [the PN] I'm telling

**Table 2.** Social, economic, and health characteristics of participants receiving emergency department patient navigation and individuals interviewed.

| | All navigation recipients (n=49) N (%) | Interviewees (n=11) N (%) |
|---|---|---|
| Food insecurity (not enough food/money to buy food in past 30 days) | | |
| Never | 21 (43) | 4 (36) |
| Sometimes | 21 (43) | 6 (55) |
| Often | 7 (14) | 1 (9) |
| Housing instability | | |
| Did not spend last 7 days in own place | 10 (20) | 3 (27) |
| Homeless in past year (≥1x) | 6 (12) | 1 (9) |
| Health literacy | | |
| Mean REALM score (scale: 0-7) | 5.0 | 5.2 |
| Low health literacy (REALM score <=6), N(%) | 33 (67) | 6 (55) |
| Health status (self-report) | | |
| Poor | 11 (22) | 3 (27) |
| Fair | 21 (43) | 5 (45) |
| Good | 9 (18) | 2 (18) |
| Very good | 4 (8) | 0 (0) |
| Excellent | 4 (8) | 1 (9) |
| Healthy days measure (mean days) | | |
| Poor physical or mental health (N days in last 30 days) | 21.0 | 19.2 |
| Unable to do usual daily activities (N days in last days) | 11.5 | 13.2 |
| Chronic conditions (self-reported) | | |
| Hypertension | 21 (43) | 4 (36) |
| High cholesterol | 11 (22) | 2 (18) |
| Coronary heart disease | 3 (6) | 1 (9) |
| Congestive heart failure | 3 (6) | 1 (9) |
| Heart attack | 2 (4) | 1 (9) |
| Asthma | 22 (45) | 4 (36) |
| Diabetes | 14 (29) | 2 (18) |
| Chronic lung disease/COPD | 2 (4) | 1 (9) |
| Depression | 27 (55) | 5 (45) |
| Anxiety | 22 (45) | 5 (45) |
| Other mental illness | 5 (10) | 2 (18) |
| Cancer | 3 (6) | 0 (0) |
| Stroke | 2 (4) | 1 (9) |
| At least one of the above chronic conditions | 42 (86) | 8 (73) |

*REALM,* Rapid Estimate of Adult Literacy in Medicine; *COPD,* chronic obstructive pulmonary disease.

you; I wouldn't have been at none of these appointments. If it wasn't for [the PN] checking on me, calling me, asking 'did you do this, did you do that,' I really was lost." (Participant 8)

*Theme 2: Navigators helped patients address health-related social needs that were drivers and barriers to healthcare utilization.*

Social, economic, and personal considerations were common factors that impacted participants' healthcare utilization. Several participants commented that navigators helped them prioritize their health and healthcare appointments despite social barriers and competing concerns. One noted, "[The PNs] helped out because when I have so many things on my mind, like … my daughter and her homework, or me trying to find the, not the right job, but

**Table 3.** Participant-reported ability to get appointments and answers to medical questions, barriers to care, and ability to coordinate and manage their medical conditions before and after receiving emergency department patient navigation.

| | All Navigation Recipients (n=49) | | Interviewees* (n=11) | |
|---|---|---|---|---|
| | PRE (n=49) N (%) | POST (n=39) N (%) | PRE (n=11) N (%) | POST (n=9) N (%) |
| Appointments as soon as needed (past 12 months) | | | | |
| Never | 10 (24) | 1 (3) | 5 (45) | 0 (0) |
| Sometimes | 10 (24) | 1 (3) | 2 (18) | 0 (0) |
| Usually | 7 (17) | 4 (11) | 0 (0) | 1 (11) |
| Always | 15 (36) | 30 (83) | 4 (36) | 8 (89) |
| Medical questions answered same day, regular business hours (past 12 months) | | | | |
| Never | 9 (26) | 0 (0) | 3 (30) | 0 (0) |
| Sometimes | 8 (24) | 1 (4) | 3 (30) | 0 (0) |
| Usually | 5 (15) | 3 (13) | 1 (10) | 0 (0) |
| Always | 12 (35) | 19 (83) | 3 (30) | 8 (100) |
| Barriers to care | | | | |
| Cost | 20 (41) | 5 (13) | 1 (9) | 1 (11) |
| Transportation | 32 (65) | 16 (41) | 9 (82) | 5 (56) |
| Work schedule | 12 (24) | 6 (15) | 2 (18) | 3 (33) |
| Childcare | 9 (18) | 4 (10) | 2 (18) | 1 (11) |
| Unsure where/how to get care | 20 (41) | 3 (8) | 4 (36) | 1 (11) |
| Hard to find Medicaid providers | 18 (37) | 8 (21) | 6 (55) | 3 (33) |
| Difficulty getting appointments soon enough | 28 (57) | 10 (26) | 5 (45) | 2 (22) |
| Difficulty communicating with providers | 6 (12) | 1 (3) | 2 (18) | 1 (11) |
| Difficulty understanding medical infor-mation | 17 (35) | 2 (5) | 4 (36) | 1 (11) |
| Difficulty filling prescription medications | 10 (20) | 3 (8) | 2 (18) | 1 (11) |
| Unhappy with past experience with provider | 17 (35) | 7 (18) | 5 (45) | 2 (22) |
| Prefer to treat self | 12 (24) | 0 (0) | 1 (9) | 0 (0) |
| Disability | 8 (16) | 1 (3) | 2 (18) | 1 (11) |
| None | 3 (6) | 10 (26) | 0 (0) | 1 (11) |
| Prepared to coordinate own care | | | | |
| Not at all prepared | 10 (20) | 2 (5) | 3 (27) | 2 (22) |
| Mostly not prepared | 5 (10) | 5 (13) | 2 (18) | 0 (0) |
| Somewhat prepared | 19 (39) | 16 (41) | 4 (36) | 6 (67) |
| Very prepared | 15 (31) | 16 (41) | 2 (18) | 1 (11) |
| Confidence in Self-Management of Medical Condition(s) (1=Not at all confident – 10 = Totally confident) | | | | |
| Mean | 6.61 | 7.74 | 6.00 | 6.78 |

*All interviews occurred after receiving emergency department patient navigation. Results here are interviewee responses to the pre- and post-survey conducted before and after receiving emergency department patient navigation.

the most beneficial employment... Is there food in the house, does she have the right shoes, this and that…So, for you to call me and remind me [to go to my appointments], that's a beautiful thing." (Participant 4)

Transportation, caregiver responsibilities, and housing were commonly cited barriers to accessing primary care. Patient navigators frequently assisted with transportation. One individual noted: "for bus passes you got to call seven days before and sometimes it'd come the day after my appointment, but if I called [the PN], they'd get right on that phone, call transportation and they'd send me a taxi that morning for my appointment." (Participant 10)

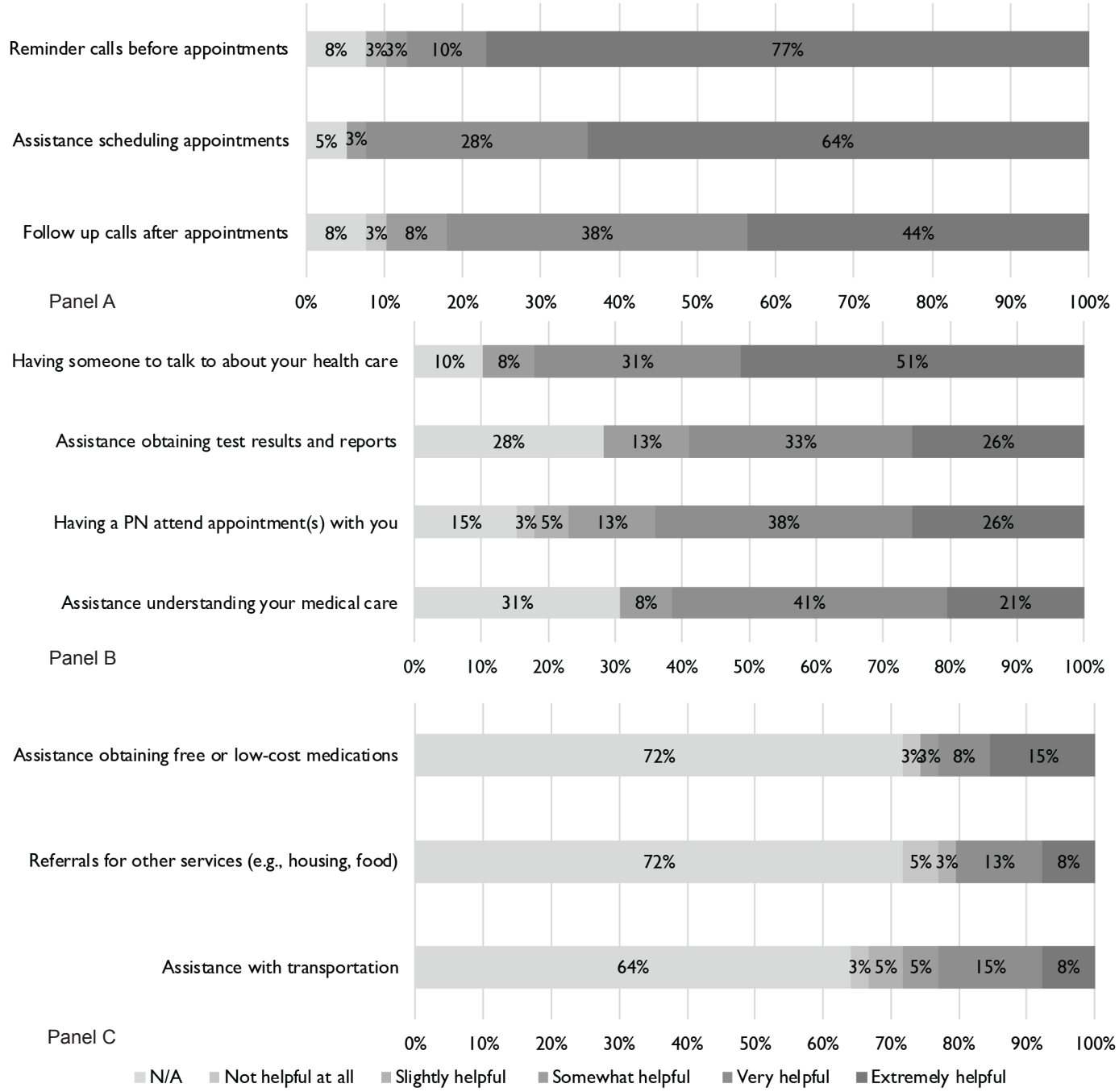


**Figure.** Helpfulness of Navigation Components. Participant reported helpfulness of patient navigation services including assistance with appointment scheduling and reminder calls (Panel A), health system navigation (Panel B), and health-related social needs (Panel C). Responses are reported as proportions of total responses in categories of NA, Not helpful at all, Slightly Helpful, Somewhat Helpful, Very Helpful, and Extremely Helpful.
*PN,* Patient navigator.

A number of participants experienced major life events, such as incarceration of family members or family health problems, that impacted their health, further demonstrating that additional support is be needed beyond the scope of the PN program. In such situations, navigators directed patients to local resources and provided emotional support. While most participants did not report receiving assistance with health-related social needs (Figure, Panel C), participants who did use these services reported positive experiences. However, the ED-PN intervention was not designed for comprehensive navigation to address these needs. During the course of the study, staff often noted feeling limited in their ability to address health-related social needs, particularly housing.

*Theme 3: Primary care utilization was driven by clinic accessibility and quality of interpersonal relationships*

Appointment availability, interactions with clinic providers and staff, and perceived care quality, thoroughness, and continuity were commonly mentioned factors impacting primary care utilization. Provider continuity and familiarity with one's past medical history cultivated trust and comfort. However, many participants who received care at the primary care resident clinic connected their decreased clinic utilization to their dissatisfaction with the clinic stemming from lack of trust in providers, feeling rushed during appointments, and lack of confidence in the quality of clinic care.

The high volume of patients at the primary care clinic and perceived lack of organization were viewed as compromising patient care. Explained one participant, "With the primary care clinic, is for one they are overpopulated. They're not able to assess each patient the way that they should…It's always hectic… when you walk into the clinic, you can just feel the energy of people waiting for two and three hours to be seen by a doctor. It's no organization in the waiting room. It's a mess. The clinic is a mess." (Participant 6)

Participants were also frustrated with lack of provider consistency at the primary care resident clinic. One participant explained, "You don't want to keep seeing different people. You want to see the same person…You're always bounced around to different people where you'd have to explain your whole story to because they don't know you. So, there goes your 15 minutes right there." (Participant 5)

Several patients commented that PN accompaniment to primary care provider visit(s) was beneficial and improved their overall experience of care. One noted: "[The PN] helped me realize you're paying for this; you have the right to ask questions… and that helped me out a lot." (Participant 8) Another participant described being treated differently when the PN attended her appointment: "They were all so nice, never happened before… I don't know if they're intimidated... because she was a woman with a badge, dressed up nice, paperwork folders... I was treated perfect." (Participant 5)

*Theme 4: Emergency department provides convenient, comprehensive care for urgent needs and fills gaps in primary care access*.

Most participants used the ED to fill gaps in primary care and described the ED as a convenient place to obtain comprehensive care for urgent needs. When weighing options for where to seek care, patients frequently viewed the ED as the only available option for urgent needs. Said one participant, "I just said, 'Forget about [making an appointment].' I couldn't take the pain anymore. So, I ended up in the emergency room." (Participant 1)

Illness acuity in combination with other issues, particularly limited transportation, also brought people to use the ED. Inability to get a timely appointment was frequently mentioned as a reason to use the ED. "When I tried to call the primary care center, they weren't available the way I needed them to be available," said one participant. She continued, "If I felt there was something important and medically urgent and to them it wasn't, I wanted it that same day and they would do three, four days later and I felt to myself it was important, I would just go straight to the ED." (Participant 5) Waiting to be seen in the ED was not viewed positively, but not necessarily a deterrent given perceived or actual inability to get timely primary care appointments. Described one participant, "It's normal to be a long wait [at the ED]. I don't bash that. Sometimes it's agitating but there are so many people like me out there that can't get help at primary care doctors and physicians that they get so packed." (Participant 5)

After the program, several participants recognized the benefits of using primary care for comprehensive care and the ED for discrete problems. One participant described, "If you go to the primary care it's like you're having an appointment, they can check everything that you think could possibly be wrong with you at this point in time. But when you go to the ER, you're treated for whatever you came there for. Like I broke my foot, but I have a cough, they're gonna treat your foot, but not the cough." (Participant 12)

Some participants reported continuing to use the ED after the ED-PN intervention when they were acutely ill, unable to get a primary care appointment, or due to hours of operation. A few participants noted that they preferred the convenience and perceived comprehensiveness of ED care. They also acknowledged that being seen in the ED could also expedite access to outpatient care. One participant described, "And you know, [ED providers] will get things going… I know that once I get in the back, once I tell them what is going on, they will do a CT scan, they will do x-rays, they will do all the emergencies that could be going on with me and refer me to my doctor and then I'll get an appointment to my primary care sooner." (Participant 6)

## DISCUSSION

In this mixed methods evaluation, Medicaid-enrolled frequent ED users were highly satisfied with the ED-PN intervention and reported increased healthcare access and self-confidence in managing their health conditions. Our findings underscore the value of navigation services to patients beyond traditional healthcare utilization and cost metrics. Participants in our study described many social factors that affected their ability to attain and maintain adequate health and access to primary care including transportation, difficulty scheduling time off from work, and problems with insurance. Given the importance and frequency of these factors in people's lives and their impact on healthcare utilization, future navigator programs need to prioritize addressing unmet social needs, help that is not traditionally given in the healthcare system. Participants noted that they needed additional help with health-related social needs, and staff reported feeling limited in their ability to address these issues. Further studies are needed to understand how best to assess and

address health related social needs and to identify needs specific to different patient groups, particularly people who do not speak English and were not included in study interviews.

Key factors driving decisions of where to seek healthcare included quality of relationships with primary care providers, appointment availability, and time spent with providers. Participants reported a significant decrease in ED utilization, which is consistent with objective findings from prior program evaluations that demonstrated reduced ED utilization and hospitalizations among people receiving PN and overall cost savings for participants who were older and had lower health literacy.[24] Despite these changes, several participants felt they had better relationships with the ED, where their history was readily accessible in the electronic health record and they would spend several more hours at a time interacting with caregivers, than with their primary care offices.

There was an overwhelming perception that the ratio of time spent making and waiting for the appointment vs time spent in the appointment was out of proportion. In the ED, on the other hand, despite long wait times, patients felt assured that they would receive a thorough workup. In addition, once in the ED, they were able to receive additional services without delay (eg, specialty consults, diagnostic tests) rather than making future appointments that might require long wait times for appointments, transportation challenges, time off from work, and childcare issues. These findings are consistent with previous studies that have evaluated the impact of these factors, often referred to as opportunity costs on healthcare utilization.[34] The ED with 24/7/365 day availability is a convenient site of care that people can access when these costs (time off work, childcare, transportation) can be minimized. This further underscores the need for a patient-centered health system that lowers barriers to preventative and primary care by minimizing patients' opportunity costs when accessing healthcare.[17,34]

## LIMITATIONS

This study has several limitations. Study participants were Medicaid-enrollees residing in and aroundNew Haven, CT and may have had specific needs not necessarily generalizable to different populations, rural areas, or smaller EDs. However, this study was designed for hypothesis generation regarding patient perspectives on PN programs. Interviewees varied slightly by gender, race, and employment status compared to non-interviewees and may have had different degrees of unmet social needs compared to the larger intervention group. Due to the small study sample and the fact that interview participation was optional, results may be subject to selection bias resulting in an increase in positive reported experiences with the PN program. Additionally, we did not interview those patients from the study control arm who primarily spoke Spanish, or those we could not reach by phone after study completion; these participants may have expressed different views. However, the types of barriers that interviews described, and the four thematic domains that emerged are comparable to findings from similar research.[14]

## CONCLUSION

This study provides a deeper understanding of patient-oriented outcomes associated with patient navigation programs in addition to traditional metrics evaluated by other programs.[17] Our findings suggest additional factors – the relationship between the navigator and clients, having a person in the healthcare system whom participants felt they could rely on and trust, and addressing health-related social needs – were highly valued by participants. This further supports the importance of tailoring navigation services to each individual. While improved healthcare utilization and patient satisfaction are important outcomes, future investigations are needed to understand how to optimize navigation programs to provide sustained support over time and improve self-reported health and quality of life. Future cost analyses of patient navigation programs that take into account program cost and changes in hospitalizations and medical complications can further assess the value of these programs.

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# Central Venous Catheter Adverse Events Are not Associated with Crowding Indicators

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**Objective:** Crowding in the emergency department (ED) impacts a number of important quality and safety metrics. We studied ED crowding measures associated with adverse events (AE) resulting from central venous catheters (CVC) inserted in the ED, as well as the relationship between crowding and the frequency of CVC insertions in an ED cohort admitted to the intensive care unit (ICU).

**Methods:** We conducted a retrospective observational study from 2008–2010 in an academic tertiary care center. Participants undergoing CVC in the ED or admitted to an ICU were categorized by quartile based on the following: National Emergency Department Overcrowding Scale (NEDOCS); waiting room patients (WR); ED patients awaiting inpatient beds (boarders); and ED occupancy (EDO). Main outcomes were the occurrence of an AE during CVC insertion in the ED, and deferred procedures assessed by frequency of CVC insertions in ED patients admitted to the ICU.

**Results:** Of 2,284 ED patients who had a CVC inserted, 293 (13%) suffered an AE. There was no association between AEs from ED CVCs and crowding scales when comparing the highest crowding level or quartile to all other quartiles: NEDOCS (dangerous crowding [13.1%] vs other levels [13.0%], P = 0.98); number of WR patients (14.0% vs 12.7%, P = 0.81); EDO (13.0% vs 12.9%, P = 0.99); and number of boarding patients (12.0% vs 13.3%), P = 0.21). In a cohort of ED patients admitted to the ICU, there was no association between CVC placement rates in the ED and crowding scales comparing the highest vs all other quartiles: NEDOCS (dangerous crowding 16% vs all others 16%, P = 0.97); WR patients (16% vs 16%, P = 0.82), EDO (15% vs. 17%, P = 0.15); and number of boarding patients (17% vs 16%, P = 0.08).

**Conclusion:** In a large, academic tertiary-care center, frequency of CVC insertion in the ED and related AEs were not associated with measures of crowding. These findings add to the evidence that the negative effects of crowding, which impact all ED patients and measures of ED performance, are less likely to impair the delivery of prioritized time-critical interventions. [West J Emerg Med. 2021;22(2)427-434.]

## INTRODUCTION

Emergency department (ED) crowding is defined as the environment in which local demand for emergency care outpaces available resources. Crowding is associated with delays in care and poor outcomes. Crowded EDs delay antibiotic and analgesic delivery. Crowding delays damage

control resuscitation in major trauma; additionally, patients admitted on days with greater ambulance diversion, a measure of high ED crowding, experience increased hospital lengths of stay, costs, and mortality.[1-8] Conceptually, crowding can cause providers to deliver hurried care and miss critical steps during complex procedures.[9]

Placement of a CVC is a complex, multi-step procedure that requires equipment, operator assistance, and time to complete. Ultrasound guidance, training, and patient comorbidities all influence success or failure of CVC placement; however, the role that crowding may play on procedure success is not known. Describing the association between crowding and the safety of CVC insertion in the ED is important because this impacts decision-making related to staffing, guidelines, and equipment. We hypothesized that the effects of crowding may impact emergency physician (EP) performance during CVC placement or may prompt EPs to defer the procedure to downstream providers. Therefore, the objective of this study was to examine the association between measures of crowding and frequency of AEs during CVC insertion in the ED and study the relationship between crowding and the frequency of CVC insertion among ED patients admitted to the ICU.

*Population Health Research Capsule*

What do we already know about this issue?
*High levels of Emergency Department (ED) crowding delay ED operations and increase hospital length of stay, cost of care, and patient mortality.*

What was the research question?
*Does high-crowding increase the rate of complications from central venous catheters inserted in the ED?*

What was the major finding of the study?
*We found no association between crowding and adverse events stemming from ED central venous catheter insertions.*

How does this improve population health?
*The negative impact of crowding does not impair the delivery and outcome of time-critical procedures, but will affect ED performance and patients in other ways.*

## METHODS

### Study Setting and Population

We conducted a retrospective observational study from March 7, 2007–July 31, 2010 from an urban academic adult-only ED Level I trauma center with an annual census of 95,000 visits. Any subject older than 18 years of age who underwent CVC placement in the ED was eligible for the study. To estimate whether ED CVC placement was deferred, we included for analysis a second sample of patients admitted from the ED to any intensive care unit (ICU) of the hospital during the identical time frame. In this second subset of patients destined for ICU admission, subjects were identified as recipient or non-recipient of a CVC placed in the ED. The study was approved by the Human Research Protection Office (HRPO) of Washington University School of Medicine.

### Study Protocol and Measurements

To obtain data on CVC inserted in the ED, we created a standardized and partly auto-populated procedure note in our electronic health record (EHR). This included details about the time CVC insertion took place, its anatomic location, the method of insertion, use of ultrasound, operator, and any immediate adverse events (AE). We held quarterly educational sessions during the first year of standardized note implementation that included the definitions of AEs and their documentation. This was followed with an audit and feedback process to ensure data capture and fidelity. Operator skill was based upon the number of CVCs performed during the operator's career, which was initially self-reported and then updated based on our database. We grouped skill level as 20 or fewer, 20-50, and more than 50 CVCs performed. We abstracted patient level data including age and diagnoses from the health record as assigned by the EP at the time of the visit.

The Division's Information Technology node collected data independently to describe operational data. We queried our research copy of the ED EHR for data elements needed to estimate the level of crowding at the time of CVC placement. This dataset receives and stores updates at 15-minute intervals throughout the day. We collected information on the number of patients in the waiting room (WR), the number of admitted patients in the ED awaiting inpatient beds or "boarders," and ED occupancy (EDO) because these measures of crowding have been linked to the quality of care or have been validated.[2,10] EDO was defined as the total number of patients in the ED divided by the total number of ED beds. Visit data were also used to generate a National Emergency Department Overcrowding Scale (NEDOCS) score that uses several operational variables to categorize different levels of crowding ranging from "not busy, 0-20"; "busy, 21-60"; "extremely busy but not overcrowded, 61-100"; "overcrowded; 101-140", "severely overcrowded; 141-180"; and "dangerously overcrowded >180."[11]

We hypothesized that EPs may also defer CVC placement in the ED during moments of high crowding. To obtain data regarding this possibility, we created a separate dataset of ED patients admitted to any hospital ICU during the same months of our original data set. Patients in the ICU present

with greater comorbidity and greater intensity of illness and are most likely to require ED CVC insertion.[12-14] Admission to the ICU was defined according to the documented destination in the EHR. In this dataset we determined CVC insertion by procedure notes collected as described above, and we collected measures of crowding in the same manner.

**Outcome Measures**

Our primary outcome was AEs attributed to CVCs inserted in the ED. AEs were defined as a failed first-pass attempt ultimately requiring a secondary attempt (rescue); unsuccessful insertion (procedure aborted); bleeding; hematoma; arterial puncture; and pneumothorax. Pneumothoraces were identified immediately after insertions of catheters to the chest and neck by chest radiograph (CXR). Trained research assistants, blinded to the main outcome of the study, also performed a retrospective review of serial CXRs for 48 hours post insertion to identify latent pneumothorax not identified in the ED. Training consisted of primary investigator educational sessions. Reviewers were blinded to the main outcome of the study. A small subset of records was oversampled to determine inter-rater reliability.

Secondary outcomes included the association between ultrasound utilization, level of operator performing the procedure, central line-associated blood stream infections (CLABSI) attributed to ED CVC placement and their association to levels of crowding. The number of ED CLABSIs was obtained from infection control. This data was limited to 28 months of the total 41-month study (March 7, 2008–June 1, 2010) and is reported separately.

Lastly, we measured the frequency of CVCs placed in the ED among a subset of all ED patients admitted to the ICU. The frequency of ED CVC in this subset was compared to different levels of crowding to examine the possibility that EPs may defer the procedure in the ED during busier times.

**Statistical Analysis**

We hypothesized that AEs would occur with more frequency in dangerous or severe crowding conditions according to the NEDOCS score compared to all other levels of crowding. We determined we would need to collect 2200 ED CVC insertions to achieve 80% power to observe a 5% difference in AEs during these levels of crowding.[15,16]

Parametric data are presented as means ± standard deviations (SD), and non-parametric data are expressed as interquartile ranges (IQR). Waiting room patients and boarders were categorized by quartiles and assessed by highest quartile vs the lowest quartiles, as well as highest compared to all others.[1] ED occupancy (percentage of overall ED beds filled) was categorized as all beds occupied vs any open beds. We analyzed the NEDOCS score by a five-category analysis consisting of the standard NEDOCS categorization with the lowest two rankings combined and by categorizing the top two NEDOCS scores (severe or dangerous crowding) vs the remaining lower scores.[17,18] We used *R,* v 3.6.2 (*R* Foundation, Vienna, Austria) to perform chi-square and Fisher's exact tests to assess the differences between groups of categorical data. We used logistic regression to control for variables previously demonstrated to affect AE rates when evaluating potential relationships with measures of crowding including renal failure, physician experience, and ultrasound guidance. We used the le Cessie-vanHouwelingen-Copas-Hosmer unweighted sum of squares to test for global goodness of fit (GoF).

**RESULTS**

During the study period 2284 subjects underwent CVC in the ED. The mean age was 59 years (±24 years). Emergency department diagnoses at the time of admission were as follows: infectious 728 (32%); metabolic 311 (14%); cardiac 299 (13%); trauma 177 (8%); and other 769 (34%), The mean ED NEDOCS score was 117.6 (SD ± 43.9) (crowded), and the mean number of WR patients was 15 (SD ± 11.5). The mean number of patients awaiting beds (number of boarding patients) was 9 (SD ± 5) and the EDO median was 100% (IQR = 91% - 100%). The least experienced operators placed 608 CVCs (27%) while the most experienced placed 568 CVCs (25%). Operators used ultrasound assistance to place CVCs in 1392 (61%) insertions. Adverse events occurred in 297 (13%) attempts (Table 1). The most common AE was failed first-pass attempt requiring rescue.

The ED was dangerously crowded during 30.4% of CVC insertions. A total of 91 (13.1%) AEs occurred while the ED was dangerously crowded compared to 206 (13.0%), *P* = 0.98, at all other levels of crowding. The number of AEs during CVC insertion when the WR was most full was 68 (14.0%) compared to 219 (12.7%), P = 0.81, during all other times. The number of AEs during highest EDO was 202 (13.0%) compared to 95 (12.9%), P = 1.00, at all other times. When the ED held the greatest number of boarded patients the number of AEs during CVC insertion in the ED was 60 (12.0%) compared to 236 (13.3%), *P* = 0.21, when the ED

**Table 1.** Adverse event during emergency department central venous cannulation by type.

| | Adverse Event | | No Adverse Event | |
|---|---|---|---|---|
| | n | (%) | n | (%) |
| All adverse events | 293 | (13) | 1,991 | (87.1) |
| Adverse event by type | | | | |
| Failed first-pass attempt requiring rescue | 224 | (9.8) | 2,060 | (90.2) |
| Aborted procedure | 3 | (.1) | 2,281 | (99.9) |
| Hematoma | 38 | (1.7) | 2,246 | (98.3) |
| Arterial puncture | 15 | (.7) | 2,269 | (99.3) |
| Pneumothorax* | 13 | (.6) | 2,271 | (99.4) |

*Kappa results for the retrospective chart review of pnuemothoraces was 0.99.

held fewer boarded patients. Figure 1 panel A demonstrates the association between AEs and different levels of crowding scales by quartile. There was no association between measures of crowding scale by quartile and AEs.

ED ultrasound utilization and level of operator experience during CVC insertion did not vary by measure of crowding (Figure 1, Panel C and Panel D). There was no association between CLABSI and levels of crowding (Table 2).

Table 3 demonstrates the results of a logistic regression model including known risk factors for CVC AEs (ultrasound utilization and renal disease) and different levels of crowding. Fewer AEs were associated with ultrasound-assisted CVC placement, but there was no effect of ED crowding in any of our models. Global GoF tests indicate that all models are an appropriate fit.

*Deferred Procedures*

A total of 9241 patients were admitted to the ICU during this time period, and 1497 (16.2%) underwent CVC placement in the ED. The mean age was 58 years (SD ± 18.9). Emergency department diagnoses at the time of admission were as follows: other 3431 (37%); trauma 2610 (28%); infectious 1405 (15%); and cardiac 1,011 (11%). Mean measures of crowding were as follows: NEDOCS, 123.7 (SD ± 43.5); number of waiting room patients, 16 (SD ± 11.6); EDO median = 100% (IQR 91% - 100%); and number of ED boarding patients, 10 (SD ± 5).

The frequency of ED CVC placement during severe or dangerous crowding was 16% (540 patients) and 16% (957 patients) ($P = 0.98$) during lower levels of crowding. There was no association between ED CVC placement and other scores of crowding comparing the highest vs all other quartiles: WR patients (16% vs 16%, $P = 0.82$), EDO (15% v. 17%, $P = 0.15$): number of boarding patients (17% vs 16%, $P = 0.08$). Figure 1 Panel B shows the frequency of CVC insertions in the ED occurring during different levels of crowding. There was no association between frequency of ED CVC insertions and crowding level by quartile.

## DISCUSSION

Our study found no association between measures of high ED crowding and CVC AEs. Conceptually, crowding

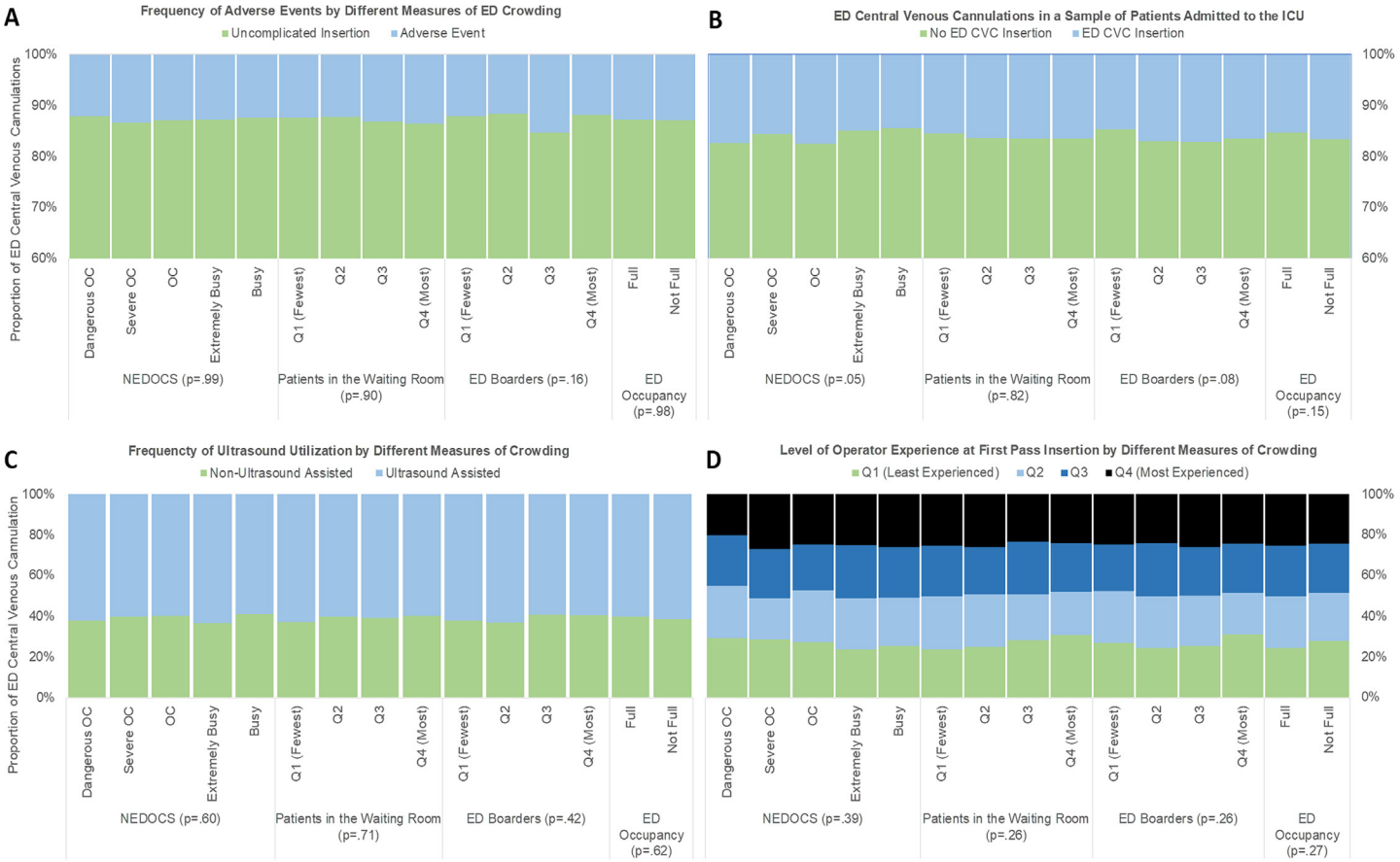


**Figure 1.** Outcomes and characteristics of central venous cannulations performed in the emergency department by different scales of crowding.
*NEDOCS*, National Emergency Department Overcrowding Scale; *ED,* emergency department; *OC*, overcrowding; *Q*, quartile.

has an effect on ED "throughput," interfering with normal operations and possibly impacting physician performance. We hypothesized that physicians may feel hurried, causing an increase in the risk of skill-set and task-based error during periods of excessive ED crowding.[19] This cognitive strain may interfere with performing a moderately complex procedure resulting in greater AEs. Providers may skip essential protective steps that result in greater risk of harm. For example, providers may skip placing the patient in Trendelenburg position or avoid using ultrasound. However, our results suggest that AEs occur with similar frequencies during all levels of ED crowding. We did observe the protective effect of ultrasound, which may have contributed to our findings. Ultrasound-guided CVC is well documented to decrease the risk of AEs in the ED setting and may mitigate some risk during times of excessive crowding by decreasing the complexity of the procedure.[20,21] Crowding had no effect on the level of training of the physician performing the procedure or whether CVCs were placed with ultrasound guidance, again suggesting that physicians treat critically ill patients similarly during different periods of ED crowding.

We also found that EPs were as likely to insert CVCs in critically ill patients during times of crowding as when the ED was less crowded, suggesting that CVC placement in the ED is not deferred to downstream clinical services. We hypothesized that EPs would perform CVC with less frequency during periods of high ED crowding since performing the procedure requires an investment of time that is otherwise not focused on other patients. We found that this relationship did not occur in a population of ED patients admitted to the ICU suggesting that EPs do not delegate critical procedures to downstream healthcare providers. Our findings agree with those of Jo et al who found that critical procedures, including CVC placement, were not delayed with the exception of a subset of trauma patients at the busiest quartiles.[22] Wu et al, noting coagulation reversal procedures occurred less often during high levels of crowding among trauma patients, suggested that crowding caused CVC insertion delays; however, the authors did not report the specific data.[1] Our study was not designed to examine the effect of CVCs placed in a subset of trauma patients. However, trauma patients represented the majority of patients in our sample of patients destined to the ICU and we did not find any association.

Crowding may not affect all patients similarly. Harris et al suggests crowding affects patients of variable acuity differently.[23] Crowding may not impact those sick enough

**Table 2.** Association between central line-associated-blood stream infections and crowding measures.

| Crowding Measure | CLABSI N = 10 | No CLABSI N = 1533 | P-Value* |
|---|---|---|---|
| NEDOCS | | | |
| Dangerous crowding | 1 (10%) | 98 (6%) | |
| Severe crowding | 2 (20%) | 311 (20 %) | |
| Crowding | 4 (40%) | 540 (35 %) | 0.84 |
| Extremely busy, no crowding | 2 (20%) | 445 (30 %) | |
| Busy | 1 (10%) | 139 (9 %) | |
| Patients in the waiting room | | | |
| Q1 (fewest) | 2 (20 %) | 458 (30%) | |
| Q2 | 3 (30 %) | 431 (28%) | 0.43 |
| Q3 | 1 (10 %) | 342 (22 %) | |
| Q4 (most) | 4 (40 %) | 302 (20%) | |
| ED Occupancy | | | |
| Full | 7 (70%) | 1,045 (68%) | 1.0 |
| Not full | 3 (30%) | 488 (32 %) | |
| # of ED patients awaiting inpatient beds | | | |
| Q1 (fewest) | 3 (30%) | 379 (25%) | |
| Q2 | 3 (30%) | 404 (26%) | 0.97 |
| Q3 | 2 (30%) | 395 (26%) | |
| Q4 (most) | 2 (30%) | 355 (23%) | |

*Fisher's exact test.
*CLASBI*, central line-associated blood stream infections; *NEDCOS*, National Emergency Department Overcrowding Scale; *Q*, quartile; *ED*, Emergency Department.

to "skip the line."[24] Patients with acute stroke symptoms do not experience delays in care during periods of crowding, and crowding may not cause clinically important delays for patients requiring emergent percutaneous coronary thrombolytic angioplasty.[23] Likewise, the mortality and quality of resuscitation among cases of out-of-hospital cardiac arrest does not differ by measure of crowding.[25] Crowding affects those triaged in the highest, most acute category the least.[26] Our data support this argument and suggests that crowding may not exert a direct effect on the outcomes of CVCs placed in ED patients, the majority of whom are critically ill.

Crowding may not factor into the physician's interaction with a patient who is critically ill. Crowding affects systems-based interactions. For example, in a cohort of patients with pneumonia, Fee et al found crowding caused delays in tasks that required nursing (antibiotic delivery) and system-based tasks (CXR results from radiology reporting) but not physician-level tasks (antibiotic ordering).[27] While Peltan et al and Gaieski et al observed an increased in time to administration of antibiotics and intravenous fluids among septic patients, they did not capture whether these were physician or nursing delays.[7,28] Owyang et al noted departures from lung protective strategies among ED patients on ventilators as the ED became busier, requiring combined respiratory therapist and physician bedside attention.[29] Asaro et al suggested that physician treatment time is most strongly influenced by clinical and demographic factors, not crowding measures.[30] This suggests that crowding may exert its greatest effect when less than critically ill patients rely on systemic efficiencies to achieve high-quality care.

**Table 3.** Adjusted odds ratio for likelihood of adverse event during central venous catheter insertions in the emergency department.

| Variable | OR (95% CI) | OR p-value | GoF P-value |
|---|---|---|---|
| AE ~ NEDOCS + US + Renal + Exp | | | |
| Dangerously crowded | 0.98 (0.56 – 1.71) | 0.93 | 0.29 |
| Severely crowded | 1.11 (0.69 – 1.82) | 0.69 | |
| Crowded | 1.04 (0.66 – 1.67) | 0.87 | |
| Extremely busy, not crowded | 1.06 (0.67 – 1.72) | 0.81 | |
| Busy | — | — | |
| AE ~ Waiting + US + Renal + Exp | | | |
| Highest quartile | 1.10 (0.77 – 1.58) | 0.61 | 0.32 |
| 3rd quartile | 1.06 (0.74 – 1.51) | 0.76 | |
| 2nd quartile | 0.97 (0.69 – 1.38) | 0.88 | |
| 1st quartile | — | — | |
| AE ~ Beds + US + Renal + Exp | | | |
| Full occupancy | 0.99 (0.77 – 1.30) | 0.96 | 0.27 |
| Not at full occupancy | — | — | |
| AE ~ Boarding + US + Renal + Exp | | | |
| Highest quartile | 0.97 (0.68 – 1.38) | 0.85 | 0.91 |
| 3rd quartile | 1.32 (0.95 – 1.85) | 0.10 | |
| 2nd quartile | 0.97 (0.67 – 1.38) | 0.92 | |
| 1st quartile | — | — | |
| AE ~ US | | | 1.00 |
| Ultrasound assisted | 0.69 (0.54 – 0.88) | 0.003 | |
| AE ~ Exp + US | | | |
| Highest Quartile | 0.91 (0.65 – 1.28) | 0.59 | 0.46 |
| 3rd quartile | 0.74 (0.52 – 1.06) | 0.10 | |
| 2nd quartile | 1.08 (0.77 – 1.50) | 0.66 | |
| 1st quartile | — | — | |
| AE ~ Renal + US | | | 0.08 |
| Renal disease | 0.87 (0.59 – 1.24) | 0.44 | |

*NEDOCS*, National Emergency Department Overcrowding Scale; *OR*; odds ratio; *GoF*, goodness of fit; *AE*, adverse events; *US*, ultrasound; *Exp*, experience.

Crowding's greatest impact may be felt by less obviously sick patients. For example, acute stroke evaluation is not delayed by crowding, but patients with subtle symptoms do experience delays to CT imaging.[31,32] Similarly, crowding can cause lab delays in obtaining critical troponin levels in non-ST elevation myocardial infarction (STEMI) cases while STEMI cases proceed with little pause to invasive interventions. We did not capture the effect on other processes occurring in parallel during delivery of intense ED care, and here is where others have found meaningful delays. Our theoretical model did not address these relationships that may have more indirect effect on overall ED quality of care. We found no evidence of a direct relationship between crowding and AEs from CVCs inserted in the ED.

## LIMITATIONS

This study was a single-center study thereby limiting the generalizability of the results, a central limitation to our conclusions. Additionally, we used a composite AE because we could not use a specific CVC AE to power our study. All AEs are not equivalent—clearly a pneumothorax is not equivalent to a failed attempt; and a "rescue attempt" of a novice is not identical to one required by an expert. This reduced our ability to identify serious AEs that may have a closer relationship to ED crowding measures.

Our retrospective review relied on self-report of AEs following CVC insertion. Although we did not encounter discrepancies between reported AEs and our patient safety officer, it is possible that minor AEs went under-reported, thus lowering the probability of finding an association between crowding and CVC AEs. The fluidity of crowding makes for measurement challenges. While we linked procedure time documentation to crowding measures, it is possible that the procedure took place when crowding scores were slightly different. It is therefore possible that some AEs took place during different measures of crowding categories. Lastly, staffing has been proposed in some studies to play a mediating role in crowding's impact on outcomes in stroke patients.[31] In our study, differences in ED staffing were not specifically accounted for and may have played a role in procedural outcomes.

Our data are retrospective and over 10 years old because our protocol encompassed a unique time frame in which sepsis care encouraged high rates of CVC insertions in the ED, CLABSI data, CVC safety data, and crowding metrics were systematically and simultaneously collected before they were disrupted by a system-wide adoption of a new EHR. Care patterns may now differ, especially in cases of sepsis. Rather than re-collecting new data, we elected to evaluate the available retrospective, albeit older, data. We propose that performance of CVC insertions has changed little if at all during this time frame making it unlikely that our data misrepresent current clinical practice.

## CONCLUSION

In a large, academic tertiary-care center, frequency of CVC insertion and related AEs are not associated with measures of crowding. These findings add to the evidence that the negative effects of crowding, which impact all ED patients and measures of ED performance, are less likely to impair the delivery of prioritized time-critical interventions.

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



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# Performance of Prognostication Scores for Mortality in Injured Patients in Rwanda

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**Introduction:** While trauma prognostication and triage scores have been designed for use in lower-resourced healthcare settings specifically, the comparative clinical performance between trauma-specific and general triage scores for risk-stratifying injured patients in such settings is not well understood. This study evaluated the Kampala Trauma Score (KTS), Revised Trauma Score (RTS), and Triage Early Warning Score (TEWS) for accuracy in predicting mortality among injured patients seeking emergency department (ED) care at the Centre Hospitalier Universitaire de Kigali (CHUK) in Rwanda.

**Methods:** A retrospective, randomly sampled cohort of ED patients presenting with injury was accrued from August 2015–July 2016. Primary outcome was 14-day mortality and secondary outcome was overall facility-based mortality. We evaluated summary statistics of the cohort. Bootstrap regression models were used to compare areas under receiver operating curves (AUC) with associated 95% confidence intervals (CI).

**Results:** Among 617 cases, the median age was 32 years and 73.5% were male. The most frequent mechanism of injury was road traffic incident (56.2%). Predominant anatomical regions of injury were craniofacial (39.3%) and lower extremities (38.7%), and the most common injury types were fracture (46.0%) and contusion (12.0%). Fourteen-day mortality was 2.6% and overall facility-based mortality was 3.4%. For 14-day mortality, TEWS had the highest accuracy (AUC = 0.88, 95% CI, 0.76–1.00), followed by RTS (AUC = 0.73, 95% CI, 0.55–0.92), and then KTS (AUC = 0.65, 95% CI, 0.47–0.84). Similarly, for facility-based mortality, TEWS (AUC = 0.89, 95% CI, 0.79–0.98) had greater accuracy than RTS (AUC = 0.76, 95% CI, 0.61–0.91) and KTS (AUC = 0.68, 95% CI, 0.53–0.83). On pairwise comparisons, RTS had greater prognostic accuracy than KTS for 14-day mortality (P = 0.011) and TEWS had greater accuracy than KTS for overall (P = 0.007) mortality. However, TEWS and RTS accuracy were not significantly different for 14-day mortality (P = 0.864) or facility-based mortality (P = 0.101).

**Conclusion:** In this cohort of emergently injured patients in Rwanda, the TEWS demonstrated the greatest accuracy for predicting mortality outcomes, with no significant discriminatory benefit found in the use of the trauma-specific RTS or KTS instruments, suggesting that the TEWS is the most clinically useful approach in the setting studied and likely in other similar ED environments. [West J Emerg Med. 2021;22(2)435-444.]

## INTRODUCTION

The impact of injury disproportionately falls on the health systems of low- and middle-income countries (LMIC). While the World Health Organization has estimated that 16% of global disease burden is due to injury,[1] approximately 90% of deaths and disability-adjusted life years lost due to injury occur in LMICs.[2,3] Commonly required injury care in LMICs is challenged by limited material resources and healthcare personnel.[4] In particular, although sub-Saharan Africa has a high burden of injury, the region has just 3% of the world's healthcare workers and less than 1% of healthcare resources.[5]

Triage systems are an important method to assist in addressing health barriers as they can facilitate the prompt identification of patients with the most urgent needs and highest risks.[6,7] Prior research has demonstrated that triage systems used in acute care settings in LMICs are associated with reduced time to treatment and mortality.[8,9] Trauma prognostication scores, which are designed to stratify patient severity and predict mortality, have the potential to enhance triage for injured patients.[10] Although the Revised Trauma Score (RTS) has been used in high-income countries (HIC),[11] this metric and other scores initially developed in HICs may have limited application in LMICs.[5,10] Accordingly, the Kampala Trauma Score (KTS) was developed in Uganda in 1996 for use in trauma prognostication in sub-Saharan Africa specifically, and has since been validated.[3,5,10,12] Several studies comparing the RTS and KTS have shown that both scores have clinical utility in risk-stratifying injury cases and predicting mortality in sub-Saharan Africa,[2,3,5,10] but their accuracy has not been directly compared to established triage tools that are more broadly applicable to both injured and non-injured patients.

In most emergency care settings, general triage systems applicable to all types of patients presenting for care are used. As HIC triage tools have previously been shown to lack applicability in LMIC settings,[13,14] the Triage Early Warning Score (TEWS) was developed as a contextually appropriate score for triage use in Africa.[15] The TEWS is a component of the South African Triage Scale (SATS), which has been used and studied in multiple countries in sub-Saharan Africa including South Africa,[16-18] Ghana,[19] Somaliland,[20] Malawi,[21] and Rwanda.[14] Although trauma prognostication scores such as the KTS and RTS have been extensively compared to each other,[2] there are minimal data evaluating the clinical accuracy of the prolifically used TEWS as compared to trauma scores.[22,23] As a result, it is unclear whether there is additional benefit conferred by the use of injury-specific scores in LMIC settings for acutely injured patients beyond the use of standard triage approaches. This study compared the accuracy of the KTS, RTS, and TEWS in predicting mortality for injured patients at the emergency department (ED) of the Centre Hospitalier Universitaire de Kigali (CHUK), a tertiary care hospital in Rwanda that has implemented use of the TEWS in standard emergency care triage practice.[14]

*Population Health Research Capsule*

What do we already know about this issue?
*Trauma-specific and general triage scores can stratify injury mortality-risk, but the comparative accuracy of scores in low-resource settings is poorly understood.*

What was the research question?
*What is the accuracy of the Kampala Trauma Score, Revised Trauma Score, and Triage Early Warning Score (TEWS) in predicting injury mortality at a Rwandan tertiary hospital?*

What was the major finding of the study?
*Among injury patients, the TEWS demonstrated the highest accuracy in predicting 14-day and overall mortality.*

How does this improve population health?
*General triage scores like the TEWS may be the most clinically useful approach in the studied setting and trauma-specific scores may offer little additional utility.*

## METHODS

### Study Setting and Population

This retrospective cohort study analyzed patients presenting to the ED of the CHUK in Kigali, Rwanda. CHUK is Rwanda's primary national public referral hospital, with approximately 500 inpatient beds and an ED that provides continuous 24 hours a day care with access to specialty diagnostic, medical, and surgical services. The CHUK ED receives approximately 20,000 visits annually and maintains the country's only emergency medicine (EM) residency training program.[4,24] Data collection and research activities were approved by the CHUK Ethics Committee.

All patients presenting to the ED from August 2015–July 2016 were eligible for inclusion. To reduce selection bias, cases for analysis were randomly selected based on standardized methods that have been described previously.[4,25,26] All ED cases were initially identified from an electronic hospital database using a composite patient identification index based on name, age, gender, home district, and date of service. All ED cases admitted during the study period were extracted using the index and subsequently coded using a unique identification number. Cases were sampled at random within each month of the accruement period (range: 135-165 cases per month). After cases were screened, we excluded all patients with insufficient documentation for data abstraction, those without acute injuries, and non-adults defined as those less than 15 years of age.[26]

**Data Management and Statistical Analysis**

Data collected included patient demographics, prehospital care information, clinical presentation, past medical history, mechanism of injury, performance of surgical interventions following admission, and outcomes. We calculated three triage and prognostication scores for each patient following previously published formulas: the KTS[12]; RTS[27]; and TEWS (Appendix 1).[15] A lower KTS or RTS score denotes a likely higher acuity in patient presentation. In contrast, a higher TEWS score indicates likely greater acuity. Serious injuries were identified as a traumatic pathology that would require hospital admission, with the number of serious injuries based on the sum number of anatomical regions of injuries involved as classified by the Abbreviated Injury Scale, as has been previously performed.[12,28] All variables were collected using a standardized data instrument and entered into a password-protected database by protocol-trained personnel.[4,25,26] Data procedures followed practices for high-quality chart review research.[29] Ten percent of entries were double-entered. For double-entered records, assessment of data quality was performed by calculating inter-rater reliability (IRR) via Cohen's kappa (κ).[30]

We conducted statistical analyses using Stata version 15 (StataCorp, College Station, TX) and R version 3.5.13 (R Foundation for Statistical Computing, Vienna, Austria). Summary statistics were calculated, with frequencies and percentages reported for categorical variables or medians with interquartile ranges (IQR) reported for continuous variables. The discriminatory capability of each score was quantified using nonparametric receiver operating curve (ROC) analysis, with bootstrapping (5000 iterations) performed to calculate 95% confidence intervals (CI). The primary outcome for analysis was 14-day, facility-based mortality, which included mortality during ED care and inpatient admission. The 14-day time point was chosen as it has been used in prior evaluations of prognostication scores in the East Africa context and previous data from the study setting has demonstrated that inpatient lengths of stay (LOS) at the study site for patients admitted from the ED have an LOS IQR of 2-14 days.[4,10] The secondary outcome was overall facility-based mortality, which recorded patients who died before discharge, regardless of duration after presentation.

Patients discharged or transferred from the CHUK to other health facilities were assumed to have survived. Area under the curve (AUC) for scores were compared using paired bootstrap hypothesis testing.[31] During AUC calculation for single scores, we analyzed all patients with non-missing data for the specific score of interest. For comparative analyses, patients with data for all three scores were analyzed. To evaluate for potential selection bias due to cases with missing data being excluded, we compared differences in case characteristics for cases with and without data on all three scores. Differences in case characteristics were also assessed for cases with and without data on mortality. We used Pearson's chi-squared and Fisher's exact tests for categorical variables, and the nonparametric Mann-Whitney test used for continuous variables.

In accordance with Bonferroni correction for multiple testing, statistical significance was maintained at $P<0.0056$ for comparisons between patients with missing and non-missing data on all three scores, $P<0.0050$ for comparisons between patients with missing and non-missing data on mortality, and at $P<0.0167$ for pairwise testing in comparative analyses of triage and prognostication scores.[32] Test characteristics of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (PLR), and negative likelihood ratio (NLR) with associated 95% CIs were calculated for the three scores of interest.

## RESULTS

**Study Population**

Among 21,117 cases treated at the CHUK ED during the study period, 4620 were randomly screened for analysis. Data were gathered from 1657 cases, of which 617 were seeking care for injuries and included for analysis (Figure 1). For double-entered records, inter-rater reliability was excellent ($\kappa = 0.95$, standard error = 0.04). The majority of patients were male (72.5%) and the mean age was 32 years (IQR: 26–45). The most common anatomical regions of injury were craniofacial (39.3%), followed by lower extremity (38.7%) and upper extremity (23.0%). The most prevalent mechanisms of injury were road traffic accident (56.2%) and blunt injury or fall (21.9%). Fracture (46.0%) and contusion (12.0%) were the most common injury patterns. Approximately half of cases were admitted for inpatient care (52.8%). Among these patients, surgical intervention was performed on 74.8%, with open reduction being the most common procedure. Mortality through 14 days was 2.6%, and overall facility-based mortality was 3.4% (Table 1).

Sufficient data was available to calculate KTS for 331 patients (53.6%), RTS for 328 patients (53.2%), and TEWS for 239 patients (38.7%). The most common missing measurements were respiratory rate for KTS and RTS (35.7%), and temperature for TEWS (43.4%). Among cases, 237 (38.4%) had complete data on all three scores. Patients had a mean score of 15.1 for KTS (median = 15, range: 12–16; Figure 2A), 7.6 for RTS (median = 7.8, range: 5.0–7.8; Figure 2B), and 6.2 for TEWS (median = 6, range: 3–12; Figure 2C). Patients with and without data on all three scores had no significant differences in age, gender, Glasgow Coma Scale (GCS), mechanism of injury, 14-day survival or overall survival based on the a priori threshold for multiple testing (Appendix 2). However, respiratory rate differed between patients with and without data (median = 18 vs 20 breaths per minute, $P<0.001$). Similarly, only respiratory rate (median = 20 vs 18 breaths per minute, $P<0.001$) and the KTS (median =15 vs 16, $P = 0.001$) differed between patients with and without data on mortality (Appendix 3).

**Table 1.** Summary characteristics for study population.

| Variable | Number (%) or Median (IQR) |
|---|---|
| Gender | |
| Male | 447 (72.4%) |
| Female | 169 (27.4%) |
| Missing | 1 (0.2%) |
| Age (Years) | 32 (26–45) |
| Heart rate | 85 (72–98) |
| Respiratory rate | 19 (18–20) |
| Systolic blood pressure | 124 (112–135) |
| Glasgow Coma Scale | |
| 3-8 | 21 (3.4%) |
| 9-12 | 40 (6.5%) |
| 13-15 | 364 (59.0%) |
| Missing | 192 (31.1%) |
| Anatomical regions of injuries* | |
| Craniofacial | 243 (39.3%) |
| Thorax | 96 (15.6%) |
| Abdomen or pelvis | 89 (14.4%) |
| Neck or spine | 51 (8.3%) |
| Upper extremity | 142 (23.0%) |
| Lower extremity | 239 (38.7%) |
| Other | 34 (5.5%) |
| Types of Injuries* | |
| Fracture | 284 (46.0%) |
| Classified as open | 105 (17.0%) |
| Burn | 12 (1.9%) |
| Contusion | 74 (12.0%) |
| Dislocation | 33 (5.3%) |
| Site of injury | |
| Home | 41 (6.7%) |
| Work site | 162 (26.2%) |
| Street | 159 (25.8%) |
| Health center | 8 (1.3%) |
| Other or unknown | 247 (40.0%) |
| Transport by formal prehospital services | |
| Yes | 437 (70.8%) |
| No | 180 (29.2%) |
| Mechanism of injury | |
| Road traffic accident | 347 (56.2%) |
| Blunt injury or fall | 135 (21.9%) |
| Penetrating injury | 75 (12.2%) |
| Burn | 12 (1.9%) |
| Animal encounter | 5 (0.8%) |
| Unknown | 43 (7.0%) |
| ED disposition | |
| Admitted | 326 (52.8%) |
| Discharged to home | 137 (22.2%) |
| Transferred | 9 (1.5%) |
| Death | 4 (0.7%) |
| Unknown | 141 (22.8%) |
| Emergency department length of stay (Days) | 1 (0–2) |
| Inpatient disposition (n = 326) | |
| Discharged to home | 273 (83.7%) |
| Transferred | 34 (10.4%) |
| Death | 17 (5.2%) |
| Unknown | 2 (0.7%) |
| Inpatient length of stay (Days) | 7 (3–16) |
| Received surgical intervention | |
| Yes | 244 (74.8%) |
| No | 82 (25.2%) |
| Surgical Interventions Performed* | |
| Open reduction | 94 (28.8%) |
| Wound debridement | 66 (20.2%) |
| Closed reduction with external fixation | 49 (15.0%) |
| Craniotomy | 37 (11.3%) |
| Laparotomy | 25 (7.7%) |
| Other | 51 (15.6%) |
| Overall Length of Stay (Days) | 6 (2–14) |
| 14-Day Survival | |
| Alive | 462 (74.9%) |
| Dead | 16 (2.6%) |
| Unknown | 139 (22.5%) |
| Overall Facility-Based Survival | |
| Alive | 457 (74.1%) |
| Dead | 21 (3.4%) |
| Unknown | 139 (22.5%) |

*Percentages do not add up to 100% for anatomical region of injuries, types of injuries, and surgical interventions performed because categories were non-mutually exclusive for these variables.
*IQR*, interquartile range.

**Prognostication Accuracy for 14-Day Mortality**

For 14-day mortality, the TEWS had the highest discriminatory accuracy (AUC = 0.88, 95% CI, 0.76–1.00, $P<0.001$), followed by RTS (AUC = 0.73, 95% CI, 0.55–0.92, $P = 0.013$), with both scores performing significantly better than chance (Figure 3A-B). KTS had the lowest

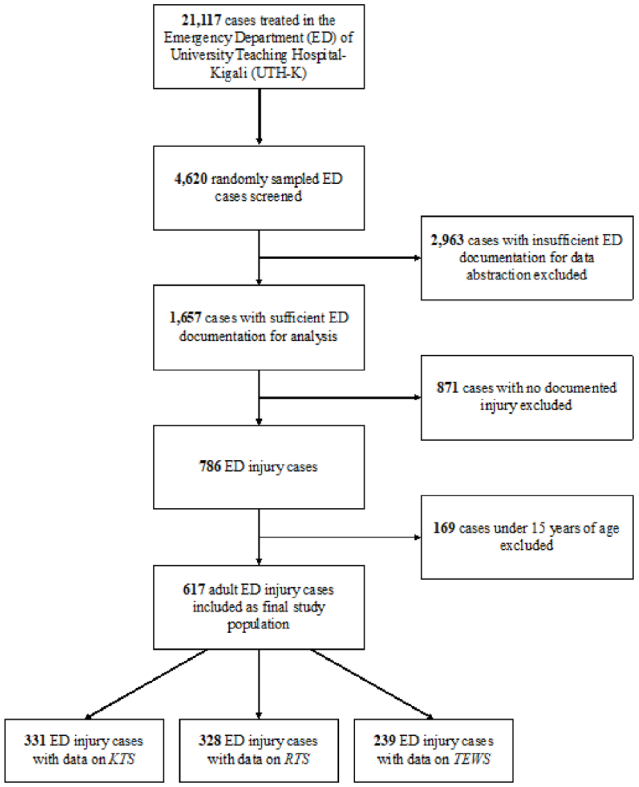


**Figure 1.** Study flow diagram.
*KTS*, Kampala Trauma Score; *RTS*, Revised Trauma Score; *TEWS*, Triage Early Warning Scale.

discriminatory accuracy (AUC = 0.65, 95% CI, 0.47–0.84, $P$ = 0.108) and did not perform better than chance (Figure 3C). In comparative analysis, the TEWS had the most accurate diagnostic performance (AUC = 0.90), followed by the RTS (AUC = 0.84) and then the KTS (AUC = 0.75; Figure 3D). The RTS had significantly better discrimination than KTS ($P$ = 0.011). No significant differences in performance were found in comparing the TEWS to the KTS ($P$ = 0.058) or the RTS to the TEWS ($P$ = 0.864).

### Prognostication Accuracy for Overall Facility-Based Mortality

For overall facility-based mortality, the TEWS had the highest discriminatory accuracy (AUC = 0.89, 95% CI, 0.79–0.98, $P$<0.001; Figure 4A), followed by RTS (AUC = 0.76, 95% CI, 0.61–0.91, $P$<0.001; Figure 4B) then KTS (AUC = 0.68, 95% CI, 0.53–0.83, $P$ = 0.020; Figure 4C), with all three scores performing significantly better than chance. The TEWS had higher discriminatory accuracy for pairwise comparisons than the KTS ($P$ = 0.007), but not the RTS ($P$ = 0.207; Figure 4D). The KTS and the RTS did not have any significant differences ($P$ = 0.101).

### Test Characteristics of Scores

Table 2 shows the range of test characteristics for TEWS using different cutoff points. Sensitivity and specificity were maximized at a threshold of ≥7 at 1.00 and 0.69, respectively. At a TEWS ≥9, the PLR demonstrated moderate clinical utility (8.65, 95% CI: 3.62–20.68). Appendix 4 shows the range of test characteristics for the KTS, and Appendix 5 shows the range of test characteristics for the RTS.

## DISCUSSION

This study evaluated the comparative accuracy of the KTS, RTS, and TEWS in predicting mortality following presentation for emergent injury care among adults in Rwanda. For the overall sample population, the TEWS exhibited the highest discriminatory accuracy among the three scores in predicting 14-day mortality and overall facility-based mortality. The TEWS also demonstrated significantly higher performance in predicting facility-based mortality compared to the KTS. These findings suggest that the TEWS may be the most clinically useful tool for risk-stratifying injured patients in the studied setting. The addition of trauma-specific scores, such as the KTS or RTS, may not yield additional clinical utility pertaining to mortality prognostication among ED patients seeking injury care.

Only two prior studies have compared the performance of the TEWS or SATS to trauma-specific scores. One study compared the KTS and TEWS for patients with gunshot wounds presenting to an urban hospital in South Africa.[23] While the KTS had better diagnostic performance for mortality than the TEWS, as quantified by AUC, the difference was not statistically significant. The disparate accuracy results for the KTS vs the TEWS in the findings from the South Africa data as compared to the current data may be due to case selection in that the cohort looked at only a specific subset of injured patients, whereas the present study from Rwanda looked at injured patients more broadly. Another report comparing the SATS, KTS, and RTS in injury cases presenting to a tertiary hospital in Ghana also found no significant differences between the three scores in predicting mortality.[22] Although the report from Ghana assessed the SATS, this triage approach uses the TEWS as a primary component in categorizing illness severity. The high performance of the TEWS in predicting injury mortality found in the Rwanda setting, coupled to the lack of benefit with trauma-specific scores from the Ghana cohort, supports the TEWS being a useful risk-stratification tool for trauma in and of itself, which has been suggested in prior studies.[23,33,34] Nevertheless, further prospective evaluation in emergency care settings of this finding to more robustly validate the utility of the TEWS for the purpose of LMIC injury populations would be beneficial.

There are several potential explanations for the TEWS having the highest risk-stratification accuracy for trauma mortality in the present study population. The TEWS is a composite of physiological measurements, presence of trauma, and patient mobility. Several earlier studies have suggested that prognostication scores based purely on physiological measurements, such as the RTS, may be suboptimal for risk-stratifying injured patients due to certain trauma cases not

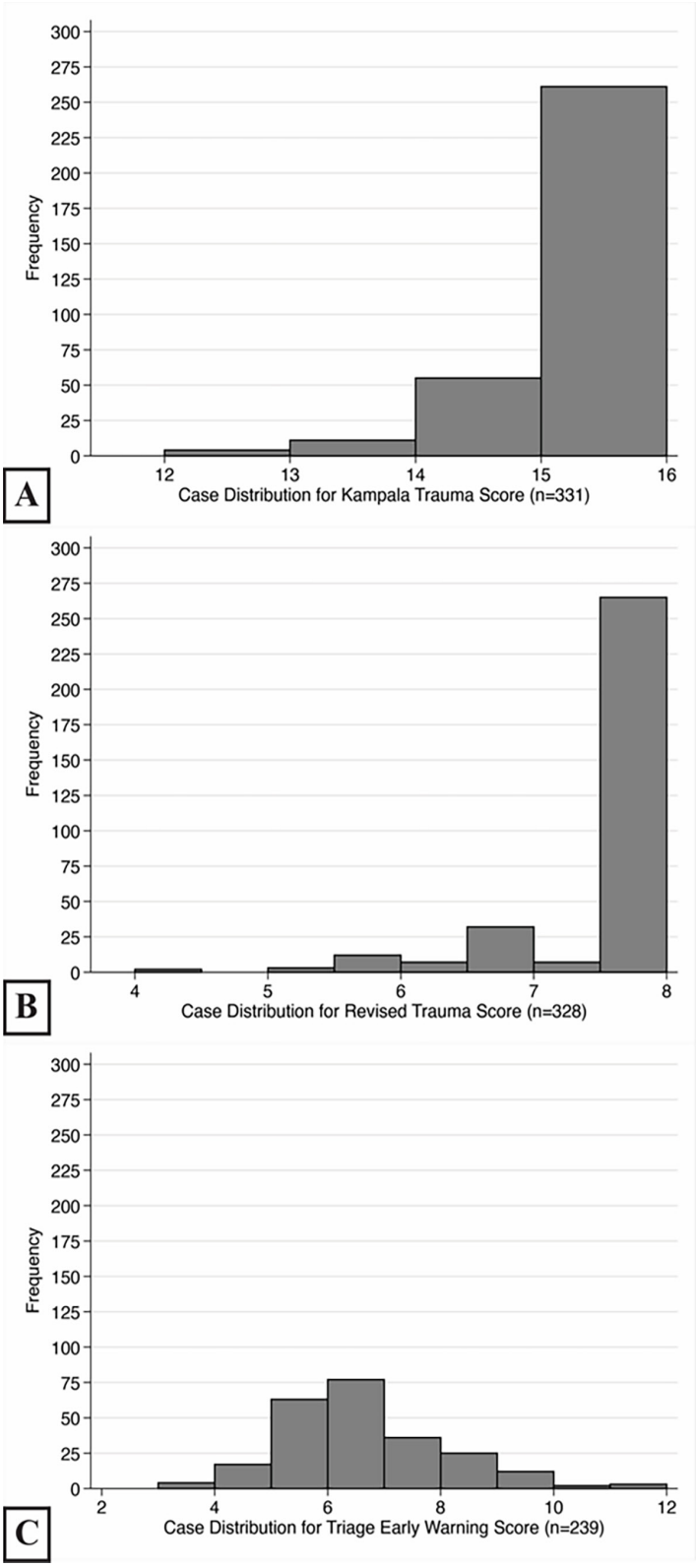


**Figure 2.** Histogram of score distributions.

necessarily presenting with physiological decompensation or varying levels of injury presenting with similar physiological measurements.[5,23] While the KTS and TEWS both have scoring components accounting for the presence of trauma, the TEWS also uniquely has a scoring component representing patient functional status, in the form of mobility,[17] which may have further improved the triaging of injured patients. Additionally, certain scoring components may be measured more accurately than others, resulting in better discrimination of illness states. For example, several studies have demonstrated heterogeneous levels of understanding and scoring for the GCS, a component of the RTS.[35-38] In contrast, the TEWS uses a simplified alert, verbal, pain, and unresponsive scale to assess a patient's level of consciousness, which is inherently a less complex differentiation than the GCS.

The present results also elucidate potential shortcomings in the inclusion of trauma-specific scores, such as the KTS and RTS, as additional triage tools for injured patients in LMIC ED settings. Earlier studies have contended that the use of separate triage tools for different presentations, such as medical or trauma patients, may introduce challenges including the necessary training of healthcare workers to apply an additional tool in practice and potential errors when applying separate metrics.[23,39] Approximately 43% of CHUK ED admissions have medical presentations and the documented proportion of medical admissions for EDs in a similar setting have varied from 56-64%.[17,19,40] Accordingly, an advantage of the TEWS over trauma-specific scores is its ability to be applied uniformly across both medical and trauma cases. Moreover, as the TEWS score can be integrated into the SATS tiered categories to guide the rapidity of needed injury interventions based on acuity, it may have greater clinical application than the KTS or RTS, which have no established cutoff points to inform decision-making for care provision.[22] These factors, in addition to the greater relative prognostic accuracy, may support the use of general clinical care triage assessment tools, such as the TEWS, for risk-stratifying injured patients over the use of separate trauma prognostication scores.

Although the TEWS and the associated SATS have been successfully applied to predict hospitalization needs and mortality in several settings across sub-Saharan Africa,[14,16,19-21] as well as outside sub-Saharan Africa,[6,41] the score's utility to inform clinical decision-making for acute injury care is an area in need of additional evaluation. This is highlighted by the calculated test characteristics for the population studied. Specifically, the PLRs derived from the TEWS only began to approach clinically useful values (ie. those that would substantially impact the post-test mortality probability) at a threshold of $\geq 9$. Furthermore, although potentially clinically useful sensitivities were found at specific thresholds, these findings may be inaccurate, stemming from low numbers of mortality events in the lower score strata evaluated. This indicates that there may be opportunities for improvement of the TEWS to enhance clinical utility at specific threshold values.

Conversely, it is reasonable that emergency care practitioners may have the ability to appropriately risk-stratify patients independent of the use of formal triage or prognostication scores,

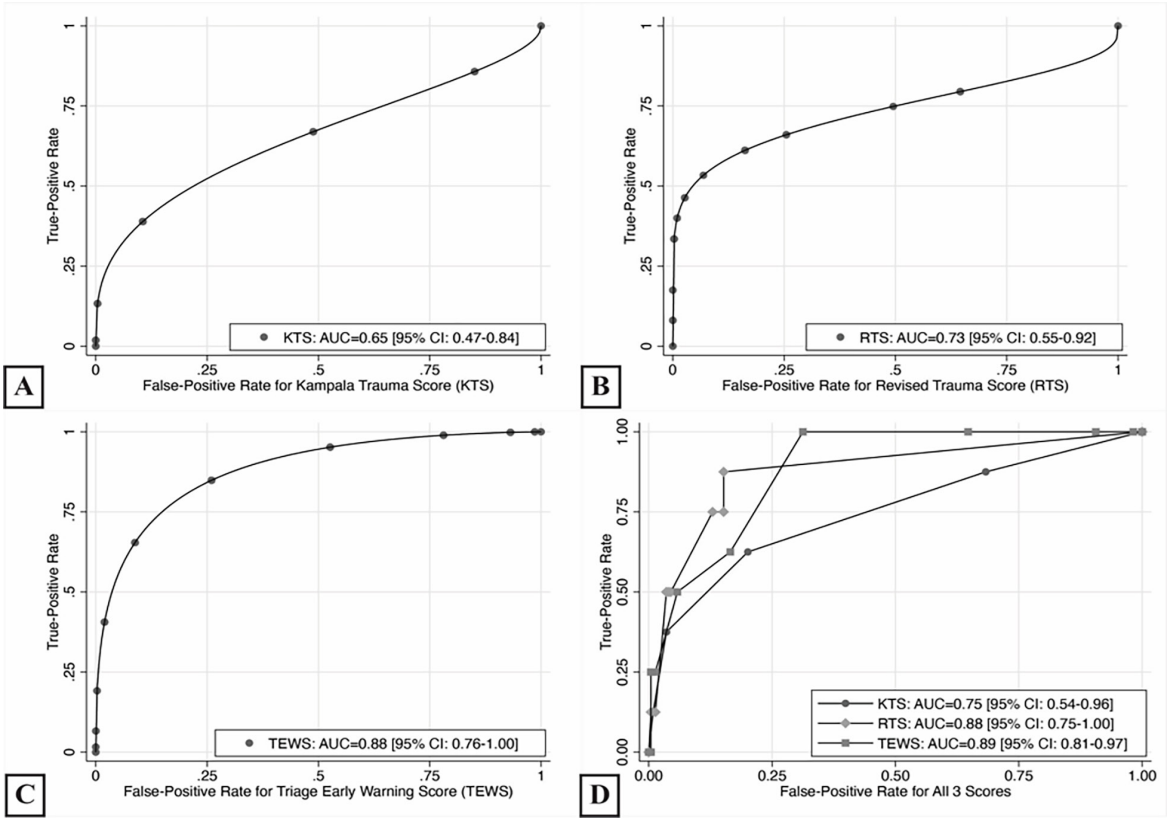


**Figure 3.** Diagnostic accuracy based on receiver operating curves for 14-day mortality.
*KTS*, Kampala Trauma Score; *RTS*, Revised Trauma Score; *TEWS*, Triage Early Warning Scale.

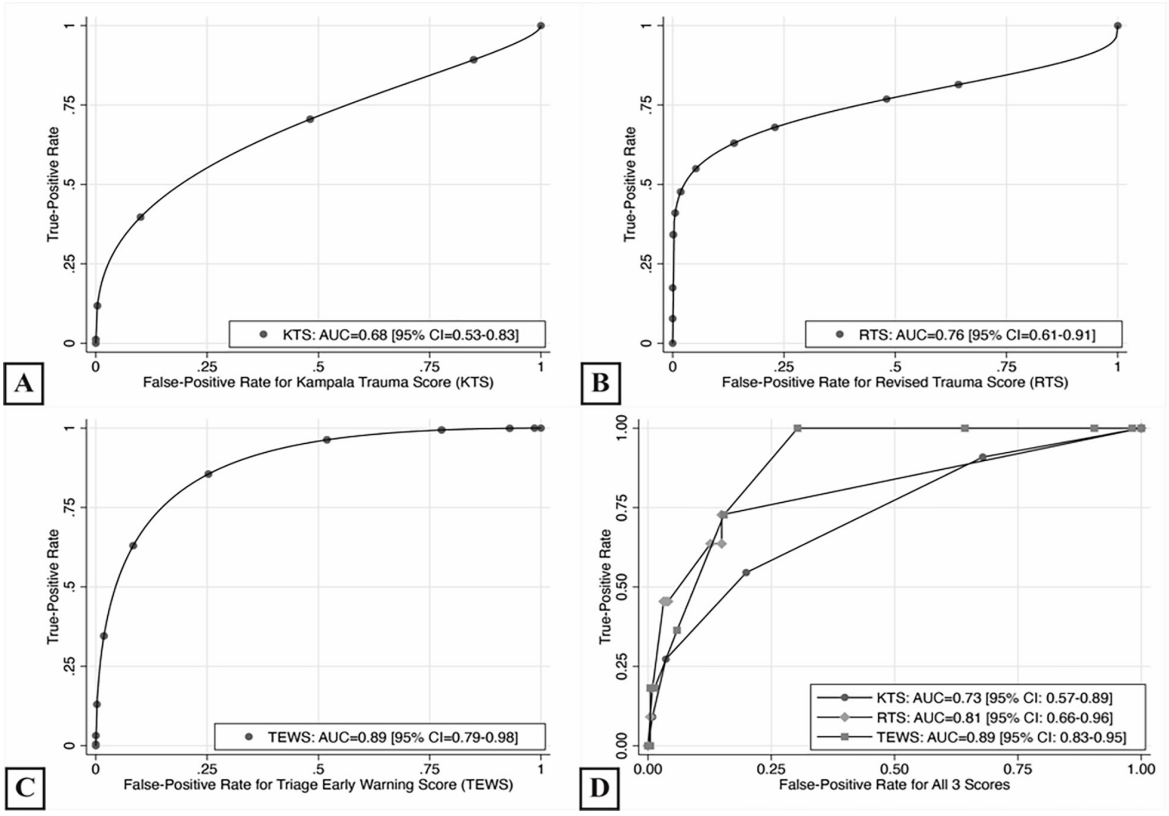


**Figure 4.** Diagnostic accuracy based on receiver operating curves for overall facility-based mortality.
*KTS*, Kampala Trauma Score; *RTS*, Revised Trauma Score; *TEWS*, Triage Early Warning Scale.

**Table 2.** Test characteristics for triage early warning score for 14-day mortality outcome.

| Threshold Score | Number (%) | Sensitivity [95% CI] | Specificity [95% CI] | PPV [95% CI] | NPV [95% CI] | PLR [95% CI] | NLR [95% CI] |
|---|---|---|---|---|---|---|---|
| ≥6 | 154 (66.1%) | 1.00 [1.00–1.00] | 0.35 [0.29–0.41] | 0.05 [0.02–0.09] | 1.00 [1.00–1.00] | 1.54 [1.40–1.70] | 0.00 [0.00-0.00] |
| ≥7 | 78 (33.5%) | 1.00 [1.00–1.00] | 0.69 [0.63–0.75] | 0.10 [0.04–0.17] | 1.00 [1.00–1.00] | 3.21 [2.65–3.90] | 0.00 [0.00-0.00] |
| ≥8 | 42 (18.0%) | 0.63 [0.29–0.96] | 0.84 [0.79–0.88] | 0.12 [0.02–0.22] | 0.98 [0.97–1.00] | 3.80 [2.06–7.01] | 0.45 [0.18–1.10] |
| ≥9 | 17 (7.3%) | 0.50 [0.15–0.85] | 0.94 [0.91–0.97] | 0.24 [0.03–0.44] | 0.98 [0.96–1.00] | 8.65 [3.62–20.68] | 0.53 [0.27–1.06] |

*PPV*, positive predictive value; *NPV*, negative predictive value; *PLR*, positive likelihood ratio; *NLR*, negative likelihood ratio.

but such clinical acumen would likely exist as a continuum based on providers' experience levels and training. Future prospective research, designed and appropriately powered to evaluate the incremental clinical utility of the TEWS and other risk-stratification scores in injured patients as compared to provider gestalt, is needed to better inform training, resource utilization and emergency care globally.

## LIMITATIONS

There are limitations to the present study. First, due to the retrospective nature of the data, information was missing information for some cases. This may have introduced bias in the results, despite this study's use of rigorous methods, including double-entering of records and random sampling of analyzed cases. However, a comparison of characteristics between the cases in the study population with and without data for the primary predictive analysis found no statistically significant differences in variables except for a two-breaths-per-minute difference in respiratory rate, which is unlikely a clinically significant difference. Missing data for mortality may have also introduced bias into the study. While a comparison of cases with and without data on mortality found no differences for most variables, it did find a similar two-breaths-per-minute difference for respiratory rate and one point in median KTS scores.

Second, due to lack of follow-up data, all analyses operated on the assumption of survival if a patient was discharged. As a result, the present study population's mortality may be under-reported, and the comparative performance of the three scores may differ with the inclusion of deaths following discharge. However, for triage of emergently injured patients, there is still considerable clinical utility in risk-stratifying death during admission. Third, standardized use of TEWS at the CHUK during the study period may have affected the performance of this score, which impacted the course of care, relative to the KTS and RTS.[14] However, the TEWS' higher relative accuracy in discriminating mortality in the study population, despite these patients ostensibly receiving more urgent treatment due to identification at triage, may lend further credence to its validity in identifying the highest-risk injured patients.

Finally, due to the dataset being drawn from the ED of a single, tertiary care institution these results may not be generalizable to all settings, especially those with fewer resources. However, the present findings represent evidence in the comparative accuracy of trauma scores and generalized triage scores in predicting mortality following injury, which may form the basis of future comparative work and guide improvements in injury care in similar settings.

## CONCLUSION

Among a cohort of injured ED patients seeking care in the Rwanda study setting, the TEWS had the highest prognostic accuracy for 14-day and overall facility-based mortality, compared to KTS and RTS. This is one of the first studies comparing the TEWS to injury-specific scores globally and the first from Rwanda. The results from this population and earlier comparisons suggest that the addition of an injury-specific score in the triage of injured patients in LMICs may offer little advantage beyond standard triage approaches for mortality prognostication. However, given the retrospective nature of the data, further prospective research is needed to understand the most optimal triage and prognostication approaches for injured ED patients in LMICs.

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# Intensive Cryotherapy in the Emergency Department (ICED): A Randomized Controlled Trial

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**Introduction:** Pain control is an essential component of musculoskeletal injury treatment in the emergency department (ED). We evaluated the most effective type of cryotherapy for analgesia of acute musculoskeletal injury and the impact on opioid utilization.

**Methods:** This was a prospective, randomized, single-blind controlled trial of adult ED patients who presented with acute musculoskeletal pain. Patients were randomized to either intensive targeted cryotherapy (crushed wetted ice in a plastic bag) or agitated chemical cold pack applied to the injury site for 20 minutes. All other diagnostic and therapeutic orders were at the discretion of the treating physician. Visual analog pain scores were measured at the time of cryotherapy application, at 20 minutes (time of cryotherapy removal), and at 60 minutes (40 minutes after removal).

**Results:** We enrolled 38 patients, 17 randomized to intensive targeted cryotherapy and 21 to chemical cold packs, with well-matched demographics. The intensive targeted cryotherapy group achieved significantly greater pain relief at 20 minutes (2.1 [95% confidence interval (CI), 1.3 – 2.9] vs 0.9 [95% CI, 0.3 – 1.5], $P < 0.05$) and at 60 minutes (2.7 [95% CI, 1.6 – 3.7] vs 1.2 [95% CI, 0.6 – 1.7], $P < 0.05$), number need to trial (NNT) = 3.2. Opioid administration in the ED was significantly lower in the intensive targeted cryotherapy group (1 [6%] vs 7 [33%], $P < 0.05$), NNT = 3.6. Those who received a discharge opiate prescription had significantly higher 60-minute pain scores (7.3 ± 2.2 vs 4.1 ± 2.7, $P < 0.05$).

**Conclusion:** Intensive targeted cryotherapy provided more effective analgesia than chemical cold packs for acute musculoskeletal injuries in the ED and may contribute to lower opioid usage. [West J Emerg Med. 2021;22(2)445-449.]

## INTRODUCTION

### Background

Musculoskeletal injuries are the most common class of presenting complaints for emergency department (ED) visits, with pain relief being the primary reason for seeking medical care.[1] Cryotherapy is a non-pharmacologic therapy with analgesic properties first recognized by Hippocrates, and commonly used for acute musculoskeletal treatment and rehabilitation in athletes.[2] The local analgesic effects of cryotherapy result from a decrease in nerve conduction velocities, edema formation, cellular metabolism, and local blood flow.[3] Although there is no ideal post-cooling tissue temperature, consensus supports that greater and faster cooling improves pain relief.[3]

A common ED practice is the application of chemical cold packs (CCP) to the skin of the injured area for rapid analgesia. However, wetted crushed ice (intensive targeted cryotherapy, ITC) in a plastic bag has been found to produce lower skin

surface temperatures than a CCP after 15-20 minutes.[3-5] While ITC has been found to reduce inflammation and pain from acute musculoskeletal injuries, evidence supporting its role in the ED is scarce.[2] During the current pandemic an estimated 1.7 billion people, or approximately one in five worldwide, have sheltered in place,[7] with a reported weekly exercise increase of 88%.[8,9] With increased exercise, it is reasonable to expect musculoskeletal pain; efficacious home analgesia could potentially prevent non-emergent hospital visits.

Opioid pain medications are often used for analgesia in the ED, with 15% of all adult patients from 2016–2017 receiving a prescription for opioids upon discharge.[10] Of 35,000 ED patients seen for acute ankle sprains from 2011–2015 in the United States, 25% were prescribed opioids.[11] It has been found that patients prescribed opioids were more likely to progress to prolonged use than those who were not.[12] Intensive targeted cryotherapy in postoperative musculoskeletal patients resulted in fewer prescription analgesics,[13] but this has not been studied in ED patients. The primary goal of this trial was to investigate whether ITC could provide more effective analgesia for acute musculoskeletal injuries than CCP, with a secondary goal of assessing the impact of cryotherapy on opioid usage.

*Population Health Research Capsule*

What do we already know about this issue?
*Anecdotes and literature from other fields of medicine demonstrate that cryotherapy has analgesic effects for patients with musculoskeletal (MSK) injuries.*

What was the research question?
*Does intensive targeted cryotherapy (ITC) relieve pain or reduce the need for opioid pain relievers in the ED?*

What was the major finding of the study?
*Compared to usual care, ITC is an effective analgesic and is associated with lower opioid utilization.*

How does this improve population health?
*Cryotherapy holds promise as a safe and effective alternative to opioids for patients with acute MSK injuries, and thus could help address the opioid epidemic.*

## METHODS

### Study Design and Setting

This was a prospective, randomized, single-blind controlled trial conducted in an academic tertiary Level I ED with more than 70,000 annual patients. From February-April 2016, research assistants enrolled patients daily between 12 PM and 9 PM. The study was approved by the institutional review board (ClinicalTrials.gov: NCT02720315).

### Selection of Participants

Eligible patients were aged 18-65 presenting with complaints of acute musculoskeletal pain. They were identified based on chief complaint and triage note in the electronic health record. Exclusion criteria included trauma activation, patients with a known pregnancy, open fracture or obvious deformity likely to require closed reduction, hip fracture, altered mental status, or if the patient was receiving an investigational drug as part of an ongoing trial. Trained research assistants approached eligible participants in the waiting room where informed consent was obtained and cryotherapy initiated. Participants enrolled on even days of the month were randomized to CCP, and those on odd days received ITC.

### Interventions

Participants received either an activated CCP (MediChoice product #1480069904, Owens & Minor, Inc, Richmond, VA) applied to the skin at the site of injury, or wetted crushed ice that was double-bagged in thin, sealed plastic bags and wrapped in place by plastic wrap, both by an ED technician. Based on the thermodynamics of the CCP, optimal sustained cooling by CCP alone would require replacing the pack every nine minutes.[14] However, in accordance with existing departmental protocol, the technician removed the respective cryotherapy modality after 20 minutes.

### Methods of Measurement

Pain severity was measured using a validated 100-millimeter (mm) visual analog scale.[15] Pain scores were obtained at three time points during the participant's stay in the ED: immediately prior to applying the ice (0 minutes); immediately after cryotherapy removal (20 minutes); and 40 minutes after cryotherapy removal (60 minutes from the initial measurement). If patients were discharged before 60 minutes, a pain score was obtained upon discharge. The participants' ED length of stay, discharge diagnoses, results of radiology studies, timing, and doses of medications received, patient disposition, and discharge medications were obtained via chart review from an author blinded to cryotherapy allocation.

### Outcome Measures

The primary outcome was the change in pain severity at 60 minutes, at which time tissue temperatures post-cryotherapy are shown to have returned to normal.[3] Each patient was categorically classified as having obtained significant pain relief or not, at each time point. The

minimum clinically significant change in patient pain was defined as 13 mm, regardless of initial pain severity.[16] Secondary outcomes included the pain change at 20 minutes, administration of opioids or benzodiazepines in the ED, length of stay, and presence of discharge prescriptions containing opioids or benzodiazepines.

**Data Analysis**

We calculated outcomes per intent-to-treat analysis. To achieve 80% power ($\mu = 0.05$, 2-tailed test), 38 participants were required to detect a difference of 13 mm in pain severity score. Pain score change was analyzed by t-test, administration of opioids or benzodiazepines in the ED by Fisher's exact test, and discharge prescriptions by $\chi^2$. P-values $< 0.05$ were considered significant and 95% confidence intervals (CI) were used. We conducted all analyses using IBM SPSS Statistics (IBM Corporation, Armonk, NY).

## RESULTS

There were 57 patients who were initially considered eligible, with 38 who consented, enrolled, and were analyzed for outcomes. Twelve individuals refused participation on CCP days, and seven on ITC days. Baseline characteristics were similar between groups (Table 1). Two patients in each group were lost to follow-up prior to obtaining the 60-minute pain score. Study participants' length of stay was similar in both groups (ITC = 117 minutes [± 84] vs CCP = 109 minutes [± 56], $P = 0.97$).

Initial pain scores were similar between the ITC (6.7 [95% CI, 5.4-8.0]) and CCP groups (7.5 [95% CI, 6.8-8.2]) $P = 0.31$). The ITC group achieved statistically significant pain reduction at 20 minutes (2.1 [95% CI, 1.31-2.94] vs 0.9 [95% CI, 0.25-1.51), $P < 0.05$) and 60 minutes (2.7 [95% CI 1.59- 3.74] vs 1.2 [CI, 0.62 – 1.69], $P < 0.05$) (Figure 1). At 60 minutes, 11 participants (65%) of the ITC group achieved significant pain reduction compared with 7 (33%) with CCP, with a number needed to treat (NNT) of 3.2 for ITC to provide significant pain relief.

There was no significant difference between the groups with non-opioid analgesic or non-steroidal inflammatory use (ITC = 7 [41%] vs CCP = 10 [48%], $P = 0.69$) nor in absence of pharmacologic analgesia during the visit (ITC = 10 [59%] vs CCP = 7 [33%], $P = 0.17$). The likelihood of a participant receiving opioid prescriptions was not correlated with injury type ($P = 0.47$). One (6%) ITC participant received opioids in the ED compared to seven (33%) in the CCP group ($P < 0.05$), with a NNT of 3.6 for ITC to reduce one patient receiving opioids.

Those who received a discharge prescription for opioids had significantly higher pain scores at 60 minutes (7.3 ± 2.2 vs 4.1 ± 2.7, $P < 0.05$), but prescriptions were not significantly associated with injury type ($P = 0.47$). There was no statistically significant difference in discharge opioid prescriptions (ITC = 4 [24%] vs CCP = 9 [43%], $P = 0.23$) nor when prescriptions included benzodiazepines (ITC = 6 [35%] vs CCP = 11 [52%], $P = 0.19$]). Non-opioid discharge prescriptions were provided to four (24%) participants in the ITC group and five (24%) participants in the CCP group, with similar absence of discharge prescriptions between the groups (ITC = 9 ([53%] vs CCP = 7 [33%], $P = 0.22$]). There were no adverse events in either group and the respective cryotherapy modality was in position at the site of injury at 20 minutes for all participants before being removed by staff.

## DISCUSSION

We found that crushed, wetted ice bags provided greater analgesia for acute musculoskeletal injuries compared to chemical cold packs. This common cryotherapy application is ubiquitous in sports medicine and is easily applicable to ED patients. Furthermore, as pain management is one of the patient experience care domains directly tied to federal hospital reimbursement, optimal cryotherapy is an implementable protocol that could improve both customer satisfaction and hospital remuneration. There have been no reported adverse side effects of cryotherapy in published clinical trials, underscoring the safety of this treatment modality when properly used.[3]

The study participants who received ITC had significantly less opioid utilization than those with CCP. And while there were half the number of opioid prescriptions in the ITC group, the small number of individuals who received opioids overall limited insight into this relationship. Although this study was not powered to evaluate the impact of ICT on opioid prescriptions, with demonstrable analgesia by ITC, this cryotherapy application may have led to decreased patient prescription requests. Prescription opioids have abuse susceptibility similar to heroin,[17] and have helped fuel one of the nation's most pressing public health challenges. As short-course opioid therapy is associated with recurrent opioid use and may contribute to development of addiction,[18] it is reasonable that improved analgesia through optimal cryotherapy could help mitigate potential opioid abuse. Larger studies are needed to further elucidate the effect of optimal cryotherapy on opioid prescriptions.

## LIMITATIONS

Although the trial met its pre-specified enrollment threshold, the primary limitation was its relatively small sample size and single-center design that limited subgroup analyses. By design, we did not focus the cryotherapy on specific anatomic locations or presumed diagnoses that may have responded better to one cryotherapy treatment over another. Similarly, the heterogenous injury pattern limited our ability to draw practice-changing conclusions regarding the use of cryotherapy for specific injuries. While individual provider practice may have confounded the outcomes, with three months of data collection and a large number of treating physicians, this is unlikely. Describing early analgesic effect

within the CCP group may have been missed by not measuring pain scores at shorter intervals (eg, at 10 or 15 minutes). However, our primary outcome of pain at 60 minutes was selected to allow for tissue temperature normalization and greater clinical relevance.

It was not logistically feasible to include a placebo arm, but as participants were blinded to which treatment arm was experimental and which was an active control, this unlikely affected the primary outcome. Possible selection bias was mitigated by allocating participants to treatment arms based on the day of the month, and by separating the roles of various members of the research team. Specifically, the research assistants were trained to enroll and consent participants for the study, so long as the inclusion criteria were met (and the exclusion criteria were not), regardless of the day of the month. These research assistants were blinded to the hypotheses of the study and were undergraduate students with training in Health Insurance Portability and Accountability Act requirements and informed consent (but without significant medical training). Although the chart reviewers were blinded to treatment received, it was impossible to blind the treating physician; thus, the potential impact this had on analgesics is unknown. However, as no treating physicians were aware that analgesia was a studied variable in this trial, it was unlikely that awareness of cryotherapy type effected opioid usage.

Although participants were enrolled in triage prior to a physician encounter, the time between cryotherapy application and physician interaction was not standardized and could have influenced pain severity and the likelihood of opioid administration. Finally, because the CCP did not likely stay as cold as the crushed ice for the full 20 minutes of application, the beneficial effect shown could be explained by the duration of effective cryotherapy received by participants. Measuring pain scores at 60 minutes attempted to account for

**Table 1.** Participant characteristics.

| Participant Characteristics | Chemical Cold Packs N, (%) | | Intensive Targeted Cryotherapy N, (%) | | *P-value* |
|---|---|---|---|---|---|
| Demographics | | | | | |
| Number | 21 | (55) | 17 | (45) | 0.57 |
| Women | 12 | (57) | 13 | (76) | 0.21 |
| Age, (years) Mean (± SD) | 33 | (± 12) | 35 | (± 14) | 0.61 |
| Cryotherapy duration, (minutes) Mean (± SD) | 20 | (± 1.6) | 21 | (± 2.9) | 0.20 |
| Clinical Characteristics | | | | | |
| Injury Site | | | | | |
| Ankle | 3 | (14) | 3 | (18) | 0.78 |
| Arm | 1 | (5) | 0 | (0) | 0.36 |
| Back | 1 | (5) | 2 | (12) | 0.43 |
| Clavicle | 1 | (5) | 0 | (0) | 0.36 |
| Coccyx | 1 | (5) | 0 | (0) | 0.36 |
| Elbow | 2 | (10) | 0 | (0) | 0.19 |
| Foot | 1 | (5) | 2 | (12) | 0.43 |
| Groin | 0 | (0) | 1 | (6) | 0.26 |
| Hand | 1 | (5) | 1 | (6) | 0.88 |
| Knee | 3 | (14) | 4 | (29) | 0.46 |
| Neck | 3 | (14) | 0 | (0) | 0.10 |
| Shoulder | 1 | (5) | 2 | (12) | 0.43 |
| Toe | 0 | (0) | 1 | (6) | 0.26 |
| Rib | 1 | (5) | 0 | (0) | 0.36 |
| Wrist | 2 | (10) | 0 | (0) | 0.19 |
| Diagnosis | | | | | |
| Fracture | 4 | (19) | 4 | (24) | 0.74 |
| Sprain or strain | 2 | (10) | 5 | (29) | 0.12 |
| Torn ligament | 3 | (14) | 1 | (6) | 0.40 |
| Contusion or pain | 12 | (57) | 7 | (41) | 0.33 |

*N*, number; *SD,* standard deviation.

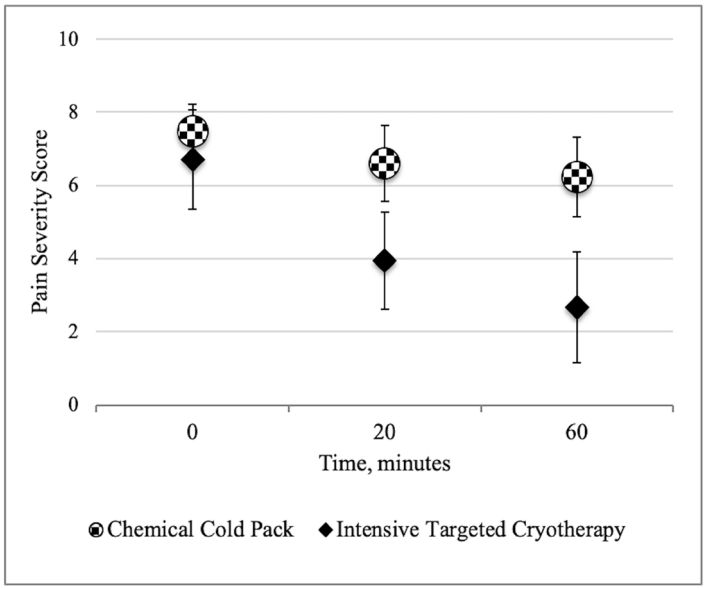


**Figure 1.** Pain difference between the study arms, with group means 95% confidence interval shown for each group at all time points.

tissue temperature equilibration, but our methodology may underestimate the analgesic potential of CCPs.

## CONCLUSION

Intensive targeted cryotherapy provided more effective analgesia than chemical cold packs for patients with acute musculoskeletal injuries in the ED and may contribute to lower opioid usage.

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# Telephonic Medical Toxicology Service in a Low- Resource Setting: Setup, Challenges, and Opportunities

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Poisoning and envenomation are a global health problem for which the mortality burden is shouldered heavily by middle- and low-income countries that often lack poison prevention programs and medical toxicology expertise. Although telehealth or teleconsult services have been used to bridge the expertise gap between countries for multiple specialties, the use of medical toxicology teleconsult services across borders has been limited. We aim to describe the use of a United States-based medical toxicology teleconsult service to support patient care at a hospital in a middle-income country that lacks this expertise. This report outlines the logistics involved in setting up such a service, including the challenges and opportunities that emerged from establishing medical toxicology teleconsult service in a low-resource setting. [West J Emerg Med. 2021;22(2)450-453.]

## INTRODUCTION

Poisonings and envenomations are an important global health problem. It is estimated that up to 75% or more of all poisoning-related deaths occur in low- and middle-income countries (LMIC).[1] The lack of poisoning prevention programs and the scarcity of medical toxicologists have been recognized as contributing factors to poisoning in LMICs.[2-5] Additionally, many of these countries lack the infrastructure for a national poison control center that would play a crucial role in guiding preventive measures.

While multiple studies have shown that patients managed by medical toxicologists have reduced hospital length of stay, hospital costs, and mortality compared with other patient groups where no medical toxicologist was involved,[6-7] many countries lack medical toxicology training programs and expertise. A number of international collaborations have attempted to bridge medical toxicology education gaps in LMICs. These include teleconferencing networks through the Global Educational Toxicology Uniting Project (GETUP) program, supported by the American College of Medical Toxicology.[4]

Alternatively, teleconsultation has also been used in some countries to seek clinical expertise. Teleconsultation is defined as a "synchronous or asynchronous consultation using information and communication technology to omit geographical and functional distance."[8] It allows physicians in remote or low-resource areas to access specialist opinion that would otherwise be unavailable to them. Teleconsultation has been used in pediatrics, orthopedics, and general medicine to assist in decision- making, treatment plan, and referral.[8] This platform of communication and delivery of care has also been increasingly used in international settings. One such example is the use of a toxicology teleconsultation, through an electronic mail system, by the US military and government healthcare providers serving overseas.[9]

While clinical teleconsultation is rising in popularity, the concept is not new to medical toxicologists through their roles at poison centers worldwide.[10] For multiple decades, medical toxicologists have used poison center telephonic services as a means to provide expert input to the public and healthcare providers. In 2019, the World Health Organization registered 331 poison centers worldwide, with centers varying in their capacity and capabilities.[11] However, this valuable resource is not available in all countries.

In Lebanon there is limited medical toxicology expertise and no national poison center to support providers with patient care. While Lebanon is classified as an upper-middle-income

country, it faces many of the challenges of low-resource settings especially in healthcare: its healthcare system is fragmented with the majority of hospitals in the private sector, concentrated in urban areas, leaving more rural settings with limited access to quality care. Furthermore, the hospital accreditation process is limited to basic standard review leading to large variations in hospital capabilities and quality of service. Finally, 80% of the healthcare budget is spent on acute care primarily delivered in private hospitals, leaving the public sector under-resourced with no established national poison center.

In addition, the field of emergency medicine (EM) is newly developed with the first residency training program established in 2012 and, as of yet, there are no local or regional training programs for medical toxicologists. To address the limited access to medical toxicology specialists in Lebanon, the American University of Beirut Medical Center (AUBMC) initiated a telephonic medical toxicology service through a collaboration with the Medical Toxicology Section of the Department of Emergency Medicine at Emory University in Atlanta, GA. The clinical service team included an AUBMC toxicology officer with training in nursing and quality management who performed consultation follow-ups. Additionally, the team included international medical toxicology fellows who are non-US physicians with specialty training in EM, internal medicine, or pediatrics from their home country. These fellows are training in medical toxicology over a 24-month period at Emory University and function as the Certified Specialist in Poison Information within poison centers, handling the initial call and data collection, in addition to providing their toxicology recommendations after discussion with the medical toxicology physician on-call.

The telephonic service, established in 2015, has provided prompt clinical toxicology consultation for 669 patients to date. In this report we describe the initial set-up and service development, as well as challenges.

*Population Health Research Capsule*

What do we already know about this issue?
*Telehealth services have been used to bridge expertise gaps between countries for multiple specialties.*

What was the research question?
*We sought to describe the use of a US-based medical toxicology teleconsult service to support patient care at a hospital in a middle-income country.*

What was the major finding of the study?
*Our team successfully implemented a telehealth toxicology service; international collaboration is a viable opportunity.*

How does this improve population health?
*A medical toxicology teleconsult service can support patient care related to toxicology-related exposure, in a low-resource country.*

## DISCUSSION

### Conception and Telephonic Service Infrastructure

In 2015 a memorandum of understanding between AUBMC and Emory University was established whereby Emory medical toxicology faculty in the US would offer round-the-clock telephonic support for toxicology cases at AUBMC ED and medical center. AUBMC is a 358-bed tertiary care medical center, with an ED that receives approximately 55,000 visits and approximately 25,000 inpatient admissions annually. Pediatric patients comprise 20% of the ED visits and 17% of hospital admission. A medical toxicology faculty member at Emory University served as the medical director for the service, overseeing the call schedule and the database quality assurance process. While data entry occurred for quality assurance purposes, no formal consultation note by the medical toxicologists was documented in the chart. This resolved any medical liability issues for the medical toxicologist, while the quality assurance process ensured reliability and accountability of the telephonic advice.

Since this was not a telemedical consultation service but rather a telephonic resource, Joint Commission requirements for credentialing and privileging the medical toxicologists at AUBMC were not required.

### Communication

The utilization of the service was not mandatory and was made at the discretion of the treating physician. On-call toxicologist's contact information was made available on AUBMC's online scheduling program (Amion, Newtown, MA). The consultation request was handled by one of the three fellows at the Emory International Medical Toxicology Fellowship Program in Atlanta, GA, who collected data regarding the history, physical exam, and test results. The assessment and plan were finalized with one of the three medical toxicology supervising attendings.

Following the implementation of the electronic health record system (EPIC, Verona, WI) at AUBMC in November 2018, a toxicology consultation note with the toxicologist's recommendations was uploaded into EPIC and signed by the on-site medical toxicologist who was ultimately recruited and assumed a third of the toxicology calls as part of a transition to in-house capacity. Language was not a barrier because the communication occurred in English, which is the default

language used in all educational and professional activities at the AUB. On the other hand, occasional communication delays occurred because of the time difference. These were resolved through a back-up call system where attendings served as second call. There is usually a six- or seven-hour time difference given Atlanta's location in the Eastern Standard Time zone.

**Utilization of Service**

A total of 669 toxicological consultations have been received by the toxicology service to date. The majority of consults have been from providers at the AUBMC ED, inpatient services, and outpatient ambulatory clinics (92.7%, 1.5%, and 0.7%, respectively). Since the service was not publicized externally, only a few consults were from outside hospitals (3%) and few calls were from the public (2.1%). There was a 90% increase in the utilization of our service from 2015 (71 consults) to 2016 (135 consults), followed by a 21% increase in 2017 (164), and a slight decrease in 2018 (129 consults). A recent descriptive study of all teleconsult cases received between March 1, 2015–December 31, 2018, which included a total of 477 cases, reported the following main findings[12]: adult women and children less than five years old constituted a large portion of the cases; the majority of patients were found to have no effect or minor effects; only 20% resulted in moderate or major outcomes, and envenomation accounted for 3.8% of all the consults; intentional exposures were slightly more common than unintentional ones; almost half of the patients were treated and discharged from the ED and 34.2 % required admission; 49 patients (10.2%) left without completing care and were lost to follow-up, with the majority (N = 38) expected to have minor effects. The most common pharmaceutical agents involved were sedative/hypnotics/ antipsychotics, analgesics, and antidepressants; the most common non-pharmaceutical agents involved were household cleaning substances, pesticides, bites, and envenomations. While benzodiazepine exposure was found to be common, opioid exposures were scarce in our population, which could be related to the strict government regulations on opioid prescribing and dispensing in Lebanon.

**Collaborations with Other Departments**

The toxicology service initiated several internal collaborations to raise awareness about its capabilities and enhance its effectiveness. The leadership team held meetings with clinical departments, the clinical laboratory, and the clinical pharmacy department, the school of public health, the environmental core lab, and the zoology department. A policy was also established to properly handle hazardous specimens from the ED to the core lab in concordance with our occupational safety and risk management team. The nursing team was involved in all of the above procedures to ensure proper communication and standardize the care of toxicology patients.

**Poison Database and Quality Assurance**

The medical toxicology fellows and the toxicology officer entered the cases into REDCap, a free, secure, web-based application designed to support data capture for research studies that is Health Insurance Portability and Accountability Act compliant The data included patient demographics, caller and hospital information, xenobiotic exposures, exposure route, history, physical exam findings, lab results, medical outcome, level of care, antidotes provided, and disposition. For the majority of variables, values were coded using a similar coding system adopted by the American Association of Poison Control Centers and used in its National Poison Data System.[13] All patients were followed up by the toxicology officer, 24-48 hours post discharge, and all follow-up calls were documented in the database. For quality assurance, the database was frequently updated and monitored for data completion. The hospital used the database for quality control with oversight by the medical director. The service issued a monthly toxicology report to track the trends and patterns of exposure among the patient population.

**Toxicology Education**

To bridge toxicology education gaps, multiple activities were provided to residents, medical students, and faculty members of various departments. These included monthly online webinars, journal clubs, and case discussions on common ingestions tailored to fit the poisoning patterns relevant to Lebanon. Additionally, seminars and grand rounds were provided to other departments to raise awareness about our service and introduce them to the common local toxicological exposures. Residents and fellows were also involved in preparing periodic, clinical case vignettes (ToxTidbits) that were circulated to all of the hospital's healthcare physicians.

**LIMITATIONS and FUTURE OPPORTUNITIES**

The provision of this telephonic toxicology resource faces several challenges and limitations. The inability to interview the patient directly potentially limits the ability of the consulting medical toxicologist to fully assess the patient. The consulting providers also encountered occasional difficulties with pharmaceutical products, local plants, snakes, and scorpions unique to Lebanon and poorly reported and characterized. Additionally, the consultant had to occasionally adjust the assessment and management recommendations to the locally available diagnostic modalities, laboratory tests, and antidotes. To address some of these limitations, consultants sought assistance from the AUB zoology and botany departments.

On the other hand, the service offered benefits and opportunities beyond its initial scope. The spectrum of exposures enriched the clinical experience of consulting physicians who do not frequently encounter in the US-specific exposures to chemicals like pesticides, hydrocarbons, and

herbicides. This knowledge translated into several, peer-reviewed publications and case presentations. In addition, the initiative led to collaborations with the Ministry of Health including the development of the national health surveillance system for chemical exposures and multiple awareness campaigns on envenomations and poisonings captured through the service (pufferfish, toxic plants, and mushrooms).

Additionally, the service has also received consultations from several other Lebanese hospitals, emphasizing the need for such a resource at a national level. Lastly, this collaboration facilitated capacity building and trained one of the AUBMC EM residency graduates in medical toxicology at Emory University. This residency program was established in 2012 and is accredited by the Accreditation Council for Graduate Medical Education International.

## CONCLUSION

Our team was successful at implementing a telehealth toxicology service, and international collaboration is a viable opportunity. Future actions should ensure the sustainability and expansion of this resource nationally through local capacity building. This is best achieved through a partnership and formal collaboration between the Lebanese government, academic institutions, and hospitals.

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# Management of Chloroquine and Hydroxychloroquine Poisoning: Do Not Miss the Time of Tracheal Intubation and Mechanical Ventilation

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To the Editor:

We would like to comment on Lebin and LeSaint's overview of chloroquine/hydroxychloroquine (CQ/HoCQ) toxicity and management.[1] The authors focused on the indications and administration modalities of hypertonic sodium bicarbonate, diazepam, and epinephrine. Surprisingly, they did not consider the role and indications of tracheal intubation and mechanical ventilation, while representing the mainstay of treatment.

Lebin and LeSaint recommended the administration of high-dose diazepam (2 milligrams per kilogram intravenously over 30 minutes) in severely CQ/HoCQ-poisoned patients.[1] As stated, this recommendation is based on observations from the 1950s by French military doctors in Africa reporting that patients referred with mixed CQ/diazepam overdoses had better outcome than patients referred with CQ exposures alone. Thereafter, experimental and clinical studies investigated the utility of diazepam to treat CQ-poisoned patients. Preliminary in vitro investigations using rat left ventricular papillary muscles exposed to CQ and diazepam suggested that diazepam-attributed protective cardiovascular effects in CQ poisoning cannot be explained by an improvement in the intrinsic cardiac mechanical properties.[2] Recently, in vivo rat models of CQ toxicity used to assess diazepam, clonazepam and Ro5-4864 administered prior, during and after CQ, and high-dose diazepam eventually co-administered with epinephrine, demonstrated that neither diazepam nor other ligands for benzodiazepine-binding sites were effective to protect against or attenuate CQ-induced cardiotoxicity.[3] Diazepam-attributed augmentation of co-administered positive inotrope effects was the only effect that contributed to reduce cardiotoxicity.

Similarly, in a double-blind placebo-controlled study, diazepam did not reverse CQ-induced clinical and electrocardiographic effects in moderate intoxication.[4] Altogether, these findings strongly suggested not administering high-dose diazepam in spontaneously breathing CQ/HoCQ-poisoned patients due to its ineffectiveness and to the elevated risk of aspiration pneumonia.[5] Clearly and in contrast to what is stated in the review paper, the belief that diazepam may improve CQ/HoCQ-induced-vasodilation or dysrhythmic effects is illusive. Although used in the reference trial,[6] the main role in the beneficial outcome of CQ/HoCQ-poisoned patients among all administered treatments should go to early tracheal intubation, mechanical ventilation, and epinephrine infusion.

High-dose IV epinephrine infusion should also be used with caution. As stated,[1] epinephrine is the vasopressor of choice to reverse CQ/HoCQ-induced hypotension, especially since toxicity combines vasodilatation and decreased myocardial contractility. Due to their fast sodium channel-blocking properties, CQ/HoCQ slow intraventricular conduction leading to the development of unidirectional block and re-entrant circuits that may degenerate into monomorphic ventricular tachycardia and fibrillation.[7] By accelerating the heart rate, epinephrine limits these effects. However, the optimal heart rate to target is unclear. As shown with class-I antiarrhythmic drugs, epinephrine-induced tachycardia may increase CQ/HoCQ binding affinity of sodium-channel receptors that vary in the course of the cardiac cycle and thus enhance the frequency-dependent drug toxicity.[8] Additionally, elevated doses of epinephrine may be responsible for excessive vasoconstriction, ventricular arrhythmia, lactic acidosis, and myocardium stunning. Thus, preferring norepinephrine/dobutamine combination may be an attractive option, although this alternative has not been evaluated in comparison to epinephrine at the bedside. Managing severely CQ/HoCQ-poisoned patients cannot be limited to blood

pressure monitoring but should include accurate hemodynamic parameter measurement in the intensive care unit.

Because of their direct cardiotoxicity through voltage-dependent sodium- and potassium-channel blockade, CQ/HoCQ may be responsible for rapid-onset dysrhythmia.[9] Hypokalaemia from impairment of outward potassium currents additionally favors polymorphic ventricular reentry dysrhythmias by slowing repolarization and prolonging the effective refractory period. Since CQ/HoCQ-poisoned patients are at risk of vomiting, drowsiness, hyperexcitability with restlessness, seizures, consciousness impairment (although rare), and central respiratory depression, they may develop aspiration pneumonia, atelectasis, and alveolar hypoventilation.[9] Pulmonary edema from either cardiogenic or non-cardiogenic origin with alveolar hemorrhage may occur. The resulting hypoxemia rapidly worsens cardiotoxicity resulting in sudden cardiac arrest. For all these reasons, early tracheal intubation to secure airways and ventilation has been recommended in severely CQ/HoCQ-poisoned patients, as early as in the prehospital setting, before the onset of complications. Intubation is required if at least one prognostic factor of death is present (ie, presumed ingested dose of ≥4 grams, systolic blood pressure ≤100 millimeters mercury, and QRS complex duration ≥100 milliseconds).[2] Noteworthy, by contrast to psychotropic drug poisonings, intubation is not guided by the Glasgow Coma Scale score nor by the signs of acute respiratory distress.

In conclusion, due to expected CQ/HoCQ overdoses following growing prescriptions in COVID-19 patients, physicians should keep in mind the importance of early intubation and mechanical ventilation when reading the remarkable Lebin and LeSaint's brief overview.

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# Response to: "Management of Chloroquine and Hydroxychloroquine Poisoning: Do Not Miss the Time of Tracheal Intubation and Mechanical Ventilation"

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To the Editor:

We thank Drs. Megarbane and Schicchi for their thoughtful comments on our manuscript and efforts to highlight pertinent in vitro and in vivo literature. As stated in our manuscript, we agree that aggressive supportive care is the mainstay of treatment for acute chloroquine and hydroxychloroquine toxicity, including management of the airway with appropriate ventilation, if necessary.

While Drs. Megarbane and Schicchi make a valid point on the importance of intubation and mechanical ventilation in patients with evidence of severe poisoning, the indications for early intubation prior to severe symptom onset are less clear. The writers suggest that intubation is required for any prognostic factor of death, such as a presumed ingestion of greater than four grams. In a retrospective case series of 167 patients with acute chloroquine poisoning, there was no correlation between the amount ingested by history and the peak blood chloroquine concentration; however, the peak blood chloroquine concentration was directly related to mortality, suggesting that the reported ingested dose has limited utility for predicting toxicity.[1] Similarly, the writers comment that intubation is also required if the QRS duration is greater than 100 milliseconds (ms); but, of the 14 patient fatalities in that cohort, almost half had a QRS duration less than or equal to 100 ms.[1] Therefore, suggesting that early intubation is required based on any single factor may result in misguided interventions without substantiated benefit. We recommend that intubation be considered based on clinician assessment of multiple factors, including severity of presenting symptoms and anticipated clinical course.

We also thank Drs. Megarbane and Schicchi for highlighting important in vitro and in vivo animal data regarding the utility of diazepam. The writers present data reporting that intravenous diazepam did not restore intrinsic mechanical performance in chloroquine-exposed rat cardiac papillary muscle or attenuate chloroquine-induced cardiotoxicity in poisoned rats.[2,3] However, the later investigation also documents that the combined administration of diazepam and epinephrine did improve cardiac contractility.[3] One important caution to consider for these data is the direct application of animal studies to human subjects, where ingested doses, symptomatology, and chronic toxicity may be variable. Thus, in patients with severe chloroquine or hydroxychloroquine poisoning who are mechanically ventilated, we believe it is reasonable to provide diazepam in addition to vasopressors and aggressive supportive care.

We encourage additional investigations examining the role and indications for intubation, mechanical ventilation, vasopressor support, and diazepam in the context of acute chloroquine and hydroxychloroquine poisoning.

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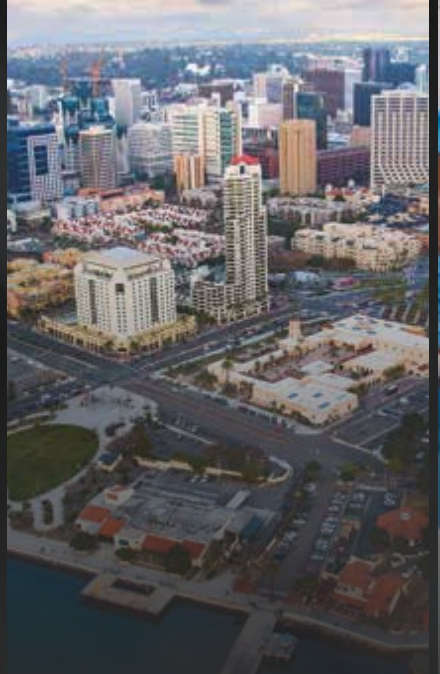
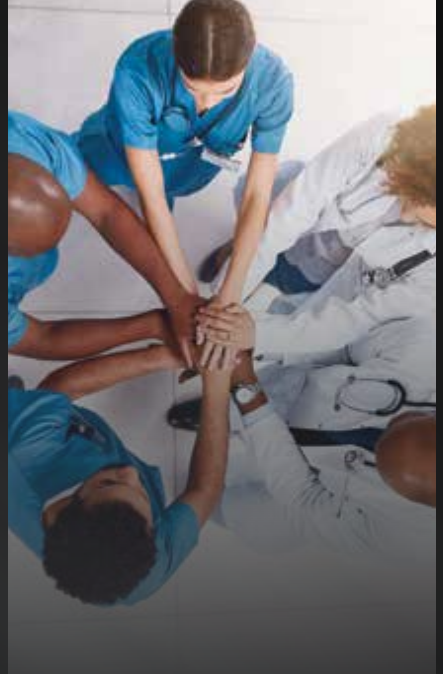
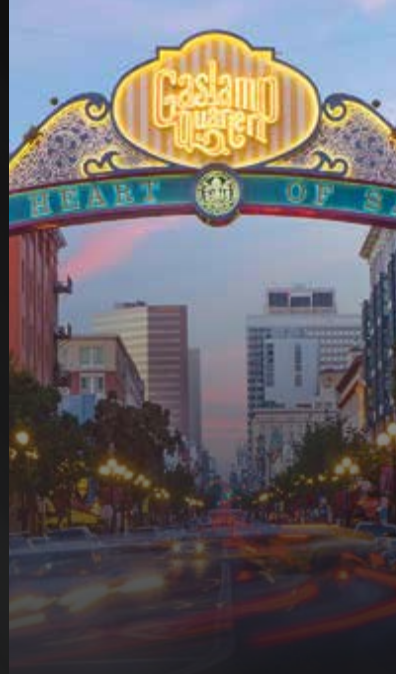


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